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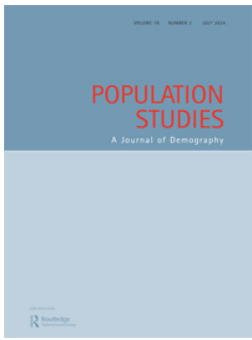
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# Spatial disparities in cause-specific mortality in Ukraine: A district-level analysis, 2006–19

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*Turbulent socio-economic development, recent political challenges, and remarkable regional diversity with deep historical roots make Ukraine an important case study for understanding mortality trends in Eastern Europe. In this paper, we provide the first comprehensive, spatially detailed analysis of cause-specific mortality trends and patterns in Ukraine, focusing on the period 2006–19. We rely on official mortality data and use various demographic and spatial analysis techniques. Our results suggest a notable attenuation of the long-standing West–East and West–South–East mortality gradients. Cardiovascular mortality at older ages largely explains the gap between the vanguard (lowest mortality) and laggard (highest mortality) areas, especially for females and in the most recent period. By contrast, the impact of mortality from external causes has greatly diminished over time. Hotspot analyses reveal strong and persistent clustering of mortality from suicide, HIV, and lung cancer. Further research should focus on in-depth assessment of the mechanisms causing the observed patterns.*

Supplementary material for this article can be accessed online at <http://dx.doi.org/10.1080/00324728.2024.2371283>

**Keywords:** Ukraine; regional mortality; causes of death; spatial patterns; mortality disparities; district-level analysis

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## Introduction

The vast amount of research conducted in recent decades has led to considerable progress in our understanding of the peculiarities of mortality patterns in Eastern Europe (Bobak and Marmot 1996; Shkolnikov et al. 2004; Jasilionis et al. 2011; Grigoriev et al. 2014; Aburto and van Raalte 2018). A combination of different factors—such as excessive alcohol consumption, high smoking prevalence, weak performance of the healthcare system, poor standards of living, and psychological stress due to economic uncertainty—have been identified as

major factors behind the unfavourable mortality trends (Leon et al. 1997; Gilmore et al. 2004; Shkolnikov et al. 2004; Brainerd and Cutler 2005; Grigoriev et al. 2010; Trias-Llimós et al. 2018; Trias-Llimós and Janssen 2018).

Compared with the large amount of evidence from studies of national populations in countries of the former Soviet Union (hereafter FSU countries), less is known about subnational mortality patterns. This is particularly the case for Ukraine, which is generally internationally under-represented in comparative mortality research. While historical events such as the 1932–33 famine (also known as the

Holodomor genocide) have been the focus of several studies (Meslé and Vallin 2012; Rudnytskyi et al. 2015; Applebaum 2017), less attention has been paid to recent spatial mortality trends and patterns. This is an important omission, given that Ukraine has experienced several dramatic events in recent decades, many with explicit spatial dimensions. These include the Chernobyl disaster of 1986, the post-communist transition crisis after the collapse of the Soviet Union, and the aggression of the Russian Federation against Ukraine, which started in 2014 with the annexation of Crimea and the war in eastern Ukraine and continued with the full-scale invasion on 24 February 2022.

The aim of this study was to conduct the first comprehensive, spatially detailed analysis of cause-specific mortality patterns in Ukraine. In this paper we focus on the assessment of spatial mortality patterns at a detailed level (districts; *rayons*) during 2006–19 and complement this analysis with an overall assessment of cause-specific mortality trends at a higher level (regions; *oblasts*) since 1990.

## Background

The collapse of the communist system and the dissolution of the Soviet Union into 15 independent states in 1991 resulted in a deep socio-economic crisis, which in turn had adverse consequences for population health (Brainerd 1998; Cornia and Paniccia 2000). Large parts of the populations of FSU countries were faced with falling living standards, erosion of the healthcare and social security systems, rising unemployment, and widening income inequalities. These circumstances caused psychological stress and the rapid spread of unhealthy behavioural patterns, with excessive alcohol consumption being most prominent (Cockerham 1997; Bobak et al. 1998, 2000; Shkolnikov et al. 2004; Brainerd and Cutler 2005). The unprecedented increase in mortality in the newly established FSU countries in the early 1990s resulted in a further widening of the long-standing East–West mortality gap in Europe (Bobak and Marmot 1996).

Given the past similarities among FSU countries in terms of historical and socio-economic developments, summarizing scientific knowledge on subnational mortality patterns in this world region is important for understanding contemporary subnational mortality patterns and differentials in Ukraine. In this section, we first focus on the similarities and peculiarities of subnational mortality

patterns in FSU countries. Then we turn to an overview of existing evidence on mortality trends and patterns in Ukraine.

### *Subnational mortality trends in FSU countries*

Previous studies on subnational mortality in Russia, Belarus, Moldova, and the Baltic States have documented substantial mortality disparities with a tendency to persist over time (Kalediene and Petrauskiene 2000, 2004; Vallin et al. 2005; Kruminis et al. 2009; Grigoriev et al. 2013, 2016, 2020; Timonin et al. 2020; Shchur et al. 2021; Penina 2022a). Vallin et al. (2005) reported a stark and persistent mortality difference between the southwestern and north-eastern regions of European Russia in both all-cause and cause-specific mortality. The first ever district-level analysis of mortality in Russia confirmed this observation (Timonin et al. 2020). Persistent geographical gradients in mortality have also been documented for several other FSU countries. In Belarus, mortality has tended to be higher in the eastern part of the country bordering Russia (Grigoriev et al. 2013), whereas in Lithuania, men's mortality was found to be higher in the southeastern part bordering Belarus (Grigoriev et al. 2016). For Moldova, Penina (2022a) reported a gradient in life expectancy between the northern districts and the municipality of Chisinau (low mortality) and the belt of districts located mainly in the centre (high mortality).

The very few existing spatial mortality studies conducted across several neighbouring countries have pointed to the relevance of the historic context and former political borders in shaping contemporary mortality patterns. In this regard, it is important to stress that the FSU region has long been characterized by large political entities (e.g. the Russian Empire, the Soviet Union) comprising people of different ethnicities or nationalities. In addition, political borders have frequently shifted, especially in the European part of the FSU. As a result, current national borders in Eastern Europe may be less relevant for understanding spatial variation in demographic behaviour than in Western Europe, where many national borders have a long history (see also Watkins 1991). Grigoriev et al. (2016) identified a large cluster of elevated alcohol mortality among men, stretching across the Belarus–Lithuania national border. The districts which formed this cluster (in north-west Belarus and south-east Lithuania) used to belong to the Vilna province (*gubernia*)

in the Russian Empire and then, until 1939, to Poland. Grigoriev et al. (2020) detected a gradient in men's alcohol-related mortality—from very high levels in north-western Russia to low levels in southern Poland—which was not explicitly demarcated by national boundaries. They identified hot-spots of alcohol-related mortality that dominated the territories of north-western and western Russia, eastern and north-western Belarus, south-eastern Lithuania, and eastern and central Poland. These patterns of alcohol-related mortality mirrored those of all-cause mortality, suggesting that excessive alcohol consumption was an important factor in the observed spatial mortality differences.

A distinct feature of mortality patterns in FSU countries is persistent urban–rural disparities, which have tended to widen in recent years in light of growing urbanization and massive depopulation trends in many rural areas. The urban–rural mortality divide, which dates back to Soviet times, is explained by several factors, including poorer socio-economic conditions, poorer access to healthcare, and higher prevalence of excessive alcohol consumption, as well as psychosocial factors associated with the lack of future prospects and entertainment opportunities in rural areas (Jasilionis 2003; Stickley and Razvodovsky 2009). In their district-level analysis of Russia, Timonin et al. (2020) identified Moscow, Saint Petersburg, and several so-called 'science' cities and cities with a special regime (often related to the defence/applied industry) as best-practice areas in terms of the highest life expectancy: life expectancy in these areas was close to the national averages for Poland and Estonia but still substantially below the averages for Western countries. In line with these findings, Shchur et al. (2021) reported growing gaps between larger cities and the 'periphery' within regions of Russia, with a particularly strong increase in disparities between 2015 and 2017. Education and population size were identified as the factors explaining roughly two-thirds of subnational variation in life expectancy. Furthermore, for Belarus, Grigoriev et al. (2013) identified a growing advantage of the capital and big cities over other areas as the main driver of rising subnational mortality differentials. Some studies conducted in the Baltic States have also confirmed the growing survival advantage of populations in major cities and urban areas, with differences in cardiovascular and external-cause mortality being mostly responsible for the subnational variation. Unhealthy lifestyles, greater social and psychological stress affecting the rural population, inequalities in healthcare accessibility, and

lack of preventative programmes in rural areas were proposed as possible explanations for the observed urban–rural mortality differentials in Lithuania (Kalediene and Petrauskiene 2000, 2004).

Several studies have attempted to assess the role of contemporary contextual factors in shaping spatial disparities. An ecological analysis of factors responsible for the regional mortality variation within Belarus confirmed a strong association between excessive alcohol consumption and all-cause mortality (Grigoriev et al. 2013). The same analysis identified unemployment as being strongly associated with cardiovascular and external-cause mortality, whereas poverty was found to be an important predictor of regional disparities in suicide and homicide mortality. Krumins et al. (2009) argued that geographical patterns observed in Estonia, Latvia, and Lithuania were influenced more by socio-economic and cultural factors specific to a given geographic area and linked to the historical context of neighbouring countries than by the fact that areas currently belonged to a particular country.

#### *National and subnational mortality trends in Ukraine*

Whereas Ukraine shares many similarities with other FSU countries in terms of general demographic trends, this applies primarily to the eastern part of the country. The western regions of Ukraine seem to be in a transition towards the mortality patterns observed in Poland, the Czech Republic, Hungary, and Slovenia (Menon et al. 2009).

An important event with implications for regional mortality variation in Ukraine was the Chernobyl disaster of 1986, which resulted in contamination of territories surrounding the nuclear power plant situated north of Kyiv at the border with Belarus (Poniakina 2014). Territories further away were also affected by radiation. Following an acute health crisis after the dissolution of the Soviet Union, life expectancy at birth in Ukraine dropped by 4.4 years among males and 2.4 years among females between 1990 and 1995 (HMD 2022). Afterwards, there was a period of short-term recovery in 1996–97, followed by another short-term decline in 1999, after the 1998 global economic crisis. As in many other FSU countries, the drop in life expectancy in the 1990s was driven by increasing mortality at working ages and rising death rates from diseases of the circulatory system and external causes (Steshenko 2001; Meslé and Vallin 2012). Previous

studies have identified deaths from preventable causes, including alcohol- and smoking-related diseases and accidents, as playing a leading role in excessive adult mortality in Ukraine (Libanova et al. 2007; Levchuk 2009). Furthermore, there was a rapid spread of the HIV epidemic across the country in the 1990s and early 2000s, particularly in regions with higher prevalence of intravenous drug use (Zaller et al. 2015; Antonenko and Martysynovska 2022).

Between 2008 and 2013, life expectancy in Ukraine increased. This remarkable improvement has been attributed to reductions in death rates from all major causes, particularly declining mortality from heart diseases (Penina 2022b). The progress was also accompanied by a substantial decline in alcohol-related deaths, due to decreased overall alcohol consumption and the gradual replacement of spirit consumption with beer consumption (Krasovsky 2012; Penina 2017). Compared with the Baltic countries, Belarus, and Russia, the improvement in life expectancy in Ukraine started a few years later, resulting in an increase of 4.0 years among males and 2.3 years among females between 2008 and 2013 (HMD 2022). However, this positive trend was interrupted around 2014 when life expectancy resumed a generally downward trend among males and stagnated among females. This interruption coincided with the start of the Russian invasion of Ukraine which resulted in Russia's annexation of Crimea and the war in Donbas. According to the latest data, life expectancy at birth in 2021 was between seven and nine years lower for Ukrainian men and five or six years lower for Ukrainian women compared with their counterparts in Poland and the Czech Republic (HMD 2022; UkrStat 2023).

These mortality developments did not occur uniformly across all regions of Ukraine. A few studies exploring regional mortality variations have identified persistent health disparities between western and south-eastern Ukraine. Murphy et al. (2013) estimated the contributions of various causes of death to regional differences in life expectancy in 2008. Their results showed that the gap in life expectancy between the eastern and southern regions of Ukraine on the one hand and the western regions on the other (the West–South–East mortality gradient) was due mostly to deaths from infectious diseases and external causes among young adults and to cardio- and cerebrovascular deaths among older adults. Other studies focusing on regional mortality in Ukraine have identified new changes in the country's health divide: lower life expectancy in the north and south, in contrast to higher life expectancy in the

western and central regions (Shevchuk 2007; Levchuk and Luschnik 2019). However, the above-mentioned studies all analysed subnational mortality variation in Ukraine at a rather high level of aggregation, the region level. Furthermore, they did not provide a detailed analysis of cause-specific mortality, and it remains unclear to what extent the new mortality gradient can be explained by a shift in cause-specific mortality patterns.

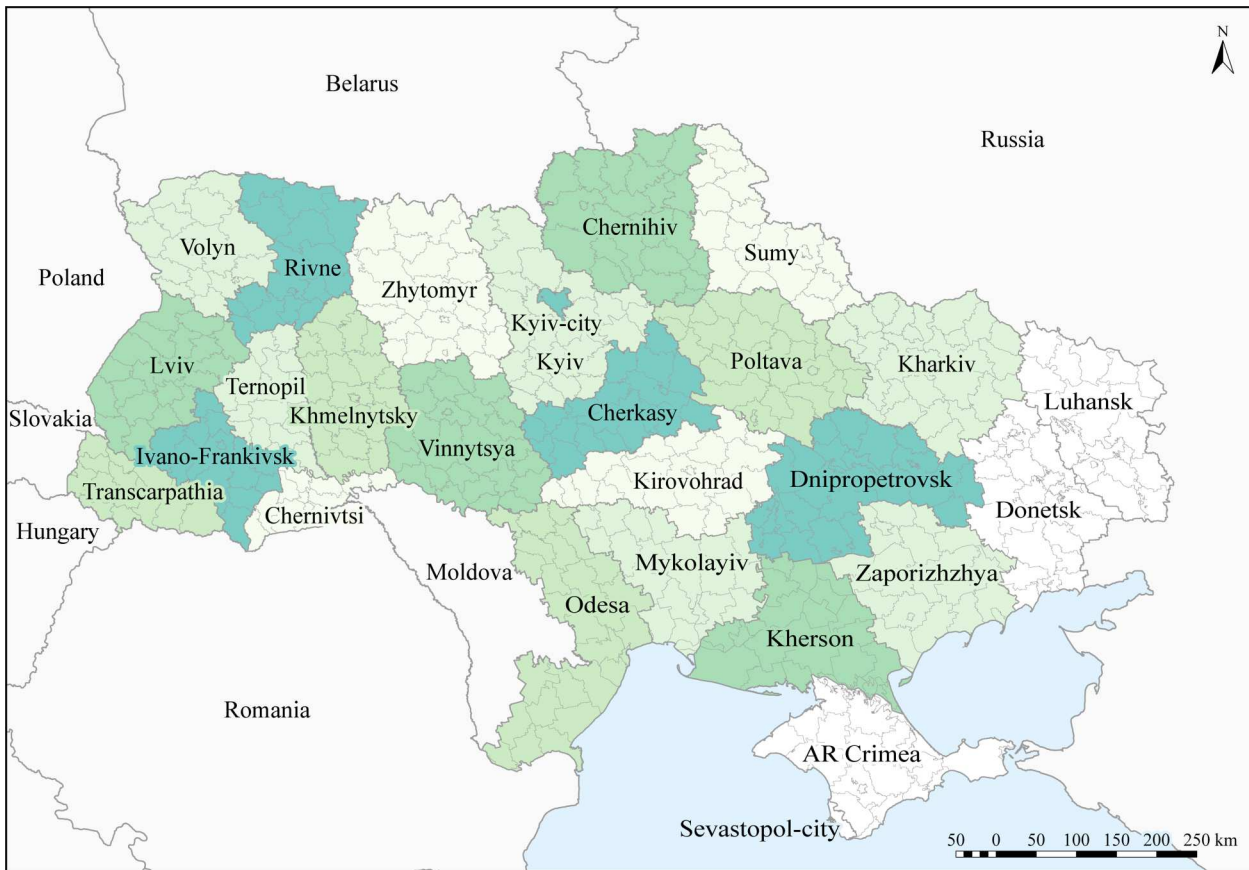
A notable exception is the study by Poniakina (2014), who performed an extensive analysis of cause-specific mortality patterns at the region level and complemented it with an assessment of mortality patterns at the district level. In her thesis, Poniakina (2014) concluded that different regions of Ukraine were at different stages of the epidemiological transition (Omran 1971). The western regions of Ukraine have managed to make the most progress towards a modern mortality structure (as displayed by Western European countries), while the eastern and southern regions are characterized by a more traditional mortality structure (high share of digestive and infectious diseases and external causes).

## Data and methods

### *Administrative territorial division*

Ukraine's higher-level administrative division consists of 27 units: 24 regions (*oblasts*), the Autonomous Republic (AR) of Crimea and two cities with special status: Kyiv and Sevastopol (Figure 1). Most of these regions' populations lie within the range of 800,000 to 3 million inhabitants, which corresponds with the European NUTS 2 regional level. Only the Dnipropetrovsk region (>3 million inhabitants), the Donetsk region (>4 million inhabitants), and the city of Sevastopol (about 500,000) are exceptions.

For the lower-level spatial units, we relied on a long-standing administrative territorial division at the district (*rayon*) level, which was in force until 2020. This division consisted of 679 districts and cities. The administrative borders of districts remained mostly unchanged over the period 2006–19. The only exception is that some cities which had been treated as part of a district became separate units. To ensure data comparability, we constructed a time-constant data set in which we merged back all the units that had been separated. Furthermore, to increase the stability of mortality rates, we also merged all cities with a population below 100,000 with their corresponding



**Figure 1** Administrative divisions of Ukraine

*Notes:* Donetsk, Luhansk, and AR Crimea (white coloured) regions are excluded from the district-level analysis.

*Source:* Prepared by the authors. Base maps: Ministry for Regional Development, Building and Housing of Ukraine; DIVA-GIS portal; Eurostat.

(surrounding) districts. Through these adjustments, we reduced the number of spatial units to 539. These modifications entailed the need not only to merge corresponding mortality and population data but also to edit the shape files used for the spatial analysis. After the complete exclusion of Luhansk, Donetsk, and AR Crimea regions, for which no data have been available since the start of the Russian aggression in 2014, the final number of lower-level spatial units (districts and cities) was 471.

### *Collected data*

Our analysis is based on official regional mortality data and population estimates provided by the State Statistics Service of Ukraine (UkrStat). Overall, we were able to collect data covering the period 2005–19 at the district level for all regions of Ukraine apart from Luhansk, Donetsk, and AR Crimea. Data were missing for a few other regions and periods (Kyiv region for 2009–11, Odesa

region for 2012, Cherkasy region for 2005). The starting point (2005) corresponds to the implementation of the abridged classification of causes of death based on ICD-10. Unfortunately, it was not possible to obtain district-level population estimates as of 1 January 2005 to calculate the mid-year population for 2005. As a result, the analyses in this paper cover the period 2006–19. The mortality data originate from the statistical table ‘c8r’: death counts by year, sex, type of settlement (urban/rural/total), region, administrative district, five-year age group (up to 100+), and cause of death. Until 2008 the Ukrainian abridged classification of causes of death consisted of 249 items and from 2008 onward of 254 items. The data on population estimates originate from the statistical table ‘VRN–2MT’: population counts by year (as of 1 January), sex, type of settlement (urban/rural/total), administrative district, and five-year age group (up to 70+). More detailed data were available only for cities with a population above 100,000 and for regions.

The quality of Ukrainian population statistics deserves particular attention. We discuss this issue in detail in the Study limitations subsection.

### Methods

First, we reduced the number of causes of death analysed, by aggregating the original (official) list into a short list containing 57 items. This list was developed in the framework of a project aimed at restoring a long retrospective cause-of-death time series. The groups were produced as the most appropriate solution to ensure comparability of major causes across several revisions of the International Classification of Diseases (ICD). The final list of causes of death which we considered in our analysis is provided in the supplementary material (Table A1). To improve the comparability of cause-specific mortality between regions, we redistributed *ill-defined* deaths across the other (well-defined) causes of death proportionally to their shares of the total number of deaths. This was done separately for each year, sex, region, and age. Additionally, the same approach was applied to *events of undetermined intent* (EUI) (codes Y10–Y34), which were redistributed between suicide (X60–X84) and assault (X85–Y09, Y35, Y36) to account for the known issue of misclassification of violent deaths, an issue affecting cause-of-death statistics not only in Ukraine (Värnik et al. 2010).

To minimize random variation due to small numbers, we pooled death and population counts across the whole analysed period into three-year sub-periods. Our analysis covers two specific periods: 2006–08 as the starting point and 2017–19 as the final observation point. Based on the official population estimates (for 1 January) we first calculated mid-year populations as the simple average between two subsequent years and then pooled them over the three-year periods. The obtained estimates were used to compute age- and cause-specific mortality rates for each period, sex, and spatial unit. Based on the obtained rates, we calculated the standardized death rates (SDR) using the 1976 European Standard Population as a population standard. To visualize the spatial distribution of cause-specific mortality and its change over time, we produced choropleth maps by selected causes of death using the *quantile method* of classification. This allowed us to split our spatial units into 10 equal groups (deciles) and is consistent with the subsequent analysis of mortality inequalities.

To measure the degree of regional disparity, we computed various measures of dispersion (both

unweighted and weighted for population size) and calculated regression-based inequality measures, such as the slope index of inequality (SII) and the relative index of inequality (RII). These calculations were performed using the R package PHEindicator-methods (Anderson 2020). To determine the age- and cause-specific components responsible for the mortality gap between the best- and worst-performing districts and cities in Ukraine, we decomposed the difference in the SDR using the algorithm of stepwise replacement proposed by Andreev et al. (2002).

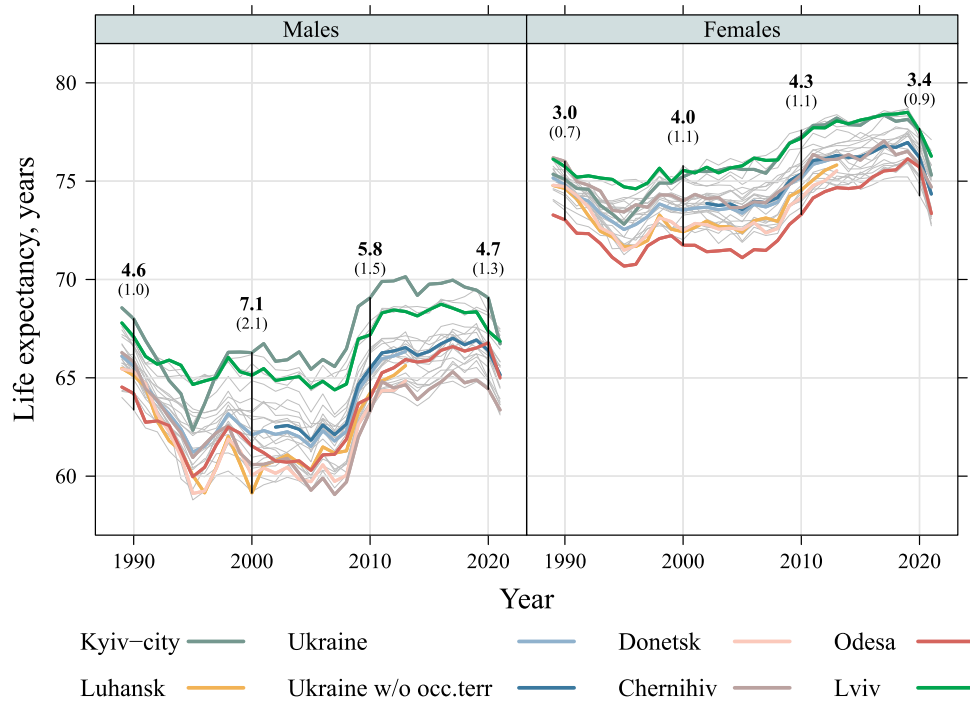
To identify statistically significant *hotspots* and *cold spots* with respectively high and low cause-specific mortality, we relied on the *Getis-Ord  $G_i^*$  statistic* (Ord and Getis 1995). To conceptualize spatial relationships, we used the *contiguity edges corners* definition of neighbourhood (also referred to as first-order queen contiguity). All spatial data operations, as well as all spatial analyses, were performed using ArcGIS software.

## Results

### *All-cause mortality trends*

Figure 2 provides a general overview of regional mortality trends in Ukraine over the last three decades. As in many other countries, regional variation among males has been much higher than among females. We also include information on the min–max range and the standard deviation of life expectancy for selected years. The year 1990 marks the minimum interregional disparity in Ukraine over the whole period of observation, for both males and females. Regional disparities quickly widened during the post-communist transition crisis of the early 1990s, as registered life expectancy declines varied strongly across Ukraine. Particularly remarkable is the capital city, Kyiv, which for both men and women belonged among the vanguard regions (with the highest life expectancy) before 1990. It temporarily lost this vanguard position in the 1990s due to an abrupt drop in life expectancy. By contrast, vanguard regions in western Ukraine (e.g. Lviv region) experienced much smaller declines and were able to keep their vanguard position. However, Kyiv city quickly recovered and was already back in a vanguard position by the late 1990s. By 2000, the mortality gap between the best- and worst-performing regions reached its peak: 7.1 years for males and 4.0 years for females. After a period of rapid improvement (2008–13) in all





**Figure 2** Life expectancy at birth by Ukrainian region, 1989–2021

*Notes:* Values above the lines are the min–max range and standard deviation (in parentheses). Lines in grey are other individual regions. ‘W/o occ. terr.’ refers to Ukraine without the occupied territories.

*Source:* Authors’ calculations based on official data from State Statistics Service of Ukraine.

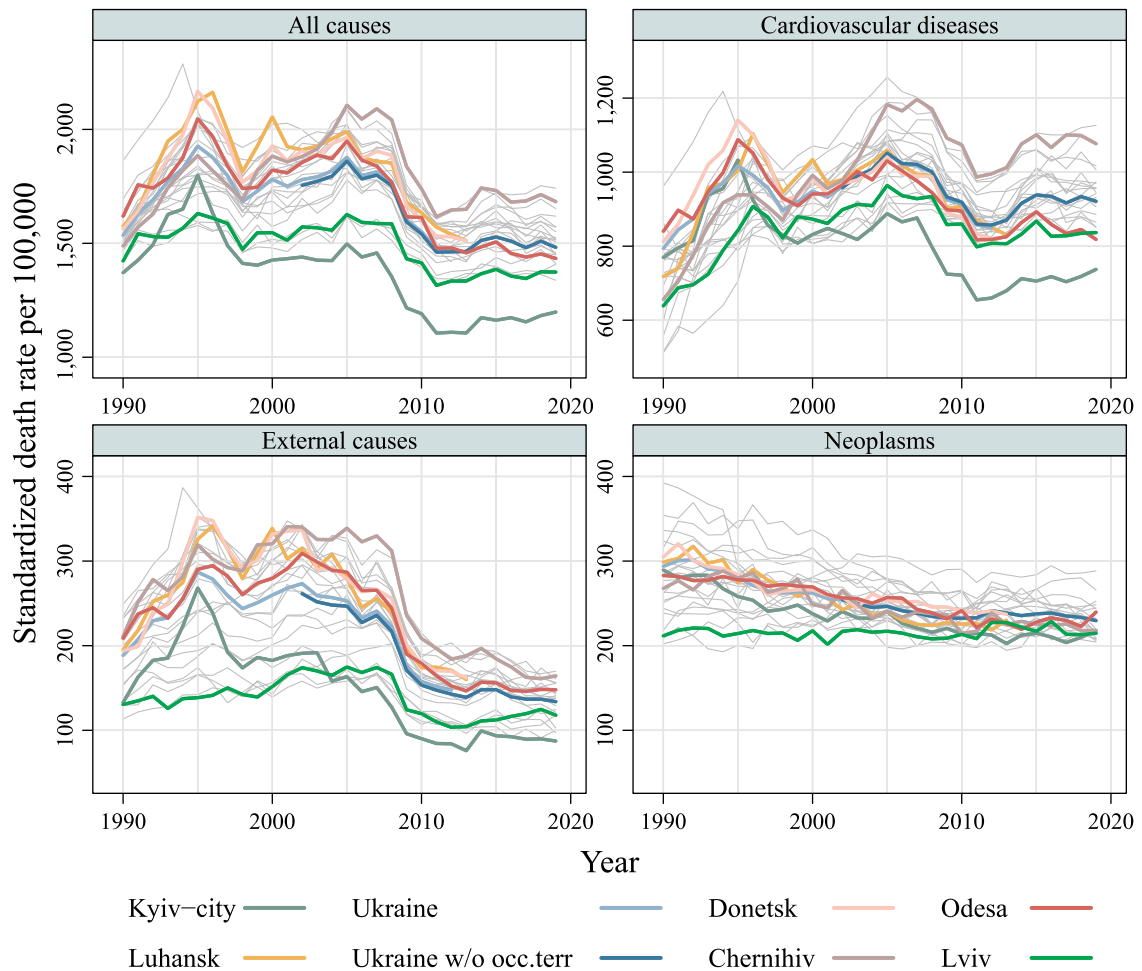
regions, the progress decelerated. In some regions, life expectancy started to stagnate and even decline, especially for men. Finally, as a result of the Covid–19 pandemic, life expectancy dropped dramatically in all regions in 2020 and 2021. This decline was accompanied by a declining interregional difference, which fell to near its minimum again as indicated by the min–max range and standard deviation.

Mortality trends by leading causes of death can provide deeper insights into the observed life expectancy trends and patterns. They are shown in Figure 3 (males) and Figure A1, supplementary material (females). It is apparent that overall mortality levels and trends across Ukrainian regions are strongly related to mortality from cardiovascular diseases (CVD). During the last three decades, there were two periods when CVD mortality was declining: (1) between the mid- and late 1990s; and (2) from 2005 to the early 2010s. Whereas the decline in the first period is likely to be attributable to the ‘rebound’ effect after the transition crisis, in the second period it appears to have been driven by real improvements, indicating signs of the so-called cardiovascular revolution (Grigoriev et al. 2014). However, these positive changes proved to be short-lived: since the 2010s, CVD mortality across

Ukrainian regions has been either stagnating or growing again.

Like CVD mortality, trends in external causes of death clearly mirror the trends in all-cause mortality. Yet their importance has notably diminished in recent years as compared with the 1990s and early 2000s. By the end of the observation period, the regional differences in mortality from external causes had converged to a level below that observed in 1990. This was particularly the case for females. The time trends in neoplasms, the second largest cause-of-death group (by number of deaths) in Ukraine, do not correlate with overall mortality dynamics over time. Thus, the time trends in neoplasms stand in stark contrast to those for the other two groups of causes. The reductions in neoplasm mortality were greater during the post-communist crises of the 1990s and early 2000s than in more recent years. These distinctive trends in cancer mortality are likely to be explained by competing mortality from CVD and accidents as well and also by birth cohort effects (Shkolnikov et al. 1999).

As a next step we turn to the analysis of detailed spatial patterns. Figure 4 depicts the spatial distribution of all-cause mortality across 471 districts and cities of Ukraine in 2006–08 and 2017–19. As



**Figure 3** Mortality from leading causes of death by Ukrainian region: males, 1990–2019

*Note:* Lines in grey are other individual regions. ‘W/o occ. terr’ refers to Ukraine without the occupied territories.

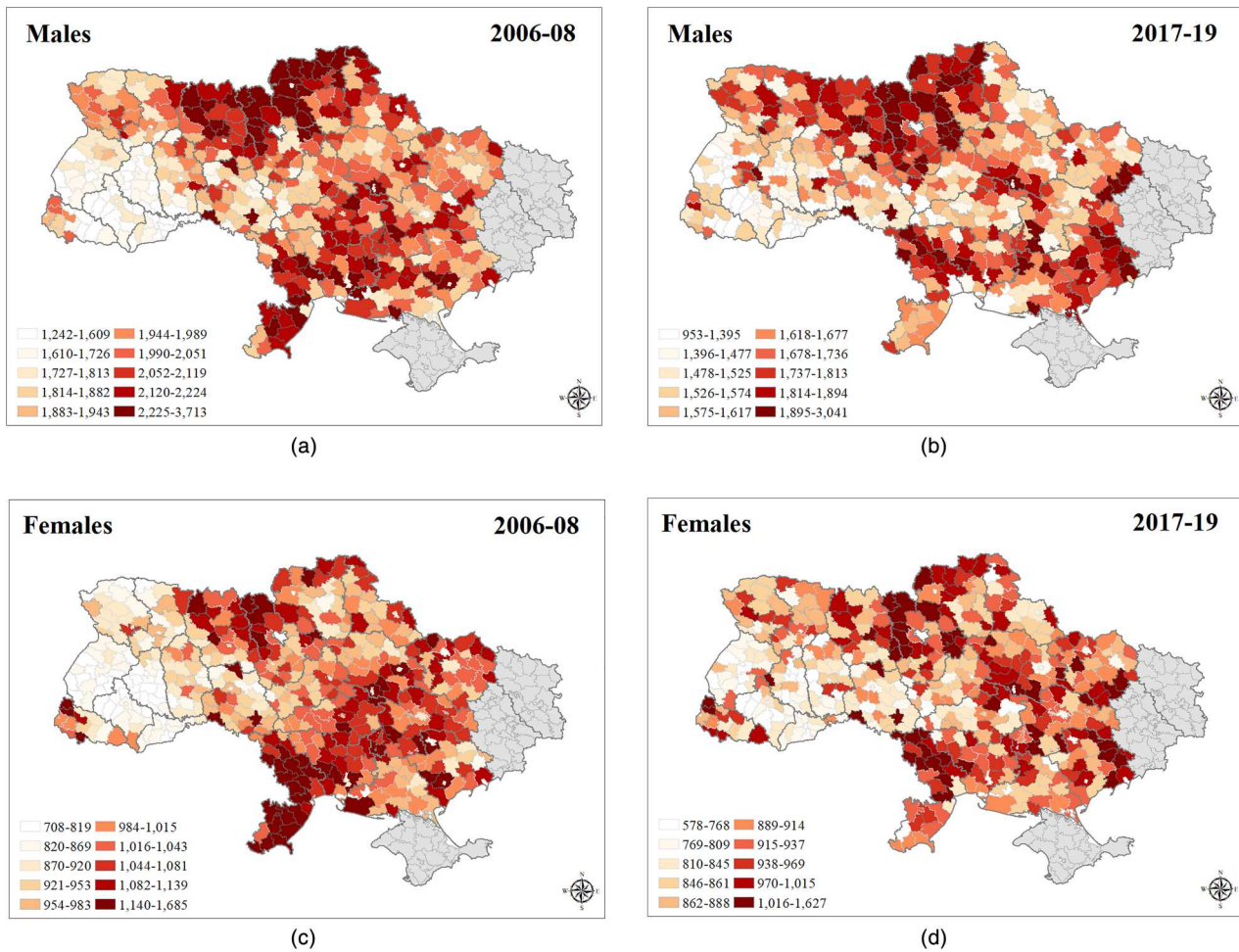
*Source:* As for Figure 2.

can be seen, there is no clear east–west mortality gradient but rather an advantage of western Ukraine as compared with the rest of the country. In 2006–08, this advantage was apparent except in part of the western Ukrainian region of Zakarpattia, which exhibited higher mortality, particularly among women. Some mortality hotspots for both men and women were concentrated in areas north of the mortality cold spot Kyiv city, including areas that were most heavily contaminated by the Chernobyl disaster. Another hotspot consisted of areas in southern Ukraine, with a particular focus on Odesa region. Between 2006–08 and 2017–19, the overall spatial pattern did not alter extensively but became more nuanced. First, the advantage of the west became less apparent. This seems particularly the case for the northern part of western Ukraine (Volyn and Rivne regions), which was still a mortality cold spot in 2006–08, at least among females. Second, while most of the districts with high mortality continued to be in the north and the south of the

country, a belt of low mortality emerged in central Ukraine.

#### *Assessing subnational mortality disparities*

As the next step, we quantify the degree of subnational disparities in all-cause mortality and their changes over time (Table 1). Both the population- and regression-based (i.e. SII) inequality measures indicate a reduction in absolute disparities between 2006–08 and 2017–19, reflecting the general trend towards improvement in mortality rates. However, in relative terms, the subnational disparities did not decrease but rather increased slightly. This is indicated by incremental increases in the weighted coefficient of variation and the RII for both males and females. As illustrated by the RII, relative mortality disparities between the top and the bottom deciles of the SDR distribution did not differ much between the sexes. For both periods, the mortality ratio



**Figure 4** Spatial distribution of all-cause mortality for males and females in Ukraine: 2006–08 and 2017–19  
*Notes:* Maps show standardized death rate (SDR) per 100,000. Donetsk, Luhansk, and AR Crimea (grey coloured) regions are excluded from the district-level analysis.

*Source:* As for Figure 2.

**Table 1** Selected indicators of mortality inequalities across Ukrainian districts and cities, 2006–08 and 2017–19

	<i>Males</i>		<i>Females</i>	
	2006–08	2017–19	2006–08	2017–19
Min–max range	2,471	2,088	977	1,078
Mean				
<i>Weighted</i>	1,780	1,494	928	820
<i>Unweighted</i>	1,942	1,645	985	893
Standard deviation				
<i>Weighted</i>	284	241	126	114
<i>Unweighted</i>	276	230	133	111
Coefficient of variation (per cent)				
<i>Weighted</i>	15.9	16.1	13.5	13.9
<i>Unweighted</i>	14.2	14.0	13.5	12.5
Slope index of inequality (SII)	920	790	410	370
Relative index of inequality (RII)	[907, 933]	[778, 802]	[403, 418]	[363, 377]
	1.70	1.72	1.57	1.58
	[1.68, 1.72]	[1.71, 1.74]	[1.55, 1.58]	[1.57, 1.60]

*Notes:* Estimates computed on the basis of the SDR (per 100,000) and the mid-year size of the total population; 95 per cent confidence limits are shown in square brackets.

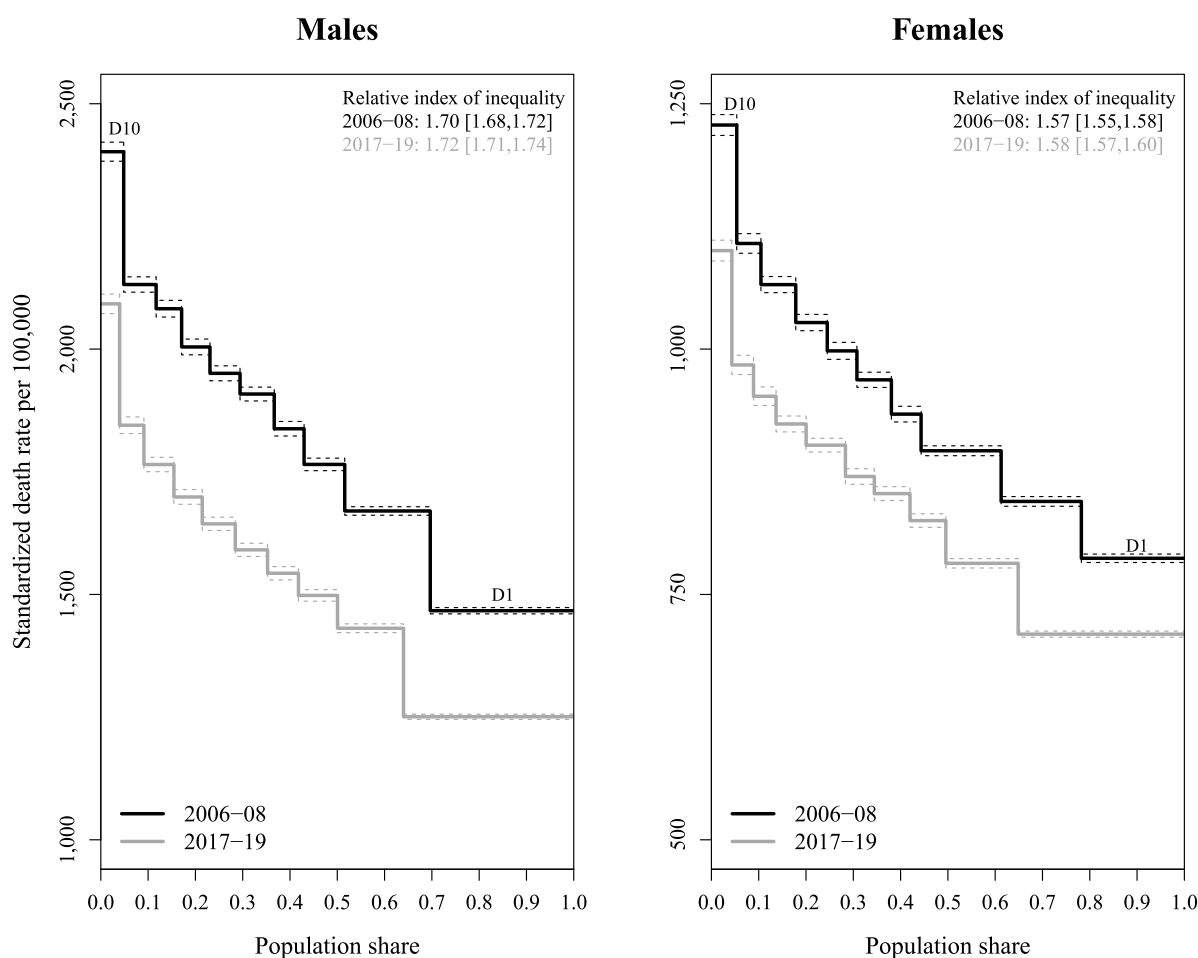
*Source:* Authors' calculations based on official data from State Statistics Service of Ukraine.

between the vanguard and laggard groups of Ukrainian districts and cities was about 1.7 for males and 1.6 for females.

Figure 5 provides a more nuanced look at the sub-national mortality profile and its change between 2006–08 and 2017–19. Each ‘step’ on the ‘inequality stairway’ represents the group SDR (y-axis) as computed for each decile on the basis of the distribution of the SDRs observed in all districts and cities in a given period. Each SDR value corresponds to a share of the total population (x-axis). The position of the 2017–19 line below the 2006–08 line indicates a clear reduction in mortality across all deciles over time. For example, for males, the SDR of the laggard group (D10), which accounted for roughly 5 per cent of the total population in both periods, decreased from 2,402 to 2,092 per 100,000. The corresponding figures for females were 1,228 and 1,100 per 100,000. That the vanguard group (D1) accommodated the largest share of the total

population reflects the fact that it consisted mostly of large cities, which have a longevity advantage over other areas. This can also be inferred from Figure 4, which shows that the capital, Kyiv, and other large cities fell in the lowest mortality category (small light spots on the maps). It is worth noting that the share of population in the 10 per cent of spatial units with lowest mortality (D1) has increased considerably, especially for females. In 2006–08, it comprised 30 and 22 per cent of the population of males and females, respectively, rising to 36 and 35 per cent in 2017–19. This implies that more districts and cities with large populations are now situated in the top decile.

The results of the decomposition analysis (Table 2) show that the mortality gap between the top and the bottom deciles has been driven by CVD, especially among females. The significance of CVD mortality increased over the period we analysed. In 2006–08, this cause of death explained more than half (54.4



**Figure 5** Inequality profile of regional mortality in Ukraine, 2006–08 and 2017–19

Note: Dashed lines are 95 per cent confidence intervals. D1 is the decile consisting of the vanguard districts and cities with the lowest mortality; D10 is the decile containing the laggard areas with the highest mortality.

Source: As for Figure 2.

**Table 2** Composition (percentages) of the cause- and age-specific contributions to the mortality gap between the top and bottom deciles of Ukrainian districts and cities: males and females in 2006–08 and 2017–19

	<i>Males</i>		<i>Females</i>	
	2006–08	2017–19	2006–08	2017–19
<b>Cause contributions</b>				
All causes	100.0	100.0	100.0	100.0
<i>Infectious diseases</i>	3.5	1.6	3.7	1.3
<i>Neoplasms</i>	5.2	7.2	2.8	2.8
<i>Cardiovascular diseases</i>	54.4	71.7	70.1	84.2
<i>Respiratory diseases</i>	7.0	2.6	0.9	1.0
<i>External causes</i>	21.9	10.9	9.8	4.4
<i>Other causes</i>	8.0	6.0	12.7	6.3
<b>Age contributions</b>				
All ages	100.0	100.0	100.0	100.0
<i>0–14</i>	1.4	0.6	2.4	1.6
<i>15–29</i>	6.1	2.0	3.5	1.7
<i>30–44</i>	15.7	11.2	10.1	7.8
<i>45–64</i>	30.4	19.4	25.2	14.0
<i>65+</i>	46.4	66.8	58.8	74.9

Note: Mortality gap is the difference in SDR between the D1 (vanguard) and D10 (laggard) groups.

Source: As for Table 1.

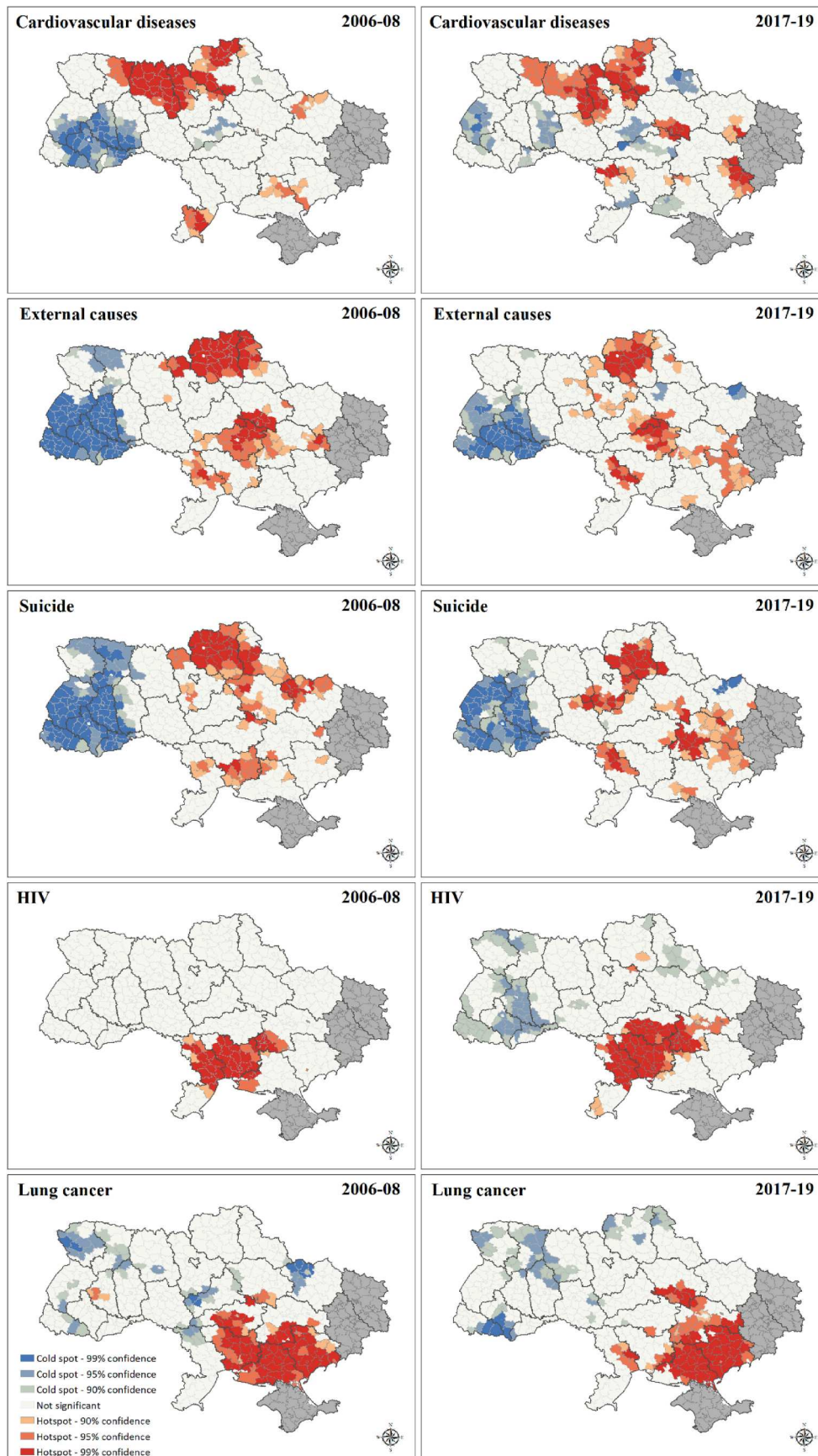
per cent) of the mortality difference between the top and bottom 10 per cent among males and more than two-thirds (70.1 per cent) among females. By 2017–19, CVD's respective contributions had reached 71.7 and 84.2 per cent. At the same time, the role of external causes diminished drastically. In 2006–08, external causes explained one-fifth of the gap in mortality between the laggard and vanguard groups for males and one-tenth of the difference for females. In 2017–19, these proportions had declined to 10.9 and 4.4 per cent for males and females, respectively. Notable changes also occurred with respect to age-specific contributions. This primarily concerns the 65+ age group, whose contribution to the mortality gap increased markedly. In 2017–19, it contributed 67 and 75 per cent among males and females, respectively, compared with 46 and 59 per cent in 2006–08.

### *Hotspots and cold spots of cause-specific mortality*

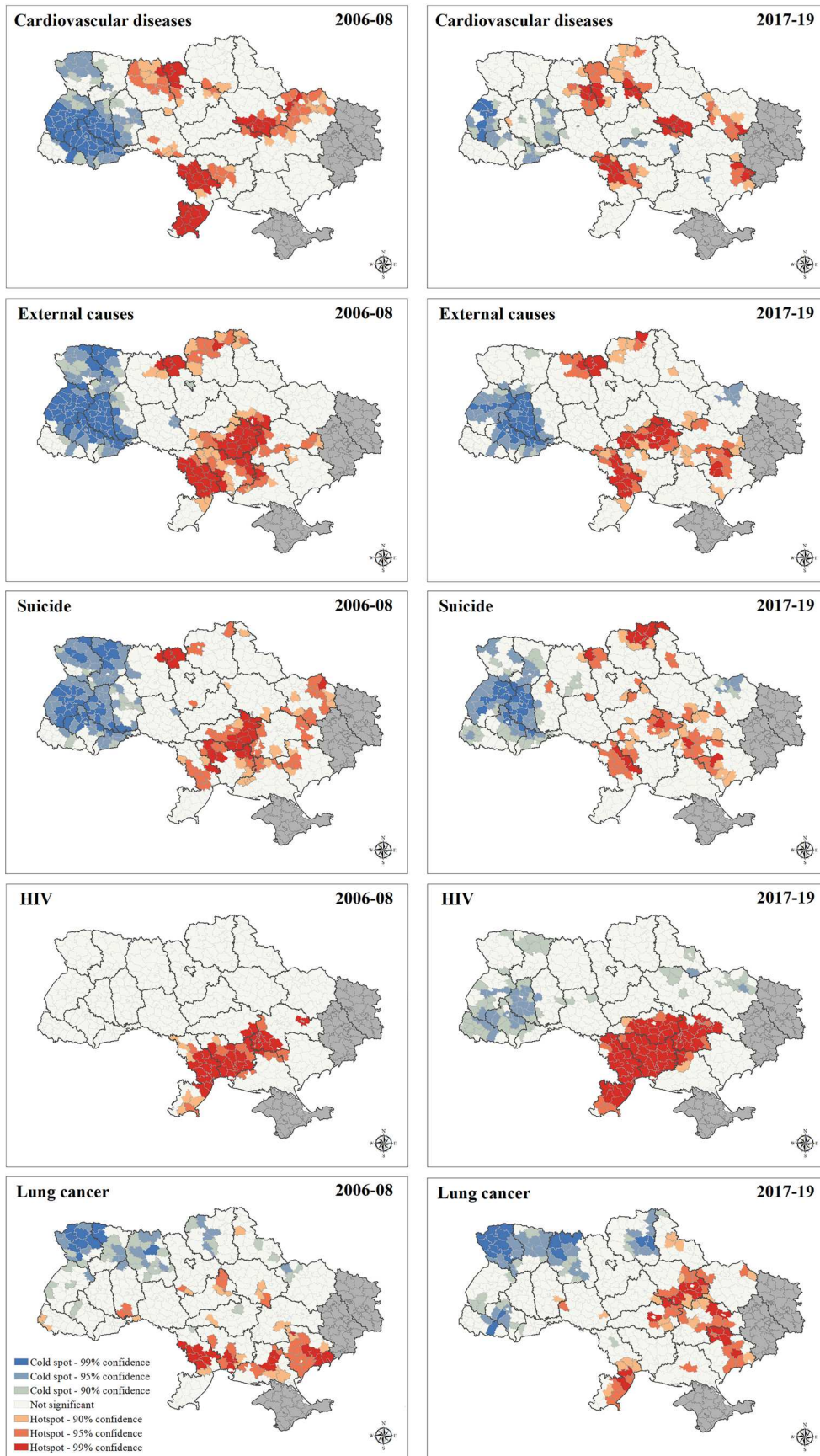
We now turn to the specific spatial distribution of mortality in Ukraine by specific causes of death. The raw mortality maps for males and females appear in the supplementary material (Figures A2 and A3). In what follows, we focus on maps of mortality hotspots and cold spots for selected causes of death (Figures 6 and 7). Traditionally, mortality from CVD has determined mortality trends in Ukraine and shaped the subnational mortality

differentials. CVD mortality hotspots for both males and females very closely mirror the spatial patterns of elevated all-cause mortality (Figure 4). However, there are important differences between the sexes in terms of the hotspot locations. For males, most of these hotspots were situated in the northern part of Ukraine, whereas for females the hotspots were scattered around various locations in the north, south, and east. Over the analysed period, the clusters of elevated CVD mortality became less homogenous and more scattered across the country (except western Ukraine). Compared with the hotspots, clustering of CVD cold spots became even less pronounced in 2017–19 as the large homogenous cluster in western Ukraine almost completely vanished. At the same time, a few clusters of low CVD mortality for males emerged in the south (Odesa and Kherson regions) and north-east (Sumy region), and low-mortality clusters expanded further in central Ukraine (Cherkasy and Kirovohrad regions).

Unlike in the case of CVD, a sharp contrast between the west and the rest of the country has persisted for mortality from external causes of death. Nevertheless, the large homogeneous cluster of low mortality (particularly visible for females) became smaller in 2017–19 due to changes in areas in the north-west (Volyn region), which were previously cold spots in 2006–08. Like for CVD mortality, clustering of hotspots of mortality from external causes became less pronounced over time. However, the geographical location of the main zones of elevated



**Figure 6** Hotspots and cold spots of mortality from selected causes: Ukraine, males, 2006–08 and 2017–19  
 Source: As for Figure 2.



**Figure 7** Hotspots and cold spots of mortality from selected causes: Ukraine, females, 2006–08 and 2017–19  
 Source: As for Figure 2.

mortality among males remained largely unchanged: the north (Chernihiv region and adjacent districts), the central part around Kirovohrad region, and some districts in eastern Ukraine. By contrast, for females, clustering of hotspots of mortality from external causes has been more pronounced in the south and the south-east (e.g. Mykolaiv and Odesa regions). The spatial patterns of suicide, which is the leading cause of violent mortality, largely mirror those of external causes.

Some communicable diseases, such as HIV, exhibit very strong hotspot clustering. Unlike for the other causes analysed, the clusters of elevated HIV mortality for males and females were alike in terms of their geographical location: southern and south-eastern Ukraine. In 2017–19, these areas expanded towards the central and eastern regions. Another important observation concerns men's mortality from lung cancer, which exhibited strong clustering of hotspots in the southern and south-eastern parts of the country (Mykolaiv, Kherson, and Zaporizhzhya regions) in both 2006–08 and 2017–19. Interestingly, this was not so much the case for females, although their lung cancer mortality has also tended to be higher in the south and south-east and lower in the north and north-west. We also examined spatial patterns of mortality for other types of cancer and for all neoplasms combined. Unlike for lung cancer mortality, no indication of spatial clustering was found (see Figure A4, supplementary material, for all neoplasms combined).

## Discussion

### *Main findings*

In this study, we performed a comprehensive assessment of spatial patterns of cause-specific mortality in Ukraine, focusing on changes during the period between 2006 and 2019 before the outbreak of the Covid-19 pandemic. Previous studies had reported strong West–East and West–South–East mortality gradients for males and females (Libanova 2004; Murphy et al. 2013; Poniakina 2014). The deteriorating mortality situation in the north of Ukraine (regions bordering Belarus) had also been highlighted earlier as an important adverse development in the evolution of regional mortality in Ukraine (Poniakina 2014). Our results suggested that towards the end of our observation period in 2019, these long-lasting mortality gradients had been to some degree attenuated, due largely to the emergence of new zones of low mortality in central

Ukraine. We also showed that the previously identified new zones of elevated mortality in northern Ukraine had not only persisted but also expanded towards the north-west of the country. The reasons for the poor performance of the north require further investigation. So far, we can offer only tentative explanations for the observed patterns.

The fact that the Ukrainian districts contaminated by the Chernobyl accident in 1986 are located in the north could be one explanation. On the one hand, there could be direct long-term health consequences for the population exposed to radiation. There is a significant positive association between residence in radiation-affected areas at the time of the accident and self-assessed poor health (Lehmann and Wadsworth 2011). The Ukrainian government set up a special welfare programme and monthly payments to residents of the contaminated territories to help people buy clean food and minimize the risk of consuming polluted foodstuffs, but these Chernobyl programmes proved unsustainable, poorly funded, and largely ineffective (Davies and Polese 2015). In these predominantly rural areas, people are used to consuming home-grown vegetables and foods foraged in the woods. Nevertheless, the evidence for adverse radiation-induced health effects in the contaminated areas is unclear except for a significant increase in thyroid cancer prevalence and a severe impact on psychological well-being (Likhtarov et al. 2006; Cardis and Hatch 2011; Kamiya et al. 2015; Danzer and Danzer 2016). Likewise, an assessment of causes of death related to the radiological impact of the Chernobyl accident in neighbouring Belarus revealed no clear picture (Grigoriev et al. 2013): although clusters of high mortality from thyroid cancer were detected in the most contaminated areas of Belarus, the observed patterns were not sufficient to conclude that Chernobyl had a significant direct impact on contemporary mortality.

On the other hand, the *indirect* effects of the Chernobyl accident could be of greater importance, as it has had profound negative ramifications for socio-economic development in the affected regions, partly due to SES-selective outmigration. For instance, in the northern districts of Zhytomyr region, production in the agro-industrial sector dropped by 40 per cent between 1986 and 1996 (Kuzmin 2016). Some evidence suggests that those who lived in more contaminated areas displayed significantly lower levels of labour market performance (labour force participation, hours worked, and wages) 20 years on (Lehmann and Wadsworth 2011).

In addition to contamination as a *push* factor, geographical proximity to the capital, Kyiv, could be an



important *pull* factor for selective migration. A similar observation has been made in Belarus: the region surrounding the capital (Minsk oblast) revealed the lowest life expectancy in the country, lower even than in the less developed regions of eastern and south-eastern Belarus (Grigoriev et al. 2013). Similarly, selective migration has been proposed as a possible explanation for the extremely high premature mortality among males in the north-west European part of Russia (also known as the ‘big triangle’ because of its proximity to three major centres of labour migration: Moscow, St. Petersburg, and the Baltic States; Grigoriev et al. 2020).

Our assessment of regional mortality inequalities indicated a clear reduction in absolute terms but no major changes in relative terms over the analysed period. With respect to the latter, we found no pronounced differences between Ukrainian males and females as indicated by the RII. We showed that the mortality gap between the best- and worst-performing regions was driven largely by differences in the level of CVD mortality at older ages. In the most recent years, the role of CVD mortality has become particularly pronounced, especially among females. This suggests that there has been faster progress towards the reduction of CVD mortality in the vanguard group, which includes the capital and other large Ukrainian cities.

It has been suggested that the clear advantage of large metropolitan areas and cities might be explained by their higher share of highly educated, economically active people, who maintain healthier lifestyles and have better access to modern health-care (Levchuk and Shevchuk 2021). Both factors are essential prerequisites for the cardiovascular revolution (Grigoriev et al. 2014), in which the vanguard group has been taking the lead. That Kyiv temporarily lost its vanguard position in the early 1990s due to a rapid decline in life expectancy fits with urban–rural patterns in other FSU countries. Initially, the magnitude of the life expectancy decline was greatest in large cities, where even food shortages emerged at times (Van Atta 1998), but large cities were also the first to recover (World Bank 2005).

Mortality from external causes has long been an important contributor to regional mortality differences, particularly among males (Libanova et al. 2007; Poniakina 2014; Ryngach 2021). However, as we showed, its relative importance has notably diminished. Nevertheless, unlike for most other causes of death, there is still a striking contrast between western Ukraine and the rest of the

country in mortality from external causes. Remarkably, the cold spot in western Ukraine follows historical borders and is centred on those parts of Ukraine that spent the shortest time under Russian or Soviet rule. The advantage of the west is also manifested in low mortality from suicide, which appears to be influenced by both individual-level characteristics and contextual (area-level) factors, as suggested by a recent analysis of longitudinal census-linked data for Lithuania (Jasilionis et al. 2020). Thus, the detected suicide mortality cold spot in western Ukraine can again be linked to historical political borders and can be attributed primarily to the cultural differences and high level of religiosity recorded in western regions, where religion is an important factor in cultural identity (Yelensky 2010; Ryngach 2017; Razumkov Centre 2019). Strong commitment to life-preserving religious or socio-cultural traditions and beliefs may have a positive impact on collective psychological well-being in these areas and reduce the suicide rate. There are a number of possible explanations for the significant clusters of high suicide rates in the north-east and south-east of the country: lower proportions of religious people, higher prevalence of alcohol- and drug-related mental disorders, and/or problems related to unemployment and economic instability in urbanized areas. In addition, there is evidence that a massive population displacement since 2014 has resulted in a much higher prevalence of depressive and anxiety disorders among internally displaced persons (IDPs), with the majority of IDPs staying in eastern Ukraine (Kuznestsova et al. 2019; Roberts et al. 2019; Batorygareieva et al. 2020). All these factors contribute to declining social cohesion, and lack of access to psychosocial support and treatment for mental disorders can also increase the risk of suicide. It is noteworthy that the small cluster of lower suicide rates in the areas close to the Russian border (in Kharkiv region) in 2017–19 is questionable and might result from suicide misclassification, with a high proportion of suicides hidden among EUI deaths (Levchuk and Shevchuk 2021).

The detected cluster of elevated HIV mortality in southern Ukraine and its further expansion towards the central part of the country is worrying. These observations are consistent with the regional data on HIV prevalence. Ukraine reports the second highest HIV prevalence in Europe, with an estimated 245,000 persons living with HIV, that is, 0.7 per cent of the adult population aged 15+ years (Antonenko and Martsynovska 2022). The country is disproportionately affected by HIV. The southern regions (Dnipropetrovsk, Mykolaiv, and Odesa) show the highest

HIV prevalence, while western regions register much lower HIV rates. The HIV epidemic in the most affected regions is associated with a high prevalence of opioid-dependent individuals (Zaller et al. 2015) and a rapid spread of infectious diseases in the late 1990s and early 2000s among people who inject drugs and among their sexual partners (Levchuk 2011). Nevertheless, the spread of the HIV epidemic in these regions is not attributed only to traditional risk factors. A recent analysis of HIV mortality across Russian regions identified lack of knowledge about sexual transmission of the HIV in the general population as an important factor responsible for the expansion of the epidemic from marginalized communities to the general population (Nikoloski et al. 2023).

The large clusters of elevated mortality from lung cancer among males in south-eastern Ukraine, which have persisted over time, warrant further investigation. They could be explained by regional differences in past smoking behaviour or by greater exposure to industrial hazards and environmental problems due to a concentration of metallurgical and mining industries in this area (Zaporizhia and Dnipropetrovsk regions). Although it is hard to obtain clear evidence of the impact of environmental factors, Voitko et al. (2009) concluded that past smoking behaviour alone could not fully explain the spatial clustering of lung cancer mortality. They suggested that air pollution might also be responsible for the increased rates of lung cancer in south-eastern Ukraine in 1995–2004. Other studies have pointed to the disadvantageous position of the south in terms of smoking prevalence. In the 1990s and early 2000s, smoking rates among Ukrainian men were among the highest in Europe and reached over 50 per cent (Gilmore et al. 2001; Pomerleau et al. 2004). According to the Demographic and Health Survey conducted in Ukraine in 2007, men's smoking was more prevalent in the south (63 per cent) than in the north (44 per cent) and west (46 per cent) (UCSR 2008). Although the effective implementation of tobacco control and taxation policies since 2006 has resulted in a substantial decrease in the prevalence of tobacco use among males, smoking remains one of the major public health issues in Ukraine, and smoking-attributable mortality will continue to play an important role in shaping regional mortality differences in Ukraine (MHU 2017).

### *Study limitations*

The study described in this paper had several limitations that must be acknowledged. The major concern

is the quality of post-censal population estimates, which are based on Ukraine's 2001 Population Census (the most recent available). Unfortunately, it is not possible to accurately quantify the impact of this unusually long post-censal period on either mortality indicators or regional mortality differentials. The error due to under-registration of migration events presumably accumulates over time, making the most recent mortality estimates less reliable. One indication of the problem with population estimates at district level is UkrStat's aggregation of official population counts into a large open age interval at ages 70+.

Before computing mortality rates, we investigated ways to split population estimates so that they matched the more detailed data on death counts. However, the obtained results turned out to be implausible. The process of splitting largely smoothed out the real and very substantial fluctuations in the population age structure (caused primarily by the cohorts born during and just after the Second World War). Furthermore, while applying the splitting to each population strata independently, we were unable to achieve internal consistency of the obtained population estimates. As a result, we had to compute mortality indicators based on data for ages 70+ combined, but the computed SDRs would have been more precise had we been able to obtain more detailed population data at older ages.

Our initial assessment of the raw mortality data indicated that the quality of death registration data varied across Ukrainian regions and over time. This is due mainly to varying proportions of *ill-defined* deaths, which are relatively low in Ukraine compared with many other industrialized countries. In 2006–08, the average proportion of ill-defined causes in our data set covering 24 regions of Ukraine (items R00–R94, R96–R99 in ICD-10) was 2.7 per cent for males and 5.8 per cent for females. The corresponding figures in 2017–19 were 2.6 and 3.9 per cent, respectively. This makes Ukrainian mortality data less sensitive to the choice of redistribution method. We addressed the issue of ill-defined causes by redistributing those deaths across the other causes of deaths, except EUI deaths. We also treated the latter as ill-defined but within the external causes category. Because of the known issue of EUI misreporting in Ukraine and elsewhere (Rockett et al. 2011; Värnik et al. 2012), at the expense of violent deaths (suicides in particular), we redistributed EUI deaths proportionally between suicide and homicide.

We must mention that although our modifications were based on evidence and on established practice

for dealing with ill-defined causes of death, the applied data adjustments were still arbitrary and by no means eliminated bias due to regional differences in coding practices. An apparent indication of such differences was the registration of CVD deaths. In our initial data assessment, we distinguished heart and cerebrovascular diseases within the CVD category. Unfortunately, it was not possible to analyse these groups separately because of the obvious interplay between them: regions with the highest mortality from heart diseases revealed the lowest mortality from cerebrovascular mortality and vice versa. The observed misreporting of CVD is a persistent phenomenon, as also noted in the study by Poniakina (2014).

The quality of population statistics could raise legitimate concerns as to whether the observed attenuation of regional mortality gradients in Ukraine was real or just an artefact of selective international or internal migration. The latter in particular intensified with the beginning of the war in Donbas in 2014. As we showed (Figures 2 and 3), the regions of Luhansk and Donetsk were distinguished by high mortality, particularly from external causes of death. Therefore, we would expect excluding the occupied territories from the analysis to have affected our conclusions. Indeed, the resettlement of evacuated persons from Donbas (the most densely populated area in the past) could have caused notable distortions because of the mixing of different survival regimes, health profiles, and self-preserving behaviour and habits of both local and displaced populations. According to official estimates (Table A2, supplementary material), the war that erupted in eastern Ukraine in 2014 resulted in forcible displacement of 1.5–1.7 million people. Unlike in 2022, when Ukrainians fled their homes throughout the country and went abroad in similar numbers, in 2014–19 the vast majority of IDPs from Donbas and Crimea were relocated within Ukraine. Out of the total 1.65 million officially registered IDPs in January 2017, the majority were located in the back-then non-occupied parts of Donetsk (34 per cent) and Luhansk regions (18 per cent), in Kharkiv region (12 per cent), and in Kyiv city (9.5 per cent). This implies that half of the displaced population remained in the Donetsk and Luhansk regions. The numbers of IDPs residing in western and central regions of Ukraine were very small. It is unlikely that displacement in 2014–19 had a substantial effect on either population or death counts in north-west Ukraine, given that IDPs comprised only 0.3–0.5 per cent of the total population in the Volyn and Rivne regions. IDPs comprised about 7 per cent of the total population in Kharkiv region

and about 5 per cent in Zaporizhzhya and Kyiv city. Likewise, this would have had only a slight impact on mortality rates.

To verify that population dynamics were not affected by any unexpected changes, we computed the annual rate of population change for each spatial unit, sex, and broad age group over the analysed period. For the vast majority of districts, the annual change evolved smoothly (–0.86 per cent on average across all observations for both sexes and all ages combined). We found no systematic differences between sexes, nor between age groups. Furthermore, we identified only a few outliers reflecting possible defects in the vital registration system. However, these issues were too small to have had any notable impact on our results. By pooling the data by three-year periods, we largely eliminated these random fluctuations. The robustness of our mortality estimates was also confirmed by the stability of identified mortality clusters over the analysed period. This was very unlikely to have occurred in the presence of very significant distortions in the data collection system. Furthermore, the long time trends in cause-specific mortality (Figure 3) did not reveal any suspicious disruptions. This was especially obvious for mortality from neoplasms, where regional trends revealed remarkable regularities over the last three decades. Again, this would not have been the case in the presence of very serious issues with the denominator (population size) due to misreporting of migration events. Therefore, we believe that the identified data quality issues have not influenced our main conclusions.

## Conclusion

This paper aimed to put Ukraine on the map in the field of contemporary spatial cause-specific mortality research. We were able to identify and discuss a number of relevant patterns, to deepen our understanding of Ukraine's achievements in mortality reduction and the remaining challenges. CVD continues to be the most significant cause of death and this is particularly the case in the mortality hotspots in northern and southern Ukraine. The northern Ukrainian CVD mortality hotspots include the areas heavily contaminated by the Chernobyl disaster. However, our data did not allow us to identify the degree to which this has been driven by contextual environmental effects or selective outmigration from contaminated areas and from Kyiv region to Kyiv city. We leave this to future research.

Overall, Ukraine still appears to be at an early stage of the cardiovascular revolution. Thus, public health investments in this area (including investments in the healthcare system but also in awareness campaigns about healthy lifestyles) still offer plenty of room for health improvements. For other important behaviour-related causes of death, such as lung cancer and HIV, we identified clear mortality hotspots. This is also helpful for public health policies aimed at tackling these issues, as they should focus especially on these hotspots.

It is beyond the scope of this paper to provide deep insights into the mechanisms that have caused the observed patterns. Furthermore, because of the ongoing war, it remains unclear whether the spatial mortality trends and patterns we have reported here will persist in future. Nevertheless, we believe that for years to come our work will serve as an important reference for future research. We have shown that northern Ukraine in particular has been lagging behind, while western Ukraine and large cities concentrated in the centre, east, and south represent mortality cold spots. Rather uncertain is the future of eastern Ukraine, particularly those territories in the Donbas that are most affected by the conflict. It is very likely that the war will substantially exacerbate the regional mortality disparities. Massive internal and international migration will eventually change the age-sex structure of the population in all Ukrainian regions. Likewise, the disruption of healthcare provision (e.g. limited access, inadequate vaccination, poor preventative measures, delays in intervention, and disruption of water and sanitation infrastructure), the economic crisis, and the violent environment will result in growing mortality from both non-communicable and communicable diseases (Leon et al. 2022). How exactly all these will affect regional mortality differences in Ukraine in future is a matter of great uncertainty.

## Notes and acknowledgements

1 Pavel Grigoriev is based at the Federal Institute for Population Research (BiB), Germany. Nataliia Levchuk is based at the Ptoukha Institute for Demography and Social Studies (at National Academy of Sciences of Ukraine) and also the Max Planck Institute for Demographic Research (MPIDR). Pavlo Shevchuk is based at the Ptoukha Institute for Demography and Social Studies, Ukraine. Svitlana Poniakina is based at the French Institute for Demographic Studies (INED).

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## Disclosure statement

No potential conflict of interest was reported by the authors.

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