Enhancing the Spatial Demography Toolbox by Moving from Regions to Disparities between Regions: Illustrated by a Study of Mortality Disparities between 334 European Regions

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Short Abstract

The study of spatial variation in mortality tends to focus on regions or individuals situated within regions. Less focus has been given to identifying and understanding disparities between adjacent intra- and international sub-regions. However, focusing on differences e.g. across international vs. subnational borders can be very fruitful to deepen our understanding on factors driving spatial mortality variation. To illustrate the potential of such analyses, we use mortality data collected for 334 European regions. For this dataset we derive all pairwise first-order relationships (i.e. regions that border each other), resulting in 232 international and 1560 intranational borders. We employ methodologies not normally used in a demographic context, such as the Earth Mover's Distance, to quantify the differences in mortality distributions between two regions, as well as an approach to reimagine clusters of mortality patterns and their boundaries simultaneously. They allow us to provide unique insights into the similarities and dissimilarities of mortality along intra- and international borders and their evolution in the decade before the COVID-19 pandemic. We identify where large differences in mortality exist between neighboring regions, how they differ by spatial distribution and sex, and measure the evolution of these patterns in the decade preceding the COVID-19 pandemic. Preliminary results indicate substantial spatial and sex-specific heterogeneity along both international and internal borders. In the subsequent analysis, results will also assess cause-specific contributions to the observed differences. Our approach to quantitatively study these cross-border disparities can easily be transferred to other research topics within the field of demography.

Background

In the context of spatial disparities in health and mortality, the predominant focus has been on indicators at the national- or large-regional level (Ho and Hendi, 2018 (National level); Bonneux et al, 2010; Richardson et al, 2013 (NUTS-2), Grigoriev and Pechholdová, 2017 (East-West Germany)). However, there is a growing interest towards examining sub-regional patterns and variations in mortality. Notably, within and between European countries, discernible east-west and north-south gradients have been identified and subjected to analysis over time (for example, Hrzic et al, 2023; Rau and Schmertmann, 2020 (Germany); Bramajo et al, 2023 (Spain); Bonnet and d'Albis, 2020 (France)). This more in-depth type of geographic consideration offers a more nuanced understanding of mortality differentials and equips researchers and policymakers with valuable insights into how regional distinctions, such as health policies, educational attainment, socioeconomic status, and other structural and environmental factors, may influence health and longevity within a region (see, for instance, Mühlichen et al 2023.). Nevertheless, these studies often focus around broader national or continental contexts, rather than seeking to pinpoint the evolution and causes of specific divergences between adjoining regions.

Another aspect of understanding these broad regional differences involves analyzing the mortality patterns of two directly adjacent intra- or inter-national regions. For instance, considering the open travel policies of the European Union, the interconnection and interdependence of two internationally bordering regions may tether their mortality trajectories more closely to each other than to the prevailing mean values within their respective countries. Furthermore, the differences between two directly bordering regions, as well as a region's relationship to the mortality patterns within its own country, may differ over time by sex and patterns in causes of death (Schootman et al, 2016). International borders may either serve as distinct boundaries between two discrete mortality regimes, or they simply exist within a larger mortality gradient across national boundaries. Likely, these patterns vary based on geographic and cultural contexts.

Even though studies on mortality differentials at (sub-)national borders can help revealing important health determinants such as certain health policies or cultural aspects, this field of research has remained largely unexplored. Klüsener, Parelli-Harris, and Gassen (2013) investigated the role of states and regions in shaping patterns of nonmartial fertility across Europe's regions. Further, Shootman et al. (2016) found substantial differences in mortality rates between adjacent counties in the US, suggesting that policy interventions can indeed reduce geographic disparities in mortality. Data limitations may be one reason for the dearth of literature and other analyses that attempt to quantify and contextualize mortality differences between two adjacent regions, as mortality data is usually available at the national or large-regional level. However, the study of differences in death rates between adjacent regions is particularly necessary to better understand what exactly contributes to the development of broader spatial patterns in mortality. In addition, it is helpful to look at cause-specific mortality, because it allows linking specific health behaviors or exposures to the observed differences, e.g., differences in lung cancer death rates can be ascribed to differences in past smoking behavior. Another shortcoming in the previous literature refers to the methodological strategy. Jacquez et al. (2008) have introduced a broad technique for examining boundaries, links, and clusters. Yet, despite the consensus regarding the necessity of using these techniques, their use is underemployed.

Our analysis seeks to enhance our comprehension of the differences in mortality between directly bordering regions. Utilizing data collected by the ERC funded REDIM project, we quantify key differences in sex- and cause of death specific mortality during two time periods (2006-09 and 2016-19) between 334 European regions that share a land border. Our results employ methodologies that are normally not used in a demographic context and provide unique insights into the similarities and dissimilarities of mortality along intra- and international borders and their evolution in the decade before the COVID-19 pandemic.

Data and Methods

We use age-specific death and population to calculate life expectancy (e0) and standardized death rates (SDR) for 334 subnational regions throughout Europe during two time periods, 2006-09 and 2016-2019.[1] From these regions, 1792 pairwise first-order relationships are identified (i.e. pairs of regions that border each other), of which 232 represent international borders and 1560 represent borders of two regions from the same country.

We initially use spatial measures such as global and local Moran's I to better understand the total amount and where the level of mortality in regions is spatially correlated. We then calculate the difference in SDR and e0 between each pair of bordering regions and compare these differences from their deviation to the country's mean. For example, we are interested to know if there are greater differences in the SDR between bordering region *1* in country *a* and region *2* in country *b*, or between region *1* in country *a* and the mean of country *a*.

Other measures are used to quantify the differences in the age-specific mortality distribution between two regions with a single quantity. For example, the earth mover's distance quantifies the

[1] The regions will differ in the final analysis—additional countries (e.g.Italy and Luxembourg) will be added, and we will refine the spatial definition to include more regions in some countries (e.g. Austriy).

smallest amount of volume from a single distribution (region 1) necessary to transform it to another (region 2) in a single number (Rubner et al, 2000).

The final analysis will also include several broad cause of death groupings such as cardiovascular diseases and external causes to better understand where and to what extent different causes of death contribute to the differences in bordering regions. We plan to use cause-deleted life tables and/or life table decomposition techniques to quantify to what extent these cause of death groupings have on overall mortality differences between borders.

First results

Figure 1 shows quantiles of absolute difference in SDR between each pair of borders currently in the analysis. The color gradient from light (low) to dark (high) represent the dissimilarity in the sex- and time- specific SDR between the two administrative regions on either side of the drawn border. Despite no international boundaries being directly plotted, some boundaries, principally those between Germany and Poland, and Germany and Czechia, are apparent on the map. Moreover, some sex differences appear—women seem to have overall smaller differences, particularly within each country, but between France and Germany/Belgium, these differences are more apparent than when considering only men. Across internal borders, there are smaller differences in female SDRs, but this may be a relic of lower overall mortality.

When considering only international borders, the difference in SDR between each regional border, relative to that of its country's mean, is very heterogeneous across space, time, and sex. Figure 2 shows the absolute difference in SDR between regions that share an international border, and are colored according to whether a) both regions have a closer SDR to their country mean, b) both regions' SDR is closer to each other, or c) one region is closer to their own country's mean SDR, but the other region is closer to its bordering region's SDR (rather than the country mean). Perhaps most visually notable are the stark differences in SDR, especially among men, between international borders in the eastern European Union; not only are the absolute differences large in both periods, but they are closer to their own country's mean. Other interesting findings include differences between sexes along the same international border—for example, the SDRs for women in regions along the French/Belgium border in 2006-2009 were largely closer to their country's mean, while the SDRs for men in the same regions mostly were closer to each other than their county mean. By the second period of study, 2016-19, it appears that some of the regions for men moved closer to that of their country mean.

Figure 3 shows the distribution of the earth mover's distance for each facet in Figures 1 and 2 (time- and age- specific), split into those borders between (international) and within (internal) countries. The value of the earth mover's distance is directly related to the cost of moving the distribution (deaths weighted by population exposure at each age) of region *1* to region *2*, so higher values are associated with larger dissimilarity between bordering regions. It is clear that as a whole, age-specific mortality schedules are more similar between regions sharing an internal border rather than an international border. However, this may vary according to specific countries and borders, and may change with the addition of causal groups. The overall density distributions show that mortality differences between some regions sharing international borders are quite large.

Outlook

To date, we have identified bordering regions and quantified their differences to the extent above. In order to better understand and contextualize our results, we will continue to perform sensitivity analyses and refine our specific methods to those that best help to provide insights into this unique aspect of spatial demography and mortality research. One goal is to reimagine mortality clusters within Europe, using the approach of Jacquez et all (2016), which will further identify which particular borders (inter or intra national) outline larger disparities in mortality patterns in Europe. Our addition of cause of death groups will add another layer of depth to our results and will help quantify to what extent singular health outcomes and diseases contribute to these mortality differentials. Together, our analysis will use innovative techniques and a rich source of unique data to provide fresh insights into regional mortality in Europe using methods that can easily be transferred to other areas of demographic research.

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Figure 1: Quantiles of absolute differences in sex-specific SDR (per 1,000) between regional borders in 2006-09 and 2016-2019.

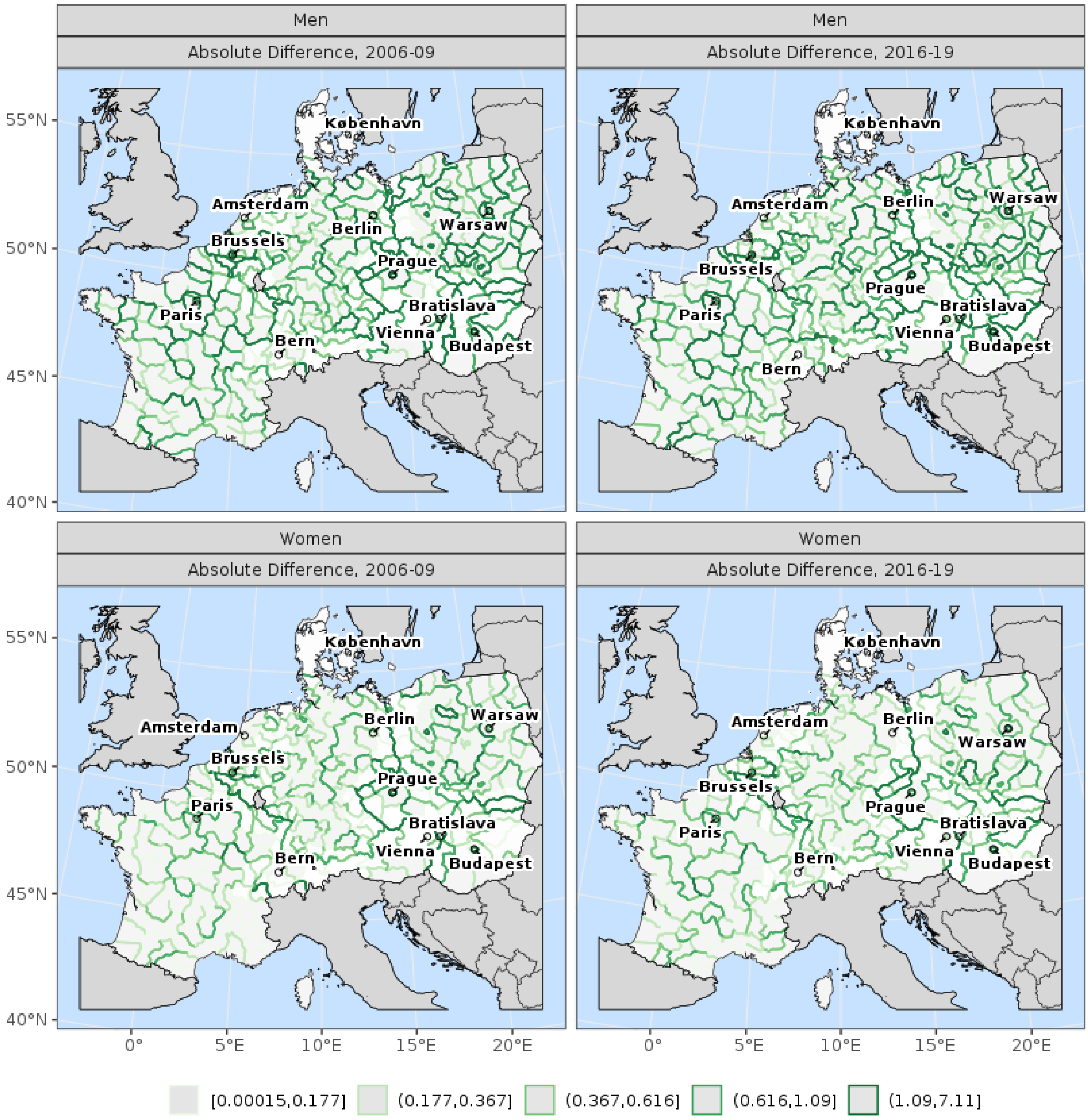

Figure 2: Differences in SDR between regions along international borders. The linewidth represents the absolute difference between the two regions, and the color corresponds to whether the SDRs in each region more closely correspond to each other or their respective country means.

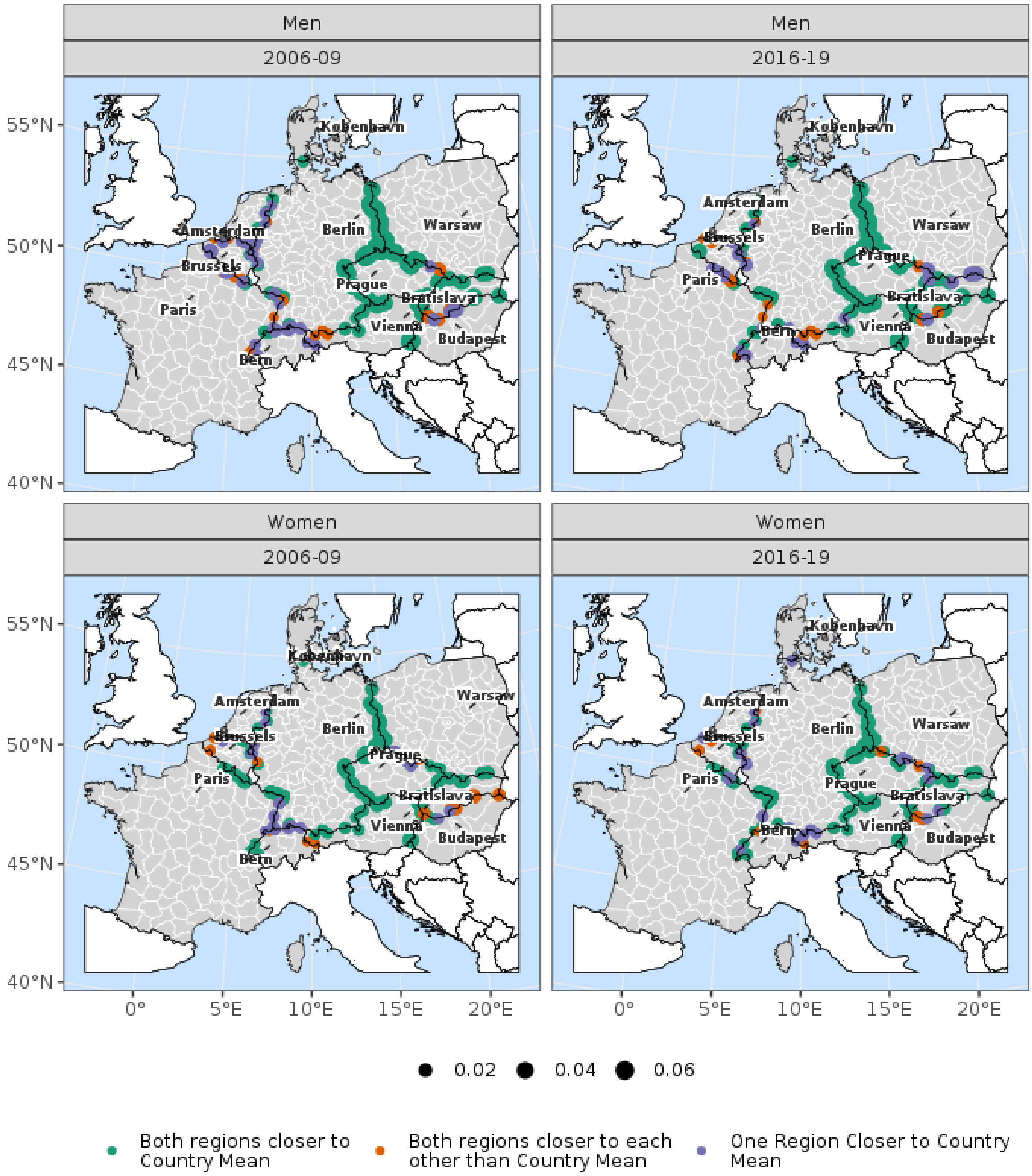

Figure 3: Distribution of the earth mover's distance between internal (left) and international (right) bordering regions according to sex and time period.