Diverging Regional Mortality Trends in Selected Avoidable Causes of Death in Poland, 2000–2019: a Fuzzy-Set Qualitative Comparative Analysis

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Abstract

Regional disparities in avoidable mortality have widened in Poland, reflecting differences in healthcare and public health system performance. While previous studies have linked mortality outcomes to regional economic, social, and healthcare factors, how these conditions interact to shape regional mortality trajectories remains poorly understood. This study is the first to apply fuzzy-set Qualitative Comparative Analysis (fsQCA) to examine combinations of contextual factors associated with mortality outcomes in a Central and Eastern European country. Death and population data from Statistics Poland were used to calculate age-standardised mortality rates (2000–2019) for 16 NUTS-2 and 73 NUTS-3 regions, disaggregated by sex and five causes of death (cerebrovascular disease; breast, lung, and colorectal cancer; and traffic injuries). After applying a cohort-period spline model to stabilise mortality estimates, the smoothed trends were used to classify regions as mortality vanguards or laggards for each cause. fsQCA was then used to assess which combinations of contextual factors, including GDP per capita, unemployment rate, proportion of residents with tertiary education, and nurse density, were associated with each regional classification. No consistent combination of factors was associated with regions being classified as mortality vanguards or laggards across the causes of death examined. The absence of necessary or sufficient configurations suggests that regional mortality disparities in Poland arise from complex, context-dependent interactions that call for tailored, region-specific interventions.

Background

While national mortality trends in Central and Eastern Europe (CEE) have been thoroughly examined,[1–7] less is known about subnational mortality disparities in CEE countries. A recent study examined regional mortality trajectories in five CEE countries and highlighted rising relative disparities in all-cause and cause-specific mortality rates, indicating the emergence of regions lagging in mortality improvements.[8] One possible explanation for these results is differences in the diffusion and uptake of healthcare or public health innovations, particularly those that prevent deaths from complex diseases such as cancer. This hypothesis has empirical support from recent studies that found growing regional disparities in avoidable mortality (deaths avoidable through medical or public health intervention) in Poland after 2014.[9,10]

This raises the question of contextual factors that influence the successful adoption of relevant health innovations at the regional level. Previous studies in Poland have found associations between regional trends in amenable mortality and various contextual factors, including access to care, healthcare resources, and socioeconomic deprivation.[9,11,12] A study highlighted that an initially significant association between amenable mortality and healthcare resource variables (e.g., primary care physicians, specialists) was substantially weakened after adjusting for socioeconomic factors.[9] The existing evidence thus highlights a complex relationship between amenable mortality and several interacting contextual factors. This complexity complicates policymakers' efforts to develop effective interventions for addressing regional disparities in amenable mortality in Poland and other CEE countries.

Complex causality has previously been addressed through a comparative case study approach known as qualitative comparative analysis (QCA). QCA applies set theory and Boolean minimisation to identify combinations of conditions that co-occur in cases of interest, enabling researchers to infer the necessary and sufficient causes of these outcomes.[13] This makes QCA an appealing approach for exploring the drivers of regional amenable mortality trajectories, particularly if we are primarily interested in which conditions (i.e., contextual factors) co-occur in regions that can be classified as mortality laggards or vanguards, and less interested in estimating the precise effect size of each factor. Despite these potential advantages, few studies have applied QCA to examine the relationship between mortality and regional context,[14] and none have used it to explore the drivers of regional amenable mortality in a CEE country.

This study aims to fill this gap by examining the co-occurrence of socioeconomic conditions, healthcare resources, and educational attainment in Polish regions that can be classified as mortality vanguards or laggards concerning selected avoidable causes of death: cerebrovascular disease, breast cancer, lung cancer, colorectal cancer, and traffic accident deaths.

Methods

Study design

Cause of death selection

Five amenable causes of death were selected as outcomes of interest because they have a well-defined clinical or public health intervention that can reduce disease incidence and case fatality rates for this cause (see Table 1). This makes them a relevant measure for the diffusion and uptake of healthcare innovations that impact mortality outcomes.

Table 1. Selected avoidable causes of death and associated healthcare innovations

Cause of death	Interventions
Cerebrovascular disease	Blood pressure control and early thrombolysis[15]
Breast cancer	Population screening and early detection[16]
Lung cancer	Tobacco control[17]
Colorectal cancer	Population screening and early detection[18]
Traffic accident	Road safety policies[19]

Contextual factor selection

The four contextual variables included in this study (regional GDP per capita, unemployment rate, nurses per capita, and proportion of population with tertiary education) were selected because they can serve as indicators for factors previously established as associated with cause-specific mortality in Poland (see above) and relevant to the diffusion of healthcare innovations in other settings.[20–23]

Data sources and preparation

Data on death and population counts by age group (0, 1, 5, …, 85, 95+), sex, cause, year (2000-2019) and region (16 NUTS-2 and 73 NUTS-3 regions) were collected from the national statistics office. Data on regional GDP per capita, unemployment rate, nurses per 1000 inhabitants, and the proportion of the population with tertiary education by region and year were extracted from the same source.

Mortality analysis at the subnational level is often complicated by erratic trends in age-specific death rates, arising from the inherent stochastic variation in death counts within small populations.[24] I used an established cohort-period spline model to stabilise mortality estimates and produce smooth age-standardised mortality trajectories by region, sex, and cause.[25]

Qualitative comparative analysis

This study applies the fuzzy-set QCA approach, which allows conditions and outcomes to be defined with two or more levels or categories.

Outcome calibration

The outcome set was defined based on a region's membership in the mortality vanguard versus laggard class. Since the definitions of mortality vanguard and laggard regions are not unequivocal, I performed the analysis using two definitions. The first defined vanguards as regions with average (over time) mortality rates below the national average for the sex and cause (coded as 1), and laggards as regions with above-average mortality rates (coded as 0). The second, more complex, definition divided the regions into four groups: (1) regions with average (over time) mortality rates below the national average for the sex and cause and a better-than-average decline in mortality throughout the period (coded as 1), (2) regions with below average mortality rates lower-than-average mortality declines (coded as 0.66), (3) regions with above average mortality rates and better-than-average mortality declines (coded as 0.33), and (4) regions with above average mortality rates and a worse-than-average mortality declines (coded as 0).

Condition calibration

The condition set was defined based on the transformed values of each contextual variable. For each variable, I first calculated a regional average over time, then calculated robust z-scores using median absolute deviation, and finally rescaled the robust z-scores to construct scores ranging from 0 to 1. The GDP per capita was additionally log-transformed to achieve a less skewed distribution. For the unemployment variable, an inverse score (employment) was used in the analysis, so that scores greater than 0.5 across all sets indicate generally favourable mortality and innovation diffusion conditions.

Analysis

The analysis comprises several parts. First, to identify necessary conditions, I calculated the necessity consistency, coverage, and relevance scores for each condition and compared them to established cut-off values (0.9, 0.6, and 0.6). Second, to identify conditions that may be necessary in combination, I examined whether any SUIN conditions were present, which are sufficient but unnecessary parts of a factor that is insufficient but necessary for an outcome. Third, to identify sufficient conditions, I calculated the sufficiency consistency, proportional reduction in inconsistency, and coverage scores for each condition and compared them with established cut-off values (0.8, 0.51, and none for coverage). Finally, to identify conditions sufficient in combination, I constructed truth tables and minimised them through Boolean algebra.[26]

Preliminary results

The analysis generally highlighted higher consistency, coverage, and relevance scores for NUTS-3 regions, the four-level definition of mortality vanguard and laggard regions, and analyses stratified by sex and cause, rather than pooling observations.

While none of the conditions reached the standard cut-off for the necessity consistency score (≥0.9), several came close (≥0.85): GDP per capita when considering traffic fatalities (particularly for men) and the proportion of the population with tertiary education when considering colon and breast cancer mortality. No additional SUIN conditions were identified in either the NUTS-2 or NUTS-3 datasets.

No single condition reached the threshold for sufficiency in classifying regions as mortality vanguards or laggards. The minimisation procedure yielded several configurations that met the conventional consistency threshold (≥0.8), indicating potential sufficiency for cardiovascular mortality in the NUTS-2 dataset. However, only two of these configurations also achieved acceptable PRI scores, and both accounted for only a small subset of cases. Moreover, these configurations were not replicated in the corresponding NUTS-3 analysis.

Overall, the findings suggest that no single condition or combination of conditions consistently met the empirical thresholds for necessity or sufficiency, underscoring the multifactorial and context-dependent nature of regional mortality advantage.

Next steps

Next steps in this analysis will focus on addressing the main study limitations. First, although the smoothing procedure stabilised most regional mortality trajectories, a few region–cause–sex combinations displayed implausible trends. I will assess the sensitivity of the QCA results to these cases by excluding them from the analysis and by testing alternative smoothing methods, such as spatio-temporal Bayesian models. Second, the current study included only a limited range of causes of death and contextual factors. Expanding the scope to encompass more broadly defined categories of avoidable mortality, for example, tobacco-related, alcohol-related, and cancer-screening-related deaths, may help stabilise regional mortality trends and better capture the influence of broader public health innovations. Likewise, incorporating additional socioeconomic and healthcare resource indicators (e.g., area deprivation scores, availability of primary and secondary care facilities) could further strengthen the robustness and explanatory power of the findings.

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