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Life Expectancy Dynamics in European Border Regions: Differences by Age and Age-Specific Contributions to Convergence and Divergence

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Abstract

Recent regional mortality analyses in Europe reveal that not all areas have benefited equally from health improvements, raising concerns about growing divergence in regional mortality patterns. EU border regions represent a key dimension for understanding the health impacts of European integration, given the ability to travel freely across borders. Border regions combine structural disadvantages, such as peripheral economic position and limited access to healthcare providers, with unique opportunities arising from European integration and cross-border mobility. Despite their relevance, longitudinal studies on population health in border regions remain scarce and have to date not examined mortality in specific age groups.

This study addresses this gap by examining age-specific contributions to life expectancy changes in European border regions between 1995 and 2024. Using harmonized mortality and population data from the REDIM project for 17 countries at the NUTS-3 level, we estimate partial and remaining life expectancy for key age groups (0–15, 15–65, 65+) in border and non-border EU regions. Decomposition techniques are applied to identify the age groups driving convergence or divergence across EU borders.

We expect to find that life expectancy in border regions remains lower and more heterogeneous than in non-border regions, with patterns of both convergence and divergence over time. Gains at older ages (65+) are anticipated to account for the largest share of improvements, reflecting advances in medical technology and healthcare access, while younger age groups contribute less due to already low mortality levels.

Background

Life expectancy in Europe has increased in the past decades, however, disparities between countries persist, highlighting enduring health inequalities. Existing studies often look at these life expectancy developments from a country level perspective and cross-country comparisons. They have found socioeconomic characteristics of populations, welfare regimes, national health care expenditure and access to and innovation of healthcare as determinants for health inequalities and differences in life expectancy (e.g. Hzric et al., 2021; Mackenbach et al., 2008; Bambra et al., 2008; Mackenbach et al., 2017). While national-level analyses reveal broad patterns of life expectancy and health inequality across Europe, they mask regional variations in life expectancy development. Sauerberg et al. (2024) raises the concern that not all regions benefit from health improvements in the past decades. Given the relationship between socioeconomic characteristics and life expectancy development, some regions perform better, often referred to as "vanguard groups", while other weaker regions might fall behind. These patterns should raise concern for policy makers at European, national and sub-national levels. Border regions could potentially be part of the vanguard groups, given their possibility to benefit from cross-border collaboration and EU integration.

The establishment of the European Union has played an important role in economic growth and increasing living standards across member states. European integration has generally improved living standards (Brandolini & Rosolia, 2021) and stimulated economic growth among EU members (Campos et al., 2019; Santos et al., 2020). Economic development, in turn, is closely linked to population health, as higher GDP per capita is associated with longer life expectancy (Swift, 2011). Health as a fundamental component of living standards has traditionally not been an integral policy field of the EU, however, improving health and the access to health care for European citizens is one of the aims of the European Union. European integration aims for convergence between member states, this also includes health equality. Based on the theoretical framework provided by Vallin and Meslé (Meslé & Vallin, 2017) this process is based on a country's ability to adopt medical innovations, public health policies and health behaviors. Where some regions are able to absorb innovations faster than others. In order for further European integration and cohesion it is important to address these remaining gaps in health inequalities.

With the ability to travel freely across borders, border regions have gained significant importance when it comes to study the effects of European integration on health. The open border principle facilitates free movement of people and services across national borders and has the potential to reduce health inequalities through improved access to healthcare and cross-border collaboration, yet it may also expose underlying disparities when neighboring regions differ in health system capacity and innovation adoption. Border regions occupy a unique position within the European regional geographical and policy landscape given that one third of the European population lives in border regions (European Commission, 2017). Border regions often have structural disadvantages, given their peripheral location within the national economy (Makkonen & Williams, 2016), often weaker infrastructure, or limited access to major

hospitals or healthcare providers (Van der Zanden & Nemer, 2024). However, these regions could potentially experience greater benefits from European integration due cross-border mobility, both for economic advantages such as trading as well as accessibility to a greater labor market. These unique geographic and economic characteristics make border regions particularly relevant for examining population health outcomes, as both the structural disadvantages and integration-related opportunities can directly influence mortality, life expectancy, and access to healthcare services.

According to a recent scoping review, studies with a longitudinal approach to population health in border regions are still greatly lacking (Stroisch et al., 2025a). Recent studies by Stroisch et al. (2025b) analyzed life expectancy patterns across border regions in Western Europe from 1995 to 2019. While some regions experienced convergence toward national averages, others diverged, with disparities between neighboring border regions often more pronounced than those between border and non-border regions within the same country (Stroisch et al., 2025b). These results raise questions as to what age groups and causes of death may contribute to these patterns of divergence and convergence.

The mechanisms through which European integration influences health, such as economic development, labor mobility, and cross-border healthcare access, are likely age-dependent. In a study by Lee et al. (2024) it is shown that for 50 out of the 53 Member States of the WHO European Region, recent gains in life expectancy were mainly driven by reduced mortality at older ages. However, a study of regional life expectancy disparities in Germany highlighted that younger and middle-aged adults in deprived areas contributed most to growing life expectancy gaps (Tetzlaff et al., 2024). These paradoxical results highlight the need to empirically examine the role of different age groups in mortality diverge-convergence trends in border regions. While overall life expectancy trends provide a useful summary, they mask the heterogeneous contributions of specific age groups. This study addresses this gap by examining age-specific contributions to life expectancy changes in European border regions between 1995 and 2024, also focusing on the benefits of different age groups in terms of life expectancy gains.

Data and methods

In order to grasp a small geographical scale, border regions are identified according to Eurostat NUTS-3 classification. This classification identifies border regions as regions with a land border or regions with more than half of the population living within 25 km of such a border (Eurostat, 2024). In case that NUTS-3 regions do not differentiate border regions well enough in small countries, Local Administrative Unites (LAU) is preferred. We make use of two reference groups: (1) border regions of opposing sites of the border and (2) non-border regions within the same country. We use harmonized regional population and death counts from the REDIM project, from national statistical offices across 17 European countries. An overview of the 17 countries and the number of border regions per country is included in table 1.

Table 1. Countries of study and the total number of regions

Country	Geo level	Number of units	Number of border regions
Austria	NUTS 3	35	23
Belgium	NUTS 3	43	32
Czechia	NUTS 3	14	11
Denmark	NUTS 3	11	3
Finland	NUTS 3	19	1
France	NUTS 3	95	22
Germany	NUTS 3	400	80
Italy	NUTS 3	92	14
Netherlands	NUTS 3	40	14
Portugal	NUTS 3	16	5
Spain	NUTS 3	50	12
Switzerland	NUTS 3	26	17
Poland	NUTS 3	73	14
Sweden	NUTS 3	21	7
Slovakia	NUTS 3	8	8
Hungary	NUTS 3	20	14
Slovenia	NUTS 3	12	10

Due to the small population sizes at this geographical scale, random fluctuation can distort mortality estimates. To address this, we apply established cohort-period smoothing techniques to stabilize age-specific mortality rates. More specifically, the CP splines smoothing method estimates age-specific mortality surfaces across time and regions, therefore capturing underlying trends while preserving realistic age profiles (Camarda, 2019).

Life expectancy estimates are derived from smoothed mortality estimates, for all border regions in the 17 EU countries incorporated in this study. To ensure comparability across time and space, we compute life expectancy at birth as well as partial and remaining life expectancy for selected age groups (0–15, 15–65, and 65+ years). This approach captures mortality dynamics across distinct life stages and allows us to identify differences in remaining and partial life expectancy in border regions and to identify age groups contributing most to regional convergence or divergence in overall life expectancy in border regions. By using age decomposition techniques, such as linear integral decomposition method, we examine which life stages contribute most, but also which life stages might benefit most in border regions. The linear integral decomposition method allows for decomposition of differences in life expectancy into continuous, age-specific contributions (Horiuchi et al., 2008).

Expected results

Based on existing evidence, we expect to find that life expectancy in European border regions remains lower and more heterogeneous than in non-border regions, with patterns of both convergence and divergence over time (Stroisch et al., 2025b). Such patterns could be explained by socioeconomic inequalities, as shown for a regional study on Germany, affecting both

working age and older populations (Tetzlaff et al., 2024). Furthermore, we expect that age-specific decomposition will reveal that improvements in life expectancy are not evenly distributed across age groups. In line with previous European studies, gains at older ages (65+) are likely to account for a growing share of overall improvements, while younger age groups may show smaller contributions due to already low mortality levels (Lee et al., 2024; Simões & Montero, 2021). These gains at older ages are primarily attributed to the reductions in cardiovascular and cancer mortality, facilitated by advanced medical technologies and improved healthcare systems across member states (Wéber et al., 2023). However, the possibility of proper implementation of health policies and the absorption of innovation across member states and subsequent regions may result in divergence between regions.

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