Divergences and convergences in recent French mortality patterns

Extended abstract for European Population Conference 2024

Jacob Martin*[1,2], Carlo Giovanni Camarda[1], and Tim Riffe[2,3]

[1]Institut national d'études démographiques
[2]Universidad del País Vasco (UPV/EHU)
[3]Ikerbasque (Basque Foundation for Science)

October 31, 2023

Abstract

The path towards low mortality and high longevity has been extensively studied at the national level. Theories of health transition predict highly heterogeneous patterns among sub-populations in the same country, with convergence in the health and mortality conditions of the sub-populations preceded by periods of divergence. Regions within a country are sub-populations that are often marked by economic inequalities and cultural and environmental differences. In this article we examine the question of regional divergence and convergence in mortality patterns among the French *départements*. Using life tables for the 95 *départements* of Metropolitan France for the years 1970–2019, we find an initial period of convergence in life expectancy at birth until the mid-1990s, followed by divergence, then a shift towards convergence again in the most recent years for men. The pattern of divergence is more pronounced for remaining life expectancy at older ages. We will also assess the degree of convergence or divergence between départements in other summary measures of mortality, including lifespan variation indicators, the modal age at death, and age standardized death rates, and compare the trends with those of life expectancy.

1 Introduction

Life expectancy rose dramatically in many countries around the world over the last two centuries (Vallin and Meslé 2010; Vaupel, Villavicencio, and Bergeron-Boucher 2021), but these increases have not been shared equally: globally, life expectancy at birth between countries has been diverging since the 1980s (Moser, V. Shkolnikov, and Leon 2005). Furthermore, focusing on data aggregated at the national level obscures important inequalities which exist between sub-populations stratified by race, socioeconomic status, or region. While the increase in life expectancy has often been accompanied by a reduction in inequality in

*Email: jacob.martin@ined.fr

length of life between sub-populations, spatial inequalities have persisted even in life expectancy vanguards such as France (Barbieri 2013; Breton et al. 2022). Regional disparities in mortality may be in part due to economic inequalities between regions, as well as cultural factors and exposures to environmental hazards only present in certain geographic areas. Taking a closer look at sub-national mortality can also reveal the emergence of local epidemiological patterns before they generalize to the national level.

In this study, we analyze spatial dynamics in French mortality patterns over the last 50 years. Metropolitan France is divided into 95 *départements* of similar geographic size, and we will take the *département* as the unit of analysis. France represents an interesting case study since the availability of data at the *département* level has revealed dynamic trajectories of mortality change: for example, the best performing *départements* in terms of life expectancy at the beginning of the 20th century were among the worst performing by the beginning of the 21st century (Bonnet and d'Albis 2020). Furthermore, French government and society is very centralized around the Paris metropole, so the French case can serve as a comparison to more decentralized contexts like the United States (Woolf 2023) or Germany (Hrzic et al. 2023).

Analyses of geographic differences in mortality have focused primarily on life expectancy at birth and its change over a large time period. While an important summary measure, life expectancy at birth does not capture certain aspects of the mortality schedule, such as age-specific mortality dynamics or variability in the timing of death (Aburto et al. 2020). Also, looking at change over a very large time period can hide important temporal dynamics: the path from higher to lower inequality may not be a linear trajectory.

2 Theoretical background

Frenk et al. (1991) proposed a theory of health transition, which characterizes the transition from high to low mortality in a population. Instead of theorizing rigid stages and outcomes of the transition, they argue for a dynamic theory which allows for a diversity of starting points and trajectories, and emphasize the different distribution of pace and path of transition among sub-populations and regions in a country. Vallin and Meslé (2004) expanded on these ideas of health transition and proposed that as countries progress towards better health and mortality conditions, first the best performing countries improve rapidly, creating a divergence between populations, then worse performing populations catch up, creating convergence. Furthermore, in line with the theoretical focus of Frenk et al. (1991), in a follow up Vallin and Meslé (2005) conjectured that the process of divergence-convergence happens at the sub-national level, among socioeconomic groups and regions.

Different approaches exist to measure inequality, divergence, and convergence. When studying regional inequalities, a straightforward way to quantify convergence is to calculate the standard deviation (or other dispersion measure) of life expectancy between the different regions. If dispersion decreases over time, this corresponds to the so-called σ-convergence, with σ referring to the canonical notation for the standard deviation. Another approach is to consider β-convergence (Barro and Sala-i-Martin 1992), which occurs when life expectancy increases more rapidly in regions with lower starting levels, causing them to catch up to the regions at higher starting levels. β-convergence is calculated by fitting the linear model

$$\frac{e_{0dt_2} - e_{0dt_1}}{t_2 - t_1} = \alpha + \beta e_{0dt_1} + \varepsilon,$$

where e_{0dt} represents life expectancy at birth in region d at time t, t_1 and t_2 are the start and end time periods, respectively, α is the intercept term, β is the regression coefficient, and ε is a normally distributed error term. In a context of overall increases in life expectancy, β-convergence occurs when $\beta < 0$, since this implies that lower starting levels of life expectancy are associated with larger increases in life expectancy. If $\beta = 0$, this means that life expectancy is changing at a constant rate in all regions, so any present inequalities will stay the same. Finally, if β is positive, life expectancy in already better forming regions will increase at a rate faster than those regions lagging behind, causing divergence.

Previous analyses of regional mortality trends in Europe have looked at both σ and β and found evidence of both σ and β convergence in the late 20th and early 21st century (Janssen et al. 2016; Hrzic et al. 2023). In France, Vallin and Meslé (2005) and Bonnet and d'Albis (2020) studied σ-convergence in life expectancy in the *départements* over a time series spanning most of the 19th and the 20th century and found periods of both divergence and convergence, though the 1970s to the present were characterized convergence until the 1990s, followed by stagnation or even divergence in the early 2000s.

Studies of regional convergence have been limited by their singular focus on life expectancy at birth as an indicator of mortality conditions, and have not considered other summary measures of mortality or the age-at-death variability.

3 Data and method

We use population exposures and death counts by period, age, sex, and *département* for the years 1970 to 2019 from Bonnet (2020). Periods are single year, and we have single year age categories as well up to the open age category of 95+.

We smoothed the death counts in two dimensions (age and time period) using P-splines (Camarda 2008; Camarda 2019), which allows us to overcome large fluctuations in the data due to the stochastic nature of mortality. After smoothing the data we prepared life tables for each *département* using standard methods (Preston, Heuveline, and Guillot 2001). With the prepared life tables, we took the first yearly difference in remaining life expectancy at each age to obtain an indicator of rate of change in mortality conditions. For each age and year, we fit a linear regression of rate of change on level of remaining life expectancy, that is,

$$e_{xdi+1} - e_{xdi} = \alpha + \beta e_{xdi} + \varepsilon_{xi}, \tag{1}$$

where e_{xdi} is remaining life expectancy at age x for *département* d and year i and ε_{xi} is the normally distributed error term for the regression for age x and year i. Since we fit the regression for each year, we can see how convergence or divergence (the β parameter of (1)) is evolving on a year-by-year basis. As we look at remaining life expectancy at each age, we can see if mortality convergence follows the same trend at older ages.

In a next step, we will perform the same analysis, but using other mortality indicators, such as lifespan variation, age standardized mortality rates, or the modal age at death, which capture different aspects of mortality signal not captured by life expectancy. Given the empirical negative correlation observed in many contexts between life expectancy and lifespan variation (V. M. Shkolnikov et al. 2011; Aburto et al. 2020), we would expect the results to be similar for indicators of lifespan variation. However, among sub-populations in low mortality countries the negative relationship has been shown to be reversed, which has led a greater divergence in lifespan variation in recent years (Sasson 2016; Permanyer et al. 2018; van Raalte, Sasson, and Martikainen 2018). Hence, we could also expect the results for lifespan variation to indicate greater divergence than those for life expectancy.

4 Preliminary results

Figure 1 shows the β coefficient for yearly change in life expectancy regressed on level of starting life expectancy as in (1). We see that near the beginning β is negative, but as time progresses it increases and becomes positive during the mid 1990s. This means that during this period, yearly changes in life expectancy created convergence between the *départements*, but that during the 1990s the yearly changes in life expectancy led to divergence. The values for β peak in 2008 for both males and females, which means that 2008 was the year in which *département* life expectancies followed a most strongly diverging trajectory. After 2008, the values for β decrease, and become negative for 2014 onward, so only for the most recent years for men are changes in mortality leading to convergence in life expectancy.

The results for life expectancy at birth confirm the findings of (Bonnet and d'Albis 2020). When considering remaining life expectancy at each age, Figure 2 reveals that for older ages, the shift towards divergence occurred earlier and was more pronounced. At ages past 75 for both men and women, remaining life expectancy increased more in better performing regions, increasing differences between regions. Since in low mortality countries increases in life expectancy at birth are due to reductions in mortality at progressively older ages, divergent trends between regions may become evident earlier for remaining life expectancy at older ages.

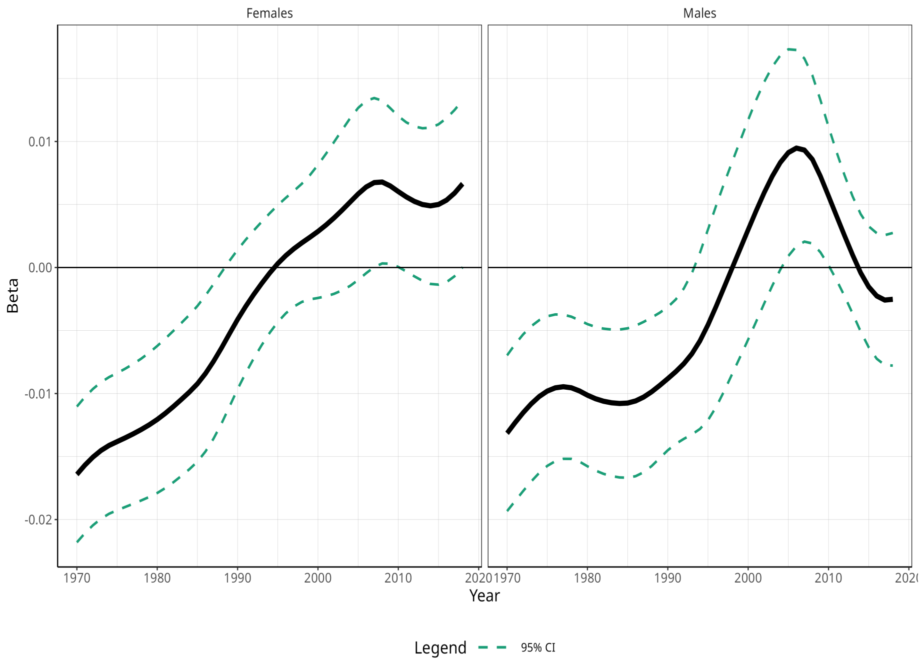

Figure 1: Beta coefficient for change versus level in life expectancy at birth by year.

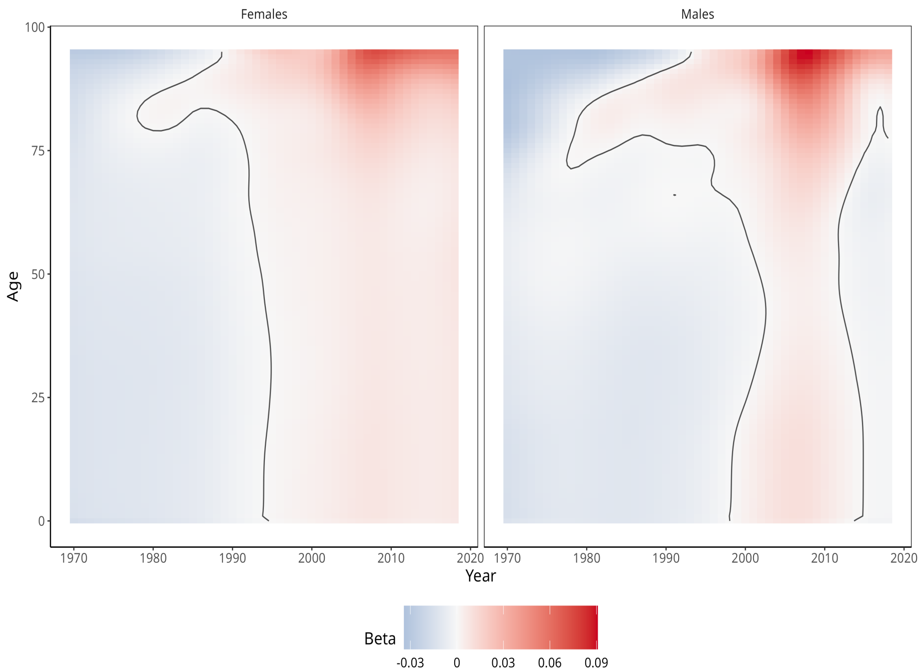

Figure 2: Beta coefficient for change versus level in remaining life expectancy by age and year.

References

Aburto, José Manuel et al. (2020). "Dynamics of life expectancy and life span equality". In: *Proceedings of the National Academy of Sciences* 117.10, pp. 5250–5259. DOI: 10.1073/pnas.1915884117.

Barbieri, Magali (2013). "La mortalité départementale en France". In: *Population* 68.3, pp. 433–479. DOI: 10.3917/popu.1303.0433.

Barro, Robert J. and Xavier Sala-i-Martin (1992). "Convergence". In: *Journal of Political Economy* 100.2, pp. 223–251. DOI: 10.1086/261816.

Bonnet, Florian (2020). "Computations of French lifetables by department, 1901–2014". In: *Demographic Research* 42, pp. 741–762. DOI: 10.4054/DemRes.2020.42.26.

Bonnet, Florian and Hippolyte d'Albis (2020). "Spatial Inequality in Mortality in France over the Past Two Centuries". In: *Population and Development Review* 46 (1), pp. 145–168. DOI: 10.1111/padr.12318.

Breton, Didier et al. (2022). "L'évolution démographique récente de la France". In: *Population* 77.4, pp. 535–614. DOI: 10.3917/popu.2204.0535.

Camarda, Carlo Giovanni (2008). "MortalitySmooth: An R Package for Smoothing Poisson Counts with P-Splines". In: *Journal of Statistical Software* 50 (1). DOI: 10.18637/jss.v050.i01.

— (2019). "Smoothed constrained mortality forecasting". In: *Demographic Research* 41, pp. 1091–1130. DOI: 10.4054/DemRes.2019.41.38.

Frenk, Julio et al. (1991). "Elements for a theory of the health transition". In: *Health Transition Review* 1.1, pp. 21–38.

Hrzic, Rok et al. (2023). "District-Level Mortality Convergence in Reunified Germany: Long-Term Trends and Contextual Determinants". In: *Demography* 60.1, pp. 303–325. DOI: 10.1215/00703370-10422945.

Janssen, Fanny et al. (2016). "Sigma and beta convergence in regional mortality: A case study of the Netherlands". In: *Demographic Research* 35, pp. 81–116. DOI: 10.4054/DemRes.2016.35.4.

Moser, Kath, Vladmimir Shkolnikov, and David A. Leon (2005). "World mortality 1950–2000: divergence replaces convergence from the late 1980s". In: *Bulletin of the World Health Organization* 93.3, pp. 202–209.

Permanyer, Iñaki et al. (2018). "Longevity and Lifespan Variation by Educational Attainment in Spain: 1960–2015". In: *Demography* 55.6, pp. 2045–2070. DOI: 10.1007/s13524-018-0718-z.

Preston, Samuel, Patrick Heuveline, and Michel Guillot (2001). *Demography: Measuring and Modeling Population Processes*. Wiley-Blackwell. ISBN: 978-1-557-86451-2.

Sasson, Isaac (2016). "Trends in Life Expectancy and Lifespan Variation by Educational Attainment: United States, 1990–2010". In: *Demography* 53.2, pp. 269–293. DOI: 10.1007/s13524-015-0453-7.

Shkolnikov, Vladimir M. et al. (2011). "Losses of Expected Lifetime in the United States and Other Developed Countries: Methods and Empirical Analyses". In: *Demography* 48.1. DOI: 10.1007/s13524-011-0015-6.

Vallin, Jacques and France Meslé (2004). "Convergences and divergences in mortality. A new approach to health transition". In: *Demographic Research* Special collection 2, pp. 11–44. DOI: 10.4054/DemRes.2004.S2.2.

— (2005). "Convergences and divergences: an analytical framework of national and sub-national trends in life expectancy". In: *Genus* 61.1, pp. 83–124.

Vallin, Jacques and France Meslé (2010). “Espérance de vie: peut-on gagner trois mois par an indéfiniment ?” In: *Population et Sociétés* 473, pp. 1–4. DOI: 10.3917/popsoc.473.0001.
van Raalte, Alyson A., Isaac Sasson, and Pekka Martikainen (2018). “The case for monitoring life-span inequality”. In: *Science* 362 (6418), pp. 1002–1004. DOI: 10.1126/science.aau5811.
Vaupel, James W., Francisco Villavicencio, and Marie-Pier Bergeron-Boucher (2021). “Demographic perspectives on the rise of longevity”. In: *Proceedings of the National Academy of Sciences* 118.9. DOI: 10.1073/pnas.2019536118.
Woolf, Steven H. (2023). “Falling Behind: The Growing Gap in Life Expectancy Between the United States and Other Countries, 1933–2021”. In: *American Journal of Public Health* 113.9, pp. 970–980. DOI: 10.2105/AJPH.2023.307310.