The changing health convergence for life expectancy and spatial interactions

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ABSTRACT

Spatial interactions are important to consider issues like health convergence between the European Union countries and Spanish provinces. Health status is measured by a combination of objective health outcome indicators, such as life expectancy: at birth, at age 65, disability-adjusted life expectancy and healthy life expectancy based on self-perceived health. The period analysed differs from one indicator to another considering 1998–2018. There are two forms of convergence: σ-convergence and absolute β-convergence. Furthermore, the Moran Test is performed to disentangle the degree of spatial dependencies and two models of spatial regression are used to include these dependencies in the absolute β-convergence estimation. Our findings suggest that there is a convergence process among European Union countries and the Spanish provinces. On the other hand, β-convergence is higher in women among European countries and in men for Spanish provinces. Nevertheless, the rise of the dispersion means that there is not clear evidence about trends in the period considered. There are two contributions in our research: to achieve an updated vision of health convergence and to incorporate spatial econometrics in Health Economics research. These insights can help to reduce health inequalities.

I. Background

The increasing life expectancy of the older population in many countries makes ageing a key issue today. In this regard, one of the Government’s objectives is to improve the quality and duration of population’s lives and to promote good health among the population (Lee et al. 2020). The state of people’s health has traditionally been measured by life expectancy and mortality indicators. However, in recent years, other perspectives have been included and considered: quality of life, socio-economic environment, disease prevention, freedom from disability, etc. Even though people’s health quality increases over time, disparities continue to exist in many ways.

The health convergence analysis allows to approximate the evolution of those inequalities among different territories. Convergence is understood as ‘the reduction or equalizing of disparities’ (Maynou et al. 2015). Although Solow (1956) advanced the convergence hypothesis in his growth theory, the most famous studies are given by Baumol (1986) and Barro and Sala-I-Martin (1990, 1992, 1995) (Sala-I-Martin 1996). Inside the literature of growth empirics, there are different perspectives for measuring convergence. A significant number of papers broadly categorized it into two parts: σ-convergence and β-convergence. The first one occurs when the dispersion between the studied regions decreases, while the second one exists when the areas that have lower values of the selected indicator at the beginning of the period have the final highest growth rates. Most convergence analysis have been based on income indicators. However, there are not as many studies that analyse convergence regarding health inequalities due to the complexity of measuring people’s health (Hembram and Haldar 2020).

To deepen these convergence analyses, spatial econometrics have been used in recent years. The beginnings of spatial econometrics date back to the 1970s, when Jean Paelinck defined it as the part of applied econometrics that deals with estimation and specification problems arising from traditional econometrics (Anselin and Bera 1998). By using these models, we have the possibility to consider the spatial dependence between observations, which often arises if data are collected on regions...
or countries located in space. In addition, these models are useful for assessing and quantifying the spillover effects in different geographical entities (LeSage and Pace 2009).

In this context, the two most important limitations of not considering space are spatial autocorrelation (or dependency) and spatial heteroscedasticity. When the presence of a certain phenomenon in a specific spatial unit makes it easily spread to its neighbouring localities favouring its grouping, spatial autocorrelation will be positive. Meanwhile, when the presence of this factor hinders its propagation to neighbouring towns, regions or countries, spatial autocorrelation will be negative (González 2016). Spatial heterogeneity refers to the relationship’s variations in space. Most problems caused by spatial heterogeneity can be solved by standard econometric techniques (Serrano and Vayá 2002). For this reason, the spatial literature usually focuses on spatial autocorrelation analysis.

In recent years, a new branch of spatial econometrics has emerged that focuses on the health analysis: Spatial Health Econometrics. It measures spatial relationships between agents at both the micro and macro levels, while testing health economic theories (Baltagi, Moscone, and Santos 2018). Hence, the importance of the contributions of our study is twofold. Firstly, the global health convergence appears to be accelerated in recent decades although there is a rise of the dispersion in some cases. Secondly, this research contributes to incorporate spatial econometrics in Health Economics research.

**II. Literature review**

The line of research presented in this manuscript is suitable to reduce the degree of uncertainty about the complexity of the issues addressed by Health Economics. In this regard, the following paragraphs review the most recent literature on the use of spatial econometrics in health convergence among European countries.

Jaworska (2014) studies life expectancy convergence in the European Union NUTS II regions between 2002 and 2012. The results show that regions with the lowest life expectancy in 2002 have experienced the greatest increases. However, it highlights that the process hasn’t been the same for all regions, as there is higher speed of convergence in the more developed countries (South-West Europe). In addition, Stańczyk (2016) analyzes the same as Jaworska (2014) and draws a complementary conclusion: socio-economic factors have a major impact on the public health state. Other authors quantify these inequalities by including more variables. This is the case of Mayou et al. (2015), who study the speed of convergence between the mortality rate and life expectancy at birth between 1995 and 2009. The results suggest that the dispersion between the two indicators isn’t decreasing. Considering the reduction of dispersion as a measure of convergence, this article is the first one who expose a lack of health convergence in all the EU regions. Maynou and Saez (2016) complement the previous study by estimating the impact of the 2008 economic crisis on health convergence process in the European Union. Their results show that there is indeed a recovery process among the different EU regions, but that there is also no reduction in the dispersion levels. On the other hand, there are several authors who carry out this type of analysis, but focus on the regions of a particular country. Eibich and Ziebarth (2014) estimate spatial health inequalities at the county level in Germany. They find large and significant spatial dependencies and groupings, and an East-West spatial health pattern. Zeren, Özcan, and Menteşe (2016) study the health care service impartiality at the county level in Turkey between 2002 and 2010. They use the convergence hypothesis to test whether inequalities are reduced and draw a double conclusion: there is province convergence and there is health care service spatial interaction between regions. Finally, Dearden, Lloyd, and Catney (2019) show the relationship between health and geography based on health inequalities in Great Britain in 1991, 2001 and 2011. Thanks to a growing positive spatial association, neighbouring areas increasingly share similarities and there is less distinction between areas characterized by good and bad health. It should be noted that one of the reasons for the existence of health inequalities is the differences between regions in terms of factors determining the population’s health status. The
most prominent are the level of environmental pollution, the wealth of society and the access to health services. Modranka and Suchecka (2014) analyse these determinants using a Spatial Durbin Model (SMD). They suggest specific factors that generate positive impacts on the general health status of inhabitants of adjacent regions, such as the pharmacy locations or the number of people who go to the gym. Obviously, there are some critical issues about spatial econometrics approach, particularly regarding the crucial issue of identification of causal parameters although any alternative approach also has to solve the identification problems that plague spatial economic analysis (Anselin 1990; Anselin and Rey 2014; Baltagi, Moscone, and Santos 2018; De Mello-Sampayo 2018; De Mello 2020; Fotheringham, Charlton, and Brunsdon 1998; Kelejan and Piras 2017; LeSage and Pace 2009; Lippi Bruni and Mammi 2017; Moscone and Knapp 2005; Moscone et al. 2019; Orea and Alvarez 2021; Percoco 2021; Piedra 2022; Yu et al. 2013; Waldorf, Chen, and Unal 2007).

The main objective of this study is to estimate the health convergence between the European Union countries and Spanish provinces in the last years of the 20th century and first decades of the 21st. Two types of convergence will be studied: σ and absolute β-convergence. Moran’s Test will be used to find out if there is spatial dependence in the observations. If there is, the Spatial Lag Model (SLM) and the Spatial Error Model (SEM) will be used to estimate spatial absolute β-convergence. Additionally, the analysis is separated between men and women to show gender differences, as the difference in health patterns between the sexes presents a challenge in the field of public health (Sörlin et al. 2011).

III. Methods

Data sources

Data were extracted from 4 different databases: World Bank Open Data (2020), World Health Organization database (2020), Eurostat (2020b, 2020c) and Spanish National Institute of Statistics (2020, 2020). It should be noted that the source of the European spatial data is Eurostat (2020a) and for Spanish data is GADM (2020).

A small data pre-processing has been carried out to correct inconsistencies and transform them into simpler formats (Hernández and Rodríguez 2008). The main problem to correct it is the treatment of not available data (NaNs). The Romanian and Croatian time series for healthy life expectancy based on self-perceived health variable had 1 (year 2006) and 4 (years 2006–2009) NaNs, respectively. To resolve this, an attempt has been made to capture the trend through a rolling window. The accumulated growth rate for the following 7 years of the NaN has been calculated and extrapolated.

Measures/variables

To estimate health status with several dimensions and to give a broad vision of the life expectancy concept, four variables have been chosen: Life Expectancy at Birth (LEB), Life Expectancy at age 65 (LE65), Disability-Adjusted Life Expectancy (DALE) and Healthy Life Expectancy based on Self-Perceived Health (HLESPH). The study will be divided into two cases: the European Union countries and the Spanish provinces convergence analysis. For the first case, all 27 EU countries have been considered, to update the existing research on these countries. In the second case, the 50 Spanish provinces and the two autonomous cities (Ceuta and Melilla) will be analysed. Spain has been chosen for the detailed analysis because it is one of the countries with the highest life expectancy value in recent years. Provinces data will be used to consider the spatial dependencies within the territory of this country. Furthermore, to make more detailed research, a distinction will be made between men and women, in all cases. Figures 5 and 6 show the evolution of possible spatial groupings in life expectancy at birth for the years 1998, 2008, 2018 and 2018. All the empirical analysis has been carried out with R 3.4.4.

Statistical analysis

The econometric methods for examining convergence applied in the analysis are based on two broad categories: σ-convergence and β-convergence.

The first kind of convergence is estimated with the calculation of the standard deviation, and it occurs when “the dispersion, measured say by the
standard deviation of the income per capita logarithm across a group of countries or regions, declines over time’ (Barro and Sala-i-Martin 1990). In this study, the interest variable is life expectancy, so the Gross Domestic Product (GDP) per capita will be replaced for each selected definition of life expectancy.

The second measure of convergence occurs when the partial correlation between GDP growth per capita over time and its initial level value is negative. It is understood as the situation where ‘poor economies tend to grow faster than rich ones’ (Sala-i-Martin 1996). β-convergence is a necessary but not sufficient condition for σ-convergence (Gächter and Theurl 2011). This study will focus on the analysis of absolute β-convergence (it occurs when all studied economies converge towards the same steady state). Following the methodology used by Sala-i-Martin (Sala-I-Martin 1996), the following regression will be estimated with cross section data:

\[
\ln \left( \frac{y_{i,t}}{y_{i,t_0}} \right) = a + b \cdot \ln(\frac{y_{i,t_0}}{y_{i,t_0}}) + u_{i,t} \quad (1)
\]

where the dependent variable is the life expectancy growth rate, \(i\) are all the countries/regions in the sample, \(t_0\) is the first year of study and \(t\) is the last one. The intercept \(a\) is assumed to be constant for all economies.

Thus, there will be absolute β-convergence when the parameter \(b\) meets two requirements: be negative and statistically significant. Additionally, the annual rate of convergence to steady state is calculated as the negative value of the Napierian logarithm of 1 plus the coefficient \(b\) divided by the number of years in the period studied (\(T\)) (Jaworska 2014), this is:

\[
- \frac{\ln(1 + b)}{T} \quad (2)
\]

However, if the sample studied has spatial dependencies, our results may not be valid (Anselin 1988; Serrano and Vayá 2002; Moscone and Tosetti 2014). That is why, secondly, the methodology for the spatial data analysis will be used.

Among the literature of growth empirics, the most widely used test to measure spatial autocorrelation comes from a statistic developed by Moran (Anselin 2001). The Moran’s I statistic is used to detect the existence of spatial dependence in the samples studied. The null hypothesis of this contrast is the spatial non-autocorrelation. Based on the methodology used by Serrano and Vayá (2002), it is formally defined as:

\[
I = \frac{N}{S_0} \sum_{i<j} w_{ij}(x_i - \bar{x})(x_j - \bar{x}) \quad (3)
\]

where \(N\) is the sample size, \(S_0\) is the scale factor equal to the addition of the weights, \(w_{ij}\) are the weights of the weight matrix \(W\), \(x_i\) is the value of the interest variable \(x\) in the region \(i\) and \(\bar{x}\) is the sample mean of the variable \(x\). If the weight matrix is standardized, \(N\) will be equal to \(S_0\).

Furthermore, the interpretation of the statistic depends on its expected value, which is defined as:

\[
E(I) = -\frac{1}{N - 1} \quad (4)
\]

If \(I > E(I)\) there is positive spatial autocorrelation and if \(I < E(I)\) there is negative spatial autocorrelation [10]. However, if the \(I\) value is close to zero, there will be an absence of spatial pattern, so the observations will be distributed randomly in space (Jackson et al. 2009).

If there is spatial autocorrelation, the β-convergence will be re-estimated, but this time using two spatial regression who allows us to consider various spatial relationships between neighbouring countries or regions (Jaworska 2014). Based on literature, there are several regression models that include spatial effects through dependent and/or independent variables or through the error term. To consider both cases, two different models will be used in this study.

First, it’s assumed that it’s the endogenous variable that is spatially correlated. In this sense, the SLM is applied, defined as:

\[
y = pW_y + X\beta + u \quad (5)
\]

where \(y\) is the vector of the interest variable growth rate (life expectancy) over the given time period, \(p\) is the autoregressive parameter that picks up the intensity of the interdependencies between the sample observations, \(W_y\) is the spatial delay of the variable \(y\), \(X\) is the vector of the observations on the interest variable in logarithms in the initial year and \(u\) is the white noise error term.
Secondly, the SEM is used. This model considers that spatial autocorrelation is present in the error term and it is formally defined as:

\[ y = X\beta + \varepsilon \]  

\[ \varepsilon = \lambda W\varepsilon + \xi \]

where \( y \) and \( X \) are defined like the previous case, \( W \) is the spatial weight matrix, \( \xi \) is an error vector and \( \lambda \) is an autoregressive parameter in the error dependence model.

In addition, the conditions for absolute \( \beta \)-convergence are the same as in the model estimated by OLS: the estimation coefficient of \( X \) must have a negative sign and be significant (González 2016). It should be noted that the specification by OLS is no longer valid for spatial models, so the description is made using the Maximum Likelihood method, in accordance with the chosen model (Jaworska 2014).

IV. Results

Analysis of the European case

Sigma-convergence

Figure 1 shows the evolution of the standard deviation in all cases. The most striking feature is that, in all variables, the women’s curve is like that of men, but it is underneath. This means that the dispersion among women is smaller than the same for men. The case of the HLESPH variable is the only one in which the men curve meets that of women.

All variables have a higher \( \sigma \) value in the first year studied than in the last one, except for men in DALE. Life expectancy at birth undergoes constant changes in trend, although LE65 is more variable. The trend of the disability-adjusted life expectancy curves is like those of the life expectancy at birth variable, although the streaks are somewhat more pronounced.

Beta-convergence

As stated above, \( \beta \)-convergence happens when the partial correlation between the life expectancy growth over time and initial level is negative. In this case, we focus on the absolute \( \beta \)-convergence analysis, which will occur if the countries converge towards the same steady state [3].

Table 1 shows the results of returning the growth rate of the interest variable over the value in the initial year.

The \( b \) interest coefficient is negative and significant for men and women in all cases, except for men in LE65 (-0.04). For the most part, there is an absolute \( \beta \)-convergence process for males and females between in LEB, LE65, DALE and HLESPH. It can be affirmed that the countries
that initially had the lowest life expectancy are those that have experienced higher growth rates and that the 27 EU countries converge towards the same steady state. It should be noted that HLESPH is the variable with the highest speed of convergence: 2.92% for men and 4.89% for women. In all cases where absolute β-convergence exists, the necessary (but not sufficient) condition for the previous analysed convergence (α) to exist is fulfilled (Gächter and Theurl 2011).

In Figure 2 we can see the negative trend between the life expectancy at age 65 growth rate and its value at the initial moment (2005).

As previously anticipated, this traditional β-convergence approach might not be valid if there is spatial dependency. Hence, Moran’s I statistic will be used to identify spatial dependence. Table 2 shows the results for both sexes in the four different variables. This suggests that the null hypothesis can be rejected in all cases and evidences the presence of spatial dependence in the analysed sample. Additionally, the autocorrelation is positive because the I statistic in all cases is higher than \(-\frac{1}{N-1}\) (-0.038). Therefore, the presence of a certain phenomenon in a specific spatial unit makes it easily spread to its neighbouring towns, so favouring its grouping.

Because of the previous results, spatial dependence between countries must be considered. This means that the absolute β-convergence must be estimated through the SLM and the SEM for the same variables and the same previous years. The conditions for absolute β-convergence to exist remain the same: b must be negative and significant (Jaworska 2014).

Table 3 shows that there have been no major changes. All the b interest coefficients that were previously negative and significant continue to be. So that in all cases in which there was absolute β-convergence it continues to be, even considering spatial dependencies. In this sense, there is still not

| Table 1. European union results of OLS (men/women). |
|---------------------------------|--------|--------|--------|--------|
|                                | OLS (men/women) | LE65 | DALE | HLESPH |
|                                | Estimate t value | Estimate t value | Estimate t value | Estimate t value |
| a (intercept)                  | 1.28***/1.50*** | -2.50/3.64 | 1.34*** | 6.82/7.33 |
| b                              | -0.28***/-0.33*** | -0.04/-0.21** | -0.12/-0.22*** | -0.25**/-0.39*** |
| Convergence speed (annual)     | 1.65%/2.02% | -1.87% | 0.88%/1.63% | 2.92%/4.89% |
| R-squared                      | 0.45/0.47 | 0.03/0.33 | 0.17/0.33 | 0.62/0.67 |
| Adjusted R-squared             | 0.43/0.46 | -0.01/0.30 | 0.13/0.30 | 0.61/0.65 |

***Significant at level 0.001; **Significant at level 0.01; *Significant at level 0.05; + Significant at level 0.1.
Adjustments (standard errors (and the resulting t values)) have been made for heteroscedasticity and autocorrelation.
Source: Authors’ estimations.

![Figure 2. European Union LE65 scatter plot (women). Life Expectancy at age 65 (LE65), Source: Authors’ elaboration from data based on Eurostat](image-url)
Table 2. European union Moran’s I statistic (men/women).

| Year | LEB 1998 | LEB 2018 | LE65 2005 | LE65 2018 | DALE 2000 | DALE 2015 | HLESHP 2006 | HLESHP 2016 |
|------|---------|---------|-----------|-----------|-----------|-----------|------------|------------|
| I    | 0.64/0.66 | 0.62/0.56 | 0.62/0.60 | 0.57/0.55 | 0.64/0.62 | 0.64/0.58 | 0.55/0.44 | 0.55/0.38 |
| p-value | 0.00026/ | 0.00042/ | 0.00049/ | 0.0013/ | 0.00025/ | 0.00023/ | 0.00187/ | 0.00176/ |

Source: Authors’ estimations.

Table 3. European union results of maximum likelihood (men/women).

| Spatial Lag Model (men/women) | LEB | LE65 | DALE | HLESHP |
|-----------------------------|-----|------|------|--------|
| a (intercept)               | 1.29***/ | 4.26/ | 0.34*/ | 2.54/ | 0.54***/ | 2.20/ | 1.31***/ | 6.75/ |
|                           | 1.57*** | 4.76 | 0.81*** | 4.59 | 1.11*** | 4.25 | 2.06*** | 9.04 |
| b                           | -0.28***/- | -4.06/- | -0.07/- | -1.48/- | -0.11***/- | -1.98/- | -0.29***/- | -6.53/- |
|                           | 0.35*** | 4.63 | 0.24*** | 4.03 | 0.24*** | 4.09 | 0.46*** | 8.82 |
| Convergence speed (annual) | 1.64%/2.14% | -2.08% | -2.80% | -2.80% | 0.80%/1.85% | 0.80%/1.85% | 3.45%/6.26% | 3.45%/6.26% |
| Log-likelihood             | 70.85/82.12 | 58.54/60.96 | 76.08/88.86 | 72.71/88.31 |

| Spatial Error Model (men/women) | LEB | LE65 | DALE | HLESHP |
|---------------------------------|-----|------|------|--------|
| a (intercept)                   | 1.29***/ | 4.63/ | 0.22/ | 1.41/ | 0.63*/ | 2.42/ | 1.14***/ | 6.65/ |
|                                | 1.50*** | 4.78 | 0.71*** | 3.56 | 0.97*** | 4.03 | 1.70*** | 8.11 |
| b                              | -0.28***/- | -4.35/- | -0.03/- | -0.56/- | -0.13*/ | -2.19/- | -0.26***/- | -6.30/- |
|                                | 0.33*** | 4.61 | 0.20** | 3.03 | 0.21*** | 3.86 | 0.39*** | 7.82 |
| Convergence speed (annual)     | 1.68%/2.02% | -1.76% | 0.95%/1.60% | 3.01%/4.86% |
| Log-likelihood                 | 71.14/82.09 | 57.54/60.63 | 75.04/85.54 | 72.09/65.64 |

**Significant at level 0.001; ***Significant at level 0.01; *Significant at level 0.05. Adjustments (standard errors (and the resulting values)) have been made for heteroscedasticity and autocorrelation. Source: Authors’ estimations.

enough evidence to justify an absolute β-convergence in life expectancy for men at age 65. The most important thing to note is that the speed of annual convergence is bigger for women than for men, in any of the life expectancy variable studied. Regardless of the model selected, the fastest convergence is among women in HLESPH (6.26% and 4.86%, respectively).

V. Analysis of the Spanish case

Sigma-convergence

The evolution of the selected variables standard deviation between 1998–2018 for the Spanish provinces is plot below (Figure 3). It can be differentiated in both cases between the dispersion curve of men and women. As in the EU countries analysis, it can be seen how the evolution of the curves is very similar between one gender and the other, but the women’s dispersion is always smaller than that of men.

The variability of LEB curves is much smaller than that of LE65, so the σ evolution in the first case is much more stable. Therefore, it could be said that there is a σ-convergence process in approximately the first half of the sample studied, while in the second there is a σ-divergence process.

Beta-convergence

After having analysed the σ-convergence in the Spanish provinces, we study the absolute β-convergence between the same years as before (1998–2018).

First, results of the traditional absolute β-convergence analysis are presented. Table 4 shows the estimation results of the model by OLS. The requirements for absolute β-convergence are still the same. Therefore, according to the estimation by OLS, there is an absolute β-convergence process in both variables for both men and women. This means that the provinces converge towards their own steady state [3]. However, it should be noted that the annual convergence rate is much higher (more than double) for men. The highest convergence speed is found by men of LE65 (4.28%). Figure 4 shows the negative slope of this regression.
**Figure 3.** Spanish σ-convergence. Life Expectancy at Birth (LEB), Life Expectancy at age 65 (LE65). Source: Authors’ elaboration from data based on Spanish National Institute of Statistics

**Table 4.** Spain’s results of OLS (men/women).

| OLS (men/women) | LEB | | | LE65 | | |
|-----------------|-----|-----|-----|-----|-----|-----|
|                 | Estimate | t value | Estimate | t value | Estimate | t value |
| a (intercept)   | 2.00***/1.15*** | 8.37/5.40 | 1.78***/0.85*** | 10.99/4.99 | |
| b               | -0.45/-0.25*** | -8.10/-5.21 | -0.58/-0.24** | -9.95/-4.22 | |
| Convergence speed (annual) | 2.97%/1.46% | -4.28%/1.37% | |
| R-squared       | 0.57/0.35 | 0.66/0.26 | |
| Adjusted R-squared | 0.60/0.40 | -0.66/0.25 | |

***Significant at level 0.001; **Significant at level 0.01; *Significant at level 0.05.

Adjustments (standard errors (and the resulting t values)) have been made for heteroscedasticity and autocorrelation.

Source: Authors’ estimations.

**Figure 4.** Spanish regions LE65 scatter plot (men). Life Expectancy at age 65 (LE65). Source: Authors’ elaboration from data based on Spanish National Institute of Statistics
Table 5. Spain Moran’s I statistic (men/women).

| Year | LEB | LE65 |
|------|-----|------|
|      | 1998 | 2018 | 1998 | 2018 |
| I    | 0.44/0.40 | 0.47/0.41 | 0.49/0.62 | 0.55/0.51 |
| p-value | 7.092e-07/3.318e-06 | 1.648e-07/2.94e-06 | 5.366e-08/1.267e-11 | 1.292e-09/8.367e-09 |

Source: Authors’ estimations.

Then, it is needed to know whether the sample data is subject to spatial dependency or not. As said before, the traditional estimation results of absolute β-convergence may not be valid if there is spatial autocorrelation in the sample (Serrano and Vayá 2002). Table 5 shows the results. Both variables reject the null hypothesis of no autocorrelation for the initial and final year. There is enough evidence to justify the presence of spatial dependence between the different Spanish provinces.

Furthermore, it is useful to consider the spatial dependencies affecting the sample. For this reason, the SLM and the SEM will be estimated using the Maximum Likelihood method. These results are reflected in Table 6. As mentioned above, absolute β-convergence happens when b is negative and significant (Jaworska 2014).

As can be seen, for both men and women in both variables the requirements for convergence are met. Therefore, even considering spatial dependencies, there is an absolute β-convergence process. Convergence rates continue to be higher for men than for women. Whether SLM or SEM is chosen, the fastest convergence is possessed by men in the LE65 variable (4.17% and 5.34%, respectively).

VI. Discussion

The first insight here is that life expectancy is much higher for women than for men, regardless of the life expectancy concept considered. This dissimilarity is mostly explained by the different risk behaviours and habits of the working age population. Although it is true that, over time, societies are much more egalitarian. Women have entered the labour market and can carry out the same activities as men, which may favour gender convergence in life expectancy (Garcia and Grande 2018).

In the EU background, the σ analysis propose that stages of σ-convergence have alternated with stages of σ-divergence between EU countries (see Figure 1). It could be said that life expectancy has converged at the end of the 20th century, while the first two decades of the 21st century show an opposite trend. Both in the initial and final year, the dispersion is greater for men than for women (except for the Healthy Life Expectancy based on Self-Perceived Health variable in 1998). However, it has decreased more in women than in men (except for the Life Expectancy at Birth).

Secondly, the spatial results suggest that spatial dependence should be considered. Moran’s Test
shows that there is a positive spatial autocorrelation. Therefore, considering both the results of the analysis without the spatial dependence and those of the study including it, the absolute β-convergence occurs in all variables, except for men in Life Expectancy at age 65 (see Table 3). This means that, for the most part, the countries with the lowest life expectancy in 1998 have had the highest growth rates. In addition, each country is approaching its own steady state. Women’s convergence rates are higher than for men in all variables. Women have the fastest convergence rate with the Healthy Life Expectancy based on Self-
Perceived Health indicator. Results also show that there could be a spatial distinction between Western and Eastern Europe countries.

Summarizing, it is confirmed that there is life expectancy convergence among EU countries, but that women are converging to a bigger extent than men. Authors such as Jaworska (2014) and Stanczyk (2015) guarantee these results for the first years of the 21st century.

On the other side, the analysis results of the Spanish provinces also show that life expectancy is constantly changing between σ-convergence and σ-divergence processes (see Figure 3). Even so, two different stages could be distinguished. The first phase is from 1998 until the first years of the economic crisis in 2008 and is characterized by a sharp dispersion reduction. The second phase starts from these years and ends in 2018 and it is characterized by an increase in standard deviation. This could be linked to the increase in poverty levels in Spain after the economic crisis of 2008. Despite the fact that the gender gap is still present and that the falls in dispersion in both genders have been very similar, it has been bigger in women for Life Expectancy at Birth, and in men for Life Expectancy at age 65.

Secondly, Moran’s Test shows that there is a positive spatial autocorrelation in the sample. It suggests that increased life expectancy in one province has led to positive effects in its neighbouring provinces. The β-convergence results are different for Spanish provinces than for European countries. Considering the results of the estimation by OLS and those of MV, there has been a convergence process in both sexes. However, this β-convergence has occurred to a bigger extent in men. Results also suggest that there are life expectancy inequalities in geographical in Spain. The northern provinces have higher life expectancy values than the southern ones, which could be due to cultural differences between the two areas. In other words, Spain embraces several socioeconomic and cultural realities as proved by the dimensions that are most correlated with objective well-being and life expectancy like those related to family, housing, work and environment (De Maya, López-Martinez, and Riquelme-Perea 2022). It may be concluded that prosperity and income growth is hardly related to an increase in happiness versus life expectancy. Hence, the regional gap is due to the areas of culture, security and academic training and a review of the regional financing model is advisable so that southern provinces can increase their investments, especially in those territories lagging behind in this issue.

In summary, the convergence process in σ and spatial absolute β in the Spanish provinces for the period 1998–2018 means that the existing inequalities (geographical and gender) are reduced. However, the trend (long term direction) of recent years shows that perhaps the dispersion between provinces will move away again. Maybe, as policy suggestion insights, in the European case and the Spanish background too for several years ago the situation did not visibly impact the overall process of health convergence over the short term, likely because of the greater influence of country and region-specific policies and determinants. Hence, the interaction of European Member States and regional issues with the mechanisms of European integration even in countries like Spain requires further study. Future enlargement procedures should boost tailored support to ensure more equitable gains from economic and social integration.

VII. Conclusion

This study analyses the σ, absolute β and spatial absolute β-convergence of four life expectancy definitions between men and women for the European Union countries and Spanish provinces during several periods, between 1998–2018.

The results show that there has been a convergence process in all cases, which could mean that health inequalities are lower in 2018 than at the end of the 20th century. Firstly, as the dispersion in the beginning is greater than in the final years, there has been a σ-convergence process. Nevertheless, this process has not remained constant throughout the period considered. The trend in the last years studied seems to indicate that the dispersion rises. Therefore, perhaps during the next few years health differences between some territories and others will increase again. Secondly, as the observations were spatially dependent, spatial interactions had to be considered for β-convergence. As the countries and provinces with lower life expectancy values at the beginning of the study are those with higher growth rates, there has been a β-convergence process. The speed of this process has been higher in women for
European countries and higher in men for Spanish provinces. Hence, gender inequalities in terms of life expectancy have been reduced in recent decades.

One limitation of the study is that the life expectancy convergence analysis serves to know whether life expectancies between some territories tend to get closer. However, it does not really show people’s quality of life, since increased life expectancy doesn’t necessarily translate into improved living conditions. Although two variables (DALE and HLESPH) have been included in this study for this purpose, they have not been sufficient to reflect the population’s standard of living, as other factors may influence it.

As future lines of research a further study on this subject is proposed including conditional β-convergence through the use of variables that measure living conditions in other areas, such as the economic or environmental (Gispert et al. 2007). This exercise could be repeated using predicted life expectancy data, differentiating between clubs or for mortality indicators. In addition, it would be interesting to assess how the COVID-19 pandemic affects life expectancy and thus changes in spatial convergence. Also, for the future, it would be interesting to assess whether the convergence of the first period in the Spanish regions could be the result of the reduction in inequality in regional health spending, carrying out a parallel analysis of spending, and whether the divergence of the second period could be the result of the culmination of the process of health transfers.

Finally, our study has a double contribution. First, it provides an updated vision of the health convergence considering gender differentiated. Secondly, it contributes to include Spatial econometrics in Health Economics analysis to reduce health population inequalities. Our analysis can be considered in order to apply policy intervention measures to reduce health population inequalities.

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Author’s contributions
The first author performed the analysis and datasets insights. All the authors were involved in designed the study and participated in the writing the manuscript.

Data availability statement for basic data sharing policy
The datasets used and/or analysed during the current study available from 4 different databases: World Bank Open Data, World Health Organization database, Eurostat and Spanish National Statistics Institute. It should be noted that the source of the European spatial data is Eurostat and for Spanish data is GADM maps and data 2020 website at https://gadm.org/. The interpretation and reporting of these data are the sole responsibilities of the authors.

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