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P 102 -Longevity pattern in Emilia Romagna (Italy) in a dynamic perspective

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1. Introduction

In recent years, the development of human longevity has continued to draw the attention of researchers belonging to different fields of analysis. Indeed it is widely recognized that the length of life is influenced by a combination of genetic and environmental factors. In various studies performed in different Italian regions (Sardinia, Calabria, Sicily and Emilia Romagna) it has been found that there exists areas in which the prevalence of oldest olds is higher than in other areas, regions or countries. High prevalence and a low female/male ratio for centenarians are observed in a specific area in Sardinia, characterized by exceptional male longevity (Poulain et al 2004).
A significant negative correlation between surname abundance and index of longevity has been detected in Calabria (Southern Italy) showing that mostly some isolated zone of male longevity present a high level of inbreeding (Montesanto et al. 2008). By comparing the results of different spatial scan statistic methods, combined solution that allows the identification of longevity “clusters” and their persistence has been detected for Emilia – Romagna region (Miglio et al. 2009).
The explanatory analysis of disparities in the frequencies of the oldest-old population reminds of environmental and genetics features differently spread at a geographical level.

In order to deepen the different aspects of this complex phenomenon, one of the scientific approaches aims at mapping the geographical diffusion of extreme longevity using different methods of spatial analysis techniques in order to identify areas, or clusters of areas, characterized by particularly high, or low, concentration of oldest-old population.

The mapping of geographical variation in the prevalence of longevity may help to identify areas where homogeneous environmental, demographic, and social characteristics are present and may influence the risk of mortality for specific causes of death. Moreover the prevalence of extreme longevity may remind of genetic aspects that contribute to a longer life.

When the geographical analysis is performed on a fine territorial scale and the phenomenon under study is characterized by a scarce number of units the territorial distribution of cases may be strongly influenced by random variation due to the sample data. These random variations invalidate both the distribution of the cases in a given time point and its dynamic evolution in terms of comparison among successive time points.

We attempt to solve this problem by adopting a Bayesian approach that permits us both to manage the geographical structure of the phenomenon and to control for variations due to random occurrences.

We also include in the model a term that allows us to consider the temporal dynamic of the longevity in terms of past history of its geographical distribution.

The final purpose of the work is to study geographical difference in longevity in Emilia-Romagna region on a municipal level and to link them to the structure of mortality in a subsequent study.

2. Area and Data

Emilia Romagna is one of the North-Eastern Italian regions (Figure 1), and shows one of the oldest age structures in Europe (with 22.6% persons aged 65+, and 6.8% persons aged 80+ in 2008 related to a total population of 4,275,802). The region is characterized by a great geographical variability: mountains, hills and a wide flat land, with a consequent heterogeneity in environmental context, social conditions and economic resources. Emilia Romagna area is split up into nine provinces (Piacenza, Parma, Reggio Emilia, Modena, Bologna, Ferrara, Ravenna, Forlì-Cesena, Rimini) and 341 municipalities (Figure 1).

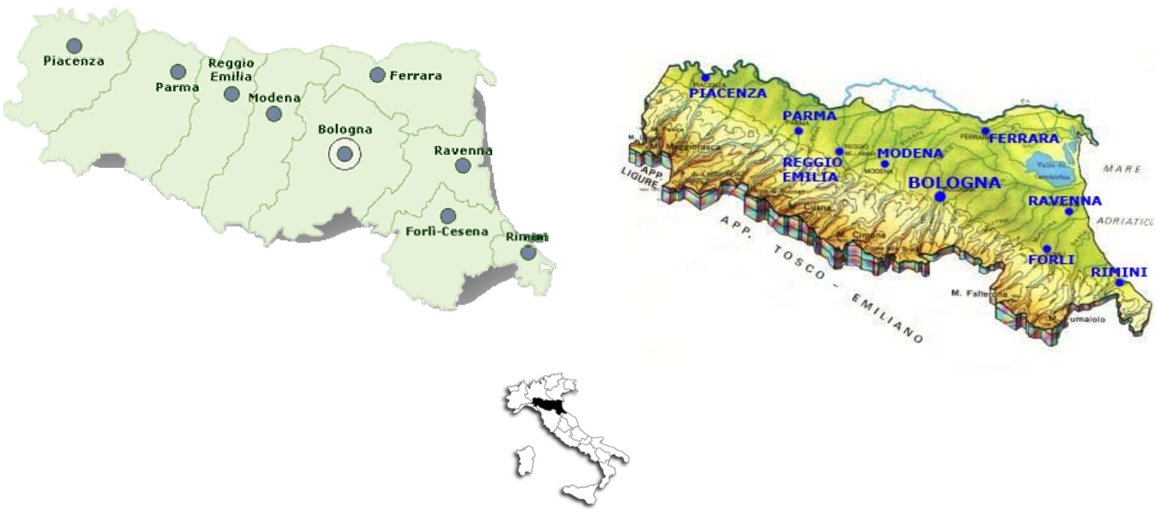

Figure1 – *Political and physical map of Emilia Romagna and its provinces*

The indicator of longevity that we use to measure the different diffusion of the phenomenon in the regional area is a modified version of the Centenarian Rate (*CR*), proposed by Robine and Caselli (2005) and Robine *et al.* (2006)[1], that we indicate as CR_{95+}[2]. It is represented by the ratio between the number of individuals aged 95 and over living in an area and the number of 55-64 or 60-69 years old persons living in the same area forty years earlier. Our hypothesis is that after the age considered work-related migration becomes negligible. Therefore, following this approach, we assume that the individuals resident in an area 40 years before year *t*, are the population exposed to the "risk" of becoming long-lived or, similarly, that long-lived population observed in year *t* comes from the cohort of individuals resident 40 years earlier in the same area.

We use the official data from the 1961 and 1971 Italian censuses and the population distributions by age and sex at the end of each calendar year for the period 2000-2004 and 2005-2009 for each municipality (Regione Emilia-Romagna, 2007).

3. Methods

Territorial differences in the presence of centenarians among the 341 municipalities of Emilia-Romagna are modelled by adopting a hierarchical spatial approach. Indeed, it allows to deal with the random variation due to the increasingly rareness of such events, by exploiting the spatial proximity and the consequent interaction of the geographical areas.

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[1]The CR allows to measure and compare the dimension of longevity in different areas by dividing the observed number of oldest old not by the number of birth in the corresponding generation, but by the number of the cohort survivors at older ages, in order to take into account the effects of the work-related migration. It is well known that in Italy, and in Emilia Romagna too, migration was very common, especially during working ages, and also among people who now belong to the oldest-old population. Using the CR is possible to remove the unknown influence of the migration process. The CR index is independent from the size of birth cohorts, infant mortality, past migrations, and policies of naturalization (Robine and Caselli 2005; Robine and Paccaud 2005).

[2]The change we have introduced concerns the ages involved in the index: instead of centenarians, we have considered all the population older than 94 years, in order to avoid inconsistency or lack of data in some municipality.

We further associate a temporal dimension to the phenomenon, by considering the evolution of the amount of centenarians in the two periods 2000-2004 and 2005-2009. Tha analysis is developed by gender.
As a final result, the estimates on quantities of interest yield more consistent inferences, thanks to the two-fold smoothing effect in both spatial and temporal sense.
In detail, we employ a hierarchical Bayesian model for count data: with respect to *i*-th geographical area (with $i=1,\ldots,341$), we assume that the observable numbers of centenarians at each time j (with $j=1,2$), denoted by y_{ij}, are Poisson distributed with means $e_{ij}\theta_{ij}$, where e_{ij} represents the expected number of events in the required location and period. Then, we follow the conventional log-linear formulation on the relative risk θ_{ij} and we allow for the possibility of different components that additively contribute to explain the spatial-temporal distribution of these risks. In this approach, we assume a model for the log relative risk of the form

$$\log(\theta_{ij}) = \beta_0 + u_i + v_i + \tau_j + \psi_{ij}$$

where β_0 represents the overall rate, the correlated and uncorrelated spatial heterogeneity (CH, UH) are denoted by u_i and v_i, respectively, and they are assumed to be constant in time, τ_j is a separate temporal random effect and, finally, ψ_{ij} is a space-time interaction term. We refer to an autoregressive prior distribution for the time effect, that is random walk with $\gamma = 1$

$$\tau_j \sim N(\gamma\tau_{j-1}, \varkappa_\tau),$$

a zero mean normal prior distribution for the interaction term

$$\psi_{ij} \sim N(0, \tau_\psi),$$

a non-informative prior distribution for the UH component, and a CAR model used for the CH effect (Lawson, 2009).
Finally, under the Bayesian perspective, only non-informative distributions on the hyper-parameters are imposed at the last level of the model hierarchy.
For the computational aspects, we use the software WinBUGS (Version 1.4) implementing Markov chain Monte Carlo (MCMC) techniques. In order to compute the posterior estimates of the relative risks and, then, of the CRs, we used the last 20,000 iterations of 30,000 in total.

4. Results

The application of the hierarchical spatial-temporal model introduced above offers the opportunity to investigate different aspects of the longevity pattern, as well as to control for variations due to random occurrences. The last feature is pursued through the so-called 'smoothing effect', which can be in practice highlighted by comparing the observed with the estimated values of CR for each area. Figure 1 plots these numbers for males of some municipalities in the second period , but the same findings can be drawn out from allthe other groups. The observed CRs show a great variability with peaks of extremely high and extremely low numbers, while the CRs estimated by our model are closer to each other (i.e., to the regional average).

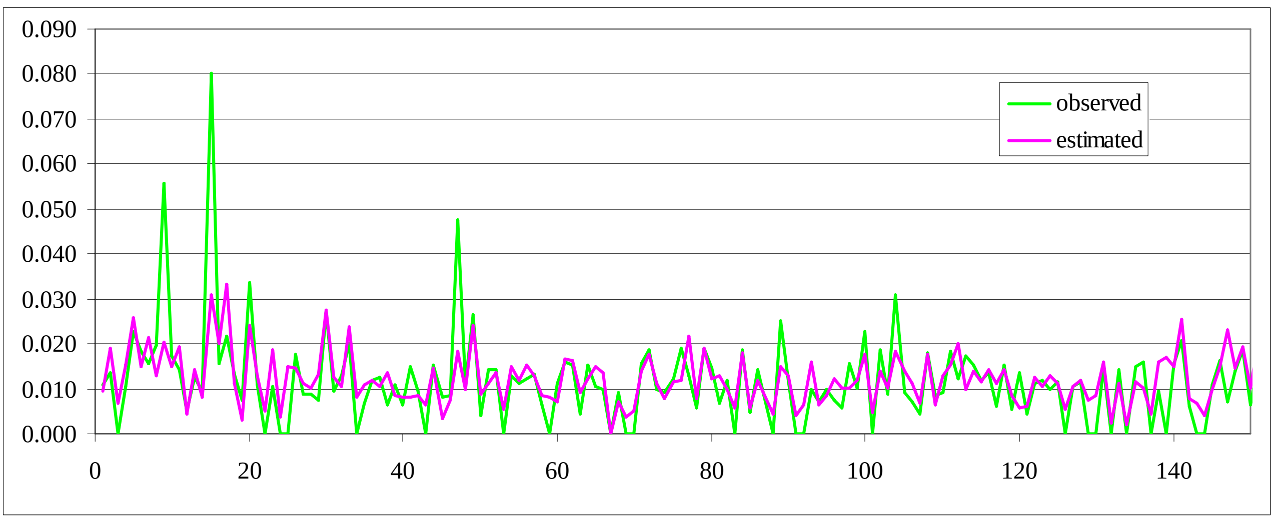


Figure 1: Plots of the CRs observed and estimated by the model for males. Emilia-Romagna 2005-2009 (for graphical reasons only results on 150 municipalities are reported).

The smoothing effect, which finally reflects the efficiency of such a model, is also evident when comparing observed and estimated CRs maps, separately by sex (Figures 2 to 5). In both cases, the model yields to more homogeneous estimates according to the geographical proximity of areas. The observed CRs are instead denoted by a set of spots, identifying localizations with strange different values from the other nearby areas.

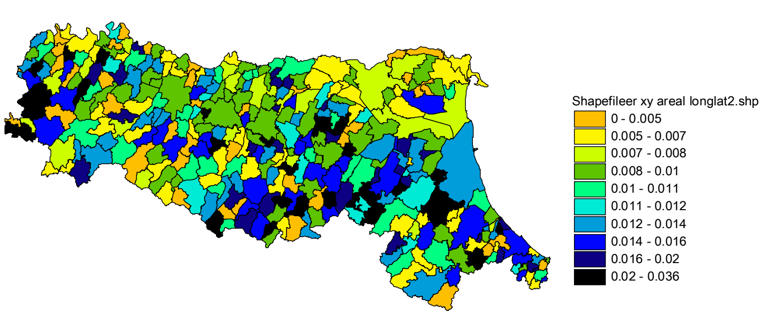
In this work, we firstly aim to evaluate the current pattern and distribution of longevity across the Emilia-Romagna region. This is the main reason why we especially focus the attention on the results referred to the second period, from 2005 to 2009. Anyway, the role of 2000-2004 data is crucial, as it represents the past pattern which contributes to the temporal smoothing of the final estimates, and it can be appreciated by comparing the CRs estimates in both periods (Figures 6 and 7 vs. Figures 3 and 5, respectively). Besides observing an increase of the general values of the CRs by time, a persistence of the areas of lower and higher occurrence can be noted.
These results show mean and median values higher than the regional ones in the municipalities belonging to the provinces of Ravenna, Bologna and Forlì-Cesena. On the other side, the municipalities of the province of Ferrara are characterized by lower values of the CR_{95+} index, showing a scarce propensity to longevity.
When gender is considered, the areas of the Adriatic coast (the Eastern part of the region) still stand out for high values of CR_{95+} for both sexes: the province of Ravenna is characterized by the highest values compared to all other provinces. The municipalities of the province of Bologna are characterized by a high value of the female CR_{95+} while the province of Ferrara confirms its reduced longevity both for males and females.

The adopted model further allows us to split the spatial variability into two parts. The first concerns the geographical structure modelled by the component *u.* and it is revealed by yielding homogeneous clusters of adjacent areas. The second part of variability is due to the peculiarities of individual areas and results from municipalities which have observed values significantly different from those of the other nearby areas. This is reflected by the component *v* in the model specification for the log relative risks.
The contribution of these two effects (homogeneity and heterogeneity) in terms of total territorial variability can be firstly evaluated through the estimates of the posterior variance of the two components *u* and *v*, given respectively by $\hat{v}$ **(U|Y)** and $\hat{v}$ **(V|Y)** (Table 1). For both sexes, the structured spatial variability seems to prevail. As a consequence, the global model representations for the CRs are more influenced by the territorial distribution of the *u* component, which identifies territorial clusters with relatively similar longevity risks, rather than by the *v* effect.

	Homogeneity $\hat{v}$ **(U|Y)**	**Heterogeneity** $\hat{v}$ **(V|Y)**
Men	0.0741	0.0064
Women	0.0614	0.0067

Table 1*: Posterior estimates of variances of homogeneity (*$\hat{v}$ ***(U/Y)****) and heterogeneity (*$\hat{v}$ ***(V/Y)****) effects, separately by gender.*

In order to compare such different contributions, distinct maps for each component (*u* and *v*) can be further produced (Figures 8 to 11). Especially for men, two big clusters with a positive contribution on the CRs can be clearly identified. The first one corresponds to the south-east area of the region, including some municipalities of Bologna, Forlì-Cesena, Ravenna and Rimini, which spreads out in the Adriatic coast, at one side, and in the Apennine municipalities of Modena, on the other side. The second cluster is smaller and includes some areas of the province of Piacenza in the south-west of the region. According to the gender, the female clusters seem to be less regular than those of men. On the other hand, the province of Ferrara is confirmed again as the worst area in terms of homogeneity contribution to the values of CR.
The heterogeneity maps, conversely, identify areas with a (positive-black or negative-orange) significant component not due to the territorial adjacency. The more difficult interpretation of such results can be simplified by focusing the attention only on those municipalities with highest or smallest values on CR and not characterized by a great clustering effect.



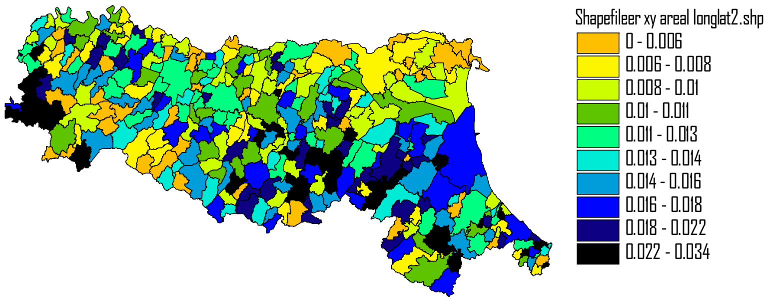
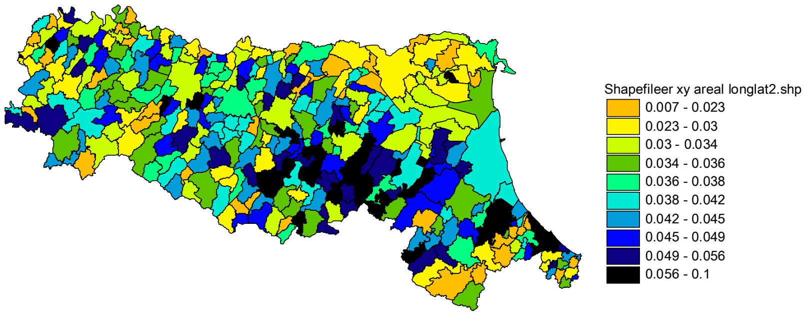


Figure 2: *Map of the observed CRs for men. Emilia-Romagna 2005-2009*

Figure 3: *Map of the CRs estimated by the model for men. Emilia-Romagna 2005-2009.*



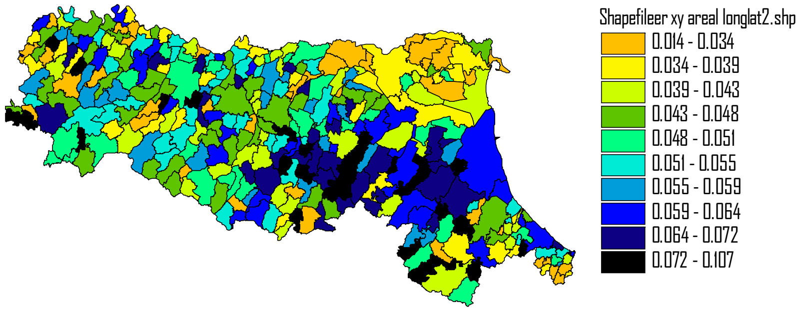


Figure 4: *Map of the observed CRs for women. Emilia-Romagna 2005-2009.*

Figure 5: *Map of the CRs estimated by the model for women. Emilia-Romagna 2005-2009.*

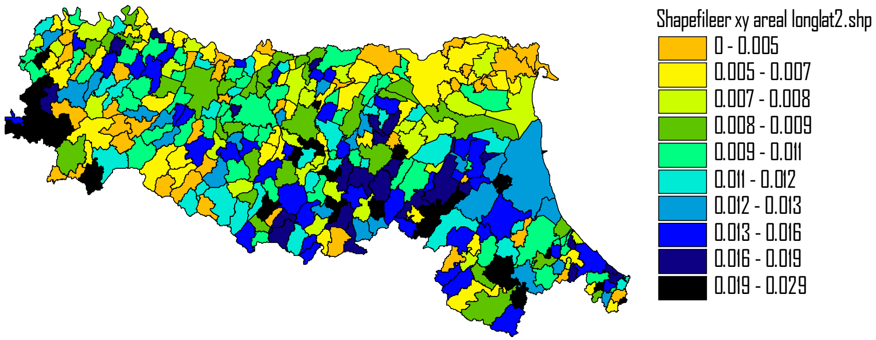


Figure 6: *Map of the CRs estimated by the model for men. Emilia-Romagna 2000-2004.*

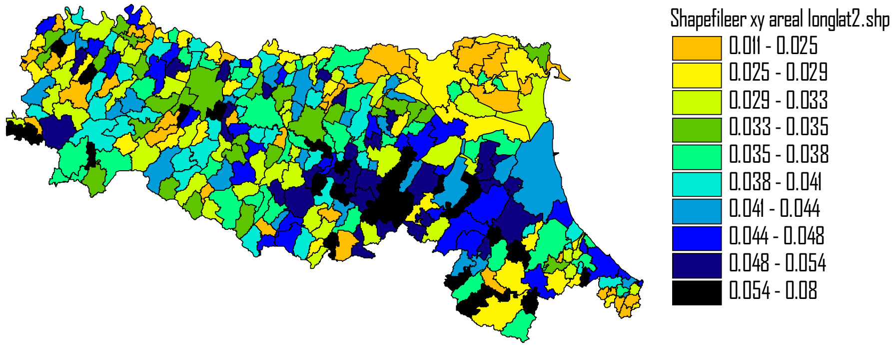


Figure 7: *Map of the CRs estimated by the model for women. Emilia-Romagna 2000-2004.*

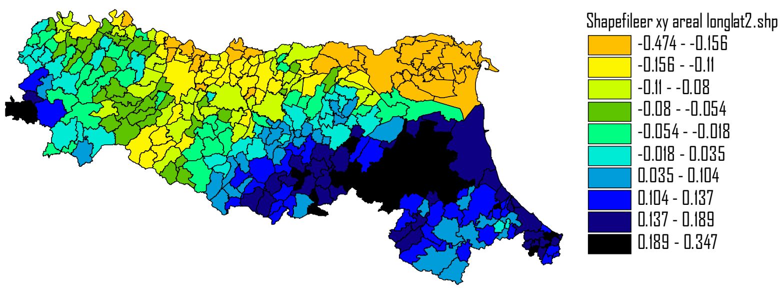


Figure 8: *Map of the homogeneity component for men. Emilia-Romagna 2000-2009.*

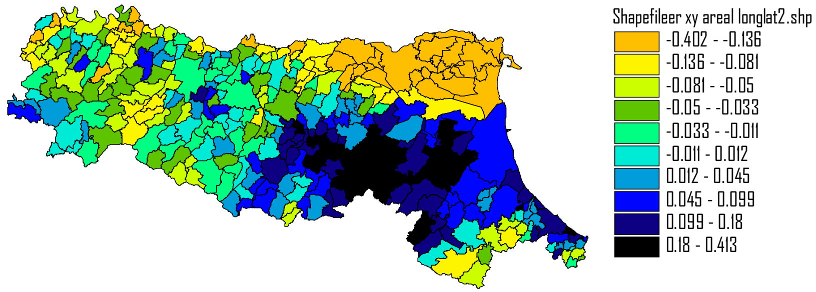


Figure 9: *Map of the homogeneity component for women. Emilia-Romagna2000-2009.*

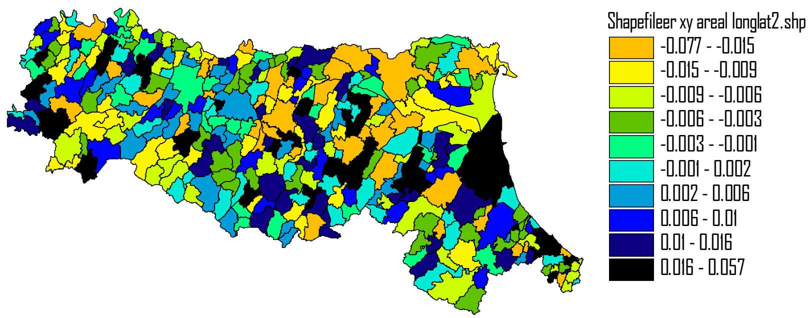


Figure 10: *Map of the heterogeneity component for men. Emilia-Romagna2000-2009.*

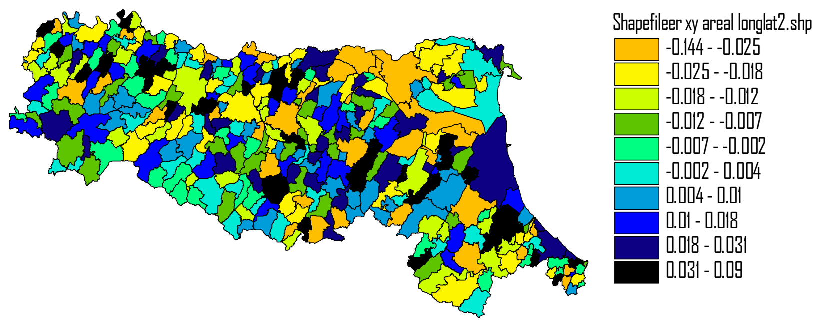


Figure 11: *Map of the heterogeneity component for women. Emilia-Romagna2000-2009.*

5. Discussion and conclusions

In recent years the frequency of Italian cases of longevity has been increasing, albeit with considerable differences in terms of geographical areas and between men and women.
We have analyzed longevity in one north-eastern Italian region (Emilia-Romagna), by creating suitable indicators for two periods 2000-2004 and 2005-2009 and by gender.
Territorial differences in the presence of centenarians among the 341 municipalities of Emilia-Romagna have been modelled by adopting a Bayesian hierarchical spatial approach. This approach allows us both to manage the geographical structure of the phenomenon and to control for variations due to random occurrences linked to the limited geographical dimensions of some municipalities.
For both sexes, the structured spatial variability seems to prevail.
Furthermore, the model adopted is able to consider also a temporal dimension of the phenomenon, by considering the evolution of the amount of centenarians in the two considered period. As a final result, the estimates on the quantities of interest yield more consistent inferences, thanks to the two-fold smoothing effect in both spatial and temporal sense.
The mapping of geographical variation in the prevalence of longevity may help to identify areas where homogeneous environmental, demographic, and social characteristics are present and may influence the risk of mortality for specific causes of death. Moreover the prevalence of extreme longevity may remind of genetic aspects that contribute to a longer life.
Our study indicates the existence of areas of high longevity in the south-eastern part of the region, as opposed to other areas in the north-eastern section which are characterized by lower values of the CR_{95+} index, with no relevant differences between men and women.
A further step that needs to be taken into account is the adoption of a cohort behaviour approach in the study of cause specific mortality, in order to study the causal link between the long-lived and their specific causes of mortality; the results of such an analysis could shed some light on the factors that affect longevity in the population. Since mortality and longevity may share the same set of risk factors, or the level of a specific cause mortality might encourage or inhibit the presence of longevity over a region, we may need a multivariate areal model to properly analyse this kind of data (Jin, Carlin and Banerjee 2005).

Another possible alternative application of the proposed methods is related to the proximity among territorial units that, till now, is expressed in terms of a geographical distance. The proximity might, however, also be expressed in terms of a more structured distance that is defined over a large set of covariates. Last, but not least, mortality patterns by broad categories of causes of death should be considered.

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