AGEING POPULATION IN ITALY: A SPACE-TIME ANALYSIS

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1. Introduction and aim

Population ageing, defined as the increase of the old population in comparison to the rest of the population, particularly the young component, is one of the most relevant demographic phenomena of this century (Bloom and Luca, 2016). The demographic factors that have led to the ageing of populations in several Western countries mainly originate from the improvements in survival and the ability to control the desired number of children (Golini, 2003). Indeed, population ageing is the result of relevant changes in demographic behaviours. On the one hand, progress in increasing life expectancy has led to people reaching previously unimaginable ages and thus has resulted in an absolute increase in the number of elderly people (WHO, 2020). On the other hand, the continuous decline in fertility rates, determined not only by individuals' wishes but also by social changes and difficulties in having many children, caused a decline of births and younger people (Golini, 1998). Furthermore, this decrease has led to a reduction in the generations of women in childbearing age which in turn has led and will continue to lead to a decline in births. All these dynamics together have determined an ever-increasing elderly population. These demographic (permanent) shocks are common factors across Western countries as well as across regions within each country. Nevertheless, there are typically socio-economic factors (such as availability of public and social services, presence of tertiary sector and others) as well as exogenous land features (altitude, proximity to the sea, accessibility, and so on) which idiosyncratically characterise each territory or region and contribute to determine a large spatial heterogeneity in population ageing.

The number of elderly people (conventionally people aged more than 65) is increasing and will increase in several developed countries, but Italy is one of the countries in the world where the phenomenon has been fastest and most intense (Golini, 1997). The Italian population over 65 increased from 18.7% to 22.9% between 1.1.2002 and 1.1.2019. The ageing index, the ratio between the old population aged more than 65 year and the younger population under 15 years, was 131.7 on 1.1.2002 and it reached the value of 174.0 old people for 100 young people on 1.1.2019. The Italian population is the oldest in the European context,

and the second in the world after Japan (Eurostat, 2021). This strong increase in ageing in Italy over the last 20 years has also been accompanied by a strong spatial heterogeneity: by looking at the major socio-economic regional level (NUTS-1 spatial units under Eurostat classification)[1], the ageing index in the South was equal to 94.3 on 1.1.2002 and 154.4 on 1.1.2019, while it was 157.7 at the beginning of the period and 184.5 at the end in the North-West. Obviously, this heterogeneity increases by using more detailed spatial units. At provincial level (NUTS-3), the ageing index ranged from 108.3 in the Naples (South), to 157.8 in Trieste (North-East) on 1.1.2002, while it ranged from 116.4 to 267.7 in the same provinces on 1.1.2019. Using the lowest administrative territorial level, the Italian municipality (LAU, under Eurostat classification), on 1.1.2019, 216 out of 8,092 municipalities have fewer older people than younger and an ageing index lower than 100, but as many as 1,319 municipalities have an ageing index higher than 300. The spatial dimension is therefore extremely important when investigating a phenomenon such as ageing in Italy. Indeed, Italy presents large differences with regard to population ageing, to the demographic factors behind it and to the economic and social contexts where this phenomenon develops and impacts.

In general, space is an important element in the study of all demographic phenomena (De Castro 2007; Howell et al. 2016; Thiede and Monnat 2016), although it has not always been considered as relevant as the time dimension (Courgeau and Lelièvre 1997). Indeed, all demographic phenomena involving individuals at a specific instant of time take place in a specific place. Differences in the observation of a phenomenon may emerge across space and this is also true for population ageing. As already stated, the dynamics of this phenomenon varies, depending on the geographic area (Schoeni and Ofstedal 2010) and, recently, investigations about population ageing and its connection with space have become more widespread than in the past (i.e., Walford and Kurek, 2008; Shiode *et al.*, 2014; Reynaud *et al.*, 2018).

This paper is part of the area of studies dealing with the analysis of demographic phenomena using both a spatial and a temporal perspective. The aim of the paper is to study population ageing in Italy by conducting a spatio-temporal analysis at a very fine territorial level. In particular, we analyse population ageing by describing ageing trend in Italian municipalities during 17 years, from 1.1.2002 to 1.1.2019 and by focusing on space-time evolution of ageing processes and on the investigation of the large-scale patterns of this process through the application of a nonparametric model incorporating a spatio-temporal trend (i.e. a smooth

[1] Italy is divided into 5 NUTS-1 regions: the North-West, the North-East, the Centre, the South and the Islands (together also known as Mezzogiorno). Then, Italy is composed by 20 NUTS-2 regions, 110 provinces (NUTS-3) and about 8,000 municipalities (LAU), the low-level administrative divisions of the country.

interaction between the spatial coordinates and the time trend) on the right-hand side. In this way, we attempt to answer the following research questions: Is there a time-trend of ageing population across Italian municipalities? (RQ1); Is there a spatial-trend of ageing population across Italian municipalities? (RQ2). The rest of the paper is organised as follows: section two presents the data and a descriptive analysis; section three reports the results of a nonparametric estimation of the spatio-temporal trend; the last section is devoted to conclusions and discussion.

2. Data and descriptive analysis

The data used for the analysis come from the inter-census estimates of the resident population, calculated by ISTAT by integrating the Census population data[2] and the demographic flows (statistics of births, deaths and migrations) in the inter-census period (ISTAT, 2021). The data cover the period between 2002 and 2019 and refer to the Italian municipalities (LAU). Since there have been several changes in the boundaries and in the number of municipalities over the years, the data have been harmonized to the classification of the municipalities at the 2011 Census, when there were 8,092 LAUs. The indicator of the age structure used in the analysis is the ageing index, computed for each municipality and for each sample year over the period between January 1 2002 and January 1 2019.

Ageing levels in the North-Centre are persistently higher than in the rest of the Country (Table 1). At the beginning of the sample period, the South had more young than older people, while the number of older people in the Islands was only slightly higher than the number of young people. In the last ten years, the increase in the levels of aging has spread to the whole national territory, so that at the end of the period the differences between the regions appear much less strong and the aging index has reached very high values in all NUTS-1 regions.

As mentioned above, the spatial differentials in the ageing index in Italy increases when we consider smaller spatial units. A huge spatial heterogeneity appears indeed at the municipality level, with values ranging from a minimum of 20 to a maximum of 11,600. During the sample period the ageing index increased substantially (Figure 1). Spatial heterogeneity also increases over time as shown by the kernel density estimates (Figure 2), obtained after excluding values greater than 750.[3] The distribution is always right-skewed: a long right tail (i.e. values above the third quantile) clearly suggests that a limited number of municipalities

[2] The latest census, for 2019, is not a traditional decennial census but a permanent census, conducted with a new methodology (Istat,2020).

[3] The threshold of 750 was only used to generate Figure 1. The subsequent analysis was carried out using the whole sample.

contribute to the exponential increase in the average value (from 183 in 2002 to 235 in 2019). Indeed, we observe a positive trend in the simple average of the municipalities' ageing indexes, with the greatest increase concentrated in the period from 2012 and 2019 (Figure 1). This evidence is likely correlated to the impact of the double economic crises (occurred in 2009 and in 2012, respectively) on demographic dynamics (Reynaud and Miccoli, 2019). While in the previous period a slight recovery in the birth rate and a strong increase in immigration slowed down the ageing process, after the two economic crises a lower birth rate, due to the difficult decision to have a child in recession periods, and a lower attractiveness for foreign immigrants accelerated the ageing process (De Rose and Strozza, 2017).

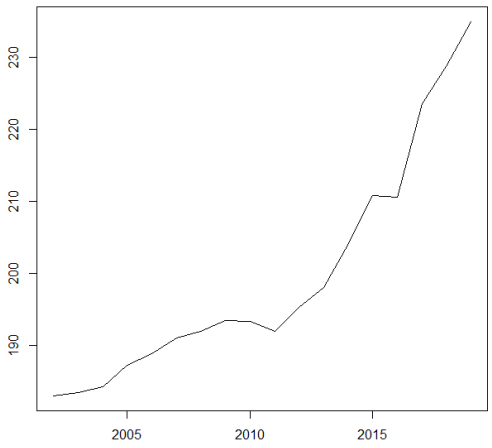
Table 1 – *Ageing index in NUTS-1 regions*

NUTS-1 regions	Ageing index		
	1.1.2002	1.1.2011	1.1.2019
North West	157.7	159.8	184.5
North East	156.9	152.8	177.9
Center	157.5	161.6	183.9
South	94.3	119.1	154.4
Islands	102.9	130.7	166.3
Italy	131.7	145.2	174.0

Source: Authors' calculation from ISTAT data.

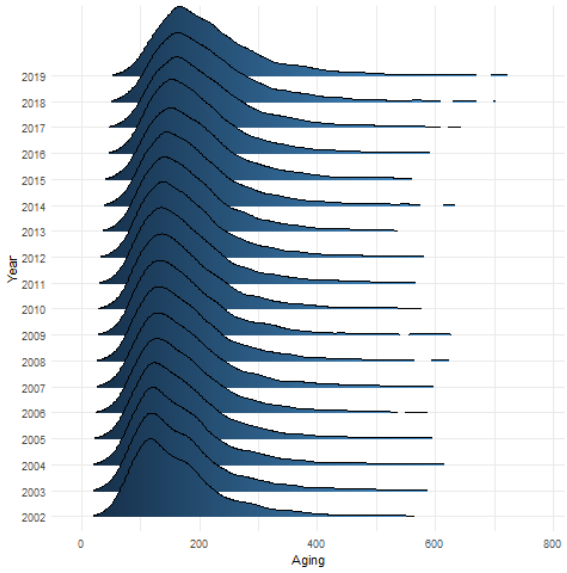
Observation of this trend shows how ageing, a phenomenon that only at the beginning of this century seemed to be confined to municipalities and areas in the Centre-North, is now a widespread phenomenon throughout the territories. As already said, high levels of ageing are also spreading to municipalities in the South and the Islands, in contexts that are therefore economically and socially disadvantaged compared to those in the Centre-North. The ageing process also seems to affect very small municipalities, often located in marginal areas, such as the inner regions, often mountainous areas. Modest levels of ageing remain only in those contexts still characterised by a high fertility.

Figure 1 – *Time trend of the simple annual average values of the ageing index across the Italian municipalities in the period 2002-2019.*



Source: Authors' calculation from ISTAT data.

Figure 2 – *Distribution of the aging index over the Italian municipalities in the period: 2002-2019. Kernel density estimate.*



Source: Authors' calculation from ISTAT data.

3. The spatio-temporal distribution of ageing in Italy

To better analyse the changes over time and space in the ageing structure of the Italian population, we also estimate a simple nonparametric model, using the logarithmic transformation of the ageing index a_{it} (number of elderly population - aged 65 years and over - per 100 individuals younger than 14 years old) as a dependent variable and including only a smooth spatio-temporal trend (i.e. a smooth interaction between the spatial coordinates of the municipalities and the time trend) on the right-hand side:

$$y_{it} = \alpha + f(s_{1i}, s_{2i}, \tau_t) + \epsilon_{it} \tag{1}$$

where *i* is an index for the spatial units (the 7,898 municipalities), and *t* is an index for the time dimension (years from 2002 to 2019); y_{it} is the log of a_{it}; s_{1i} and s_{2i} are the spatial coordinates (latitude and longitude) of the municipality *i*; τ_t is the time period; and ϵ_{it} is an idiosyncratic error term assumed to be identically and independently distributed.

As the estimation of this spatiotemporal trend can be very complex with a large dataset, we consider a spatiotemporal ANOVA model as proposed by Lee and Durbán (2011), disaggregating the trend into spatial and temporal main effects, as well as second- and third-order interactions between them:

$$\begin{aligned} y_{it} &= \alpha + f_1(s_{1i}) + f_2(s_{2i}) + f_t(\tau_t) + \\ & f_{1,t}(s_{1i}, \tau_t) + f_{2,t}(s_{2i}, \tau_t) + f_{1,2}(s_{1i}, s_{2i}) + f_{1,2,t}(s_{1i}, s_{2i}, \tau_t) + \epsilon_{it} \end{aligned} \tag{2}$$

The model is estimated using a penalized regression approach based on a basis representation of the unknown functions, which is combined with a penalty on the likelihood to control the wiggliness of the curve/surface. In particular, we use the approach introduced by Eilers and Marx (1996) which applies cubic B-splines as bases functions, and second-order differences of adjacent coefficients as penalties.

As shown in Table 2, all ANOVA components of the spatio-temporal trend, but the third-order interaction between the spatial coordinates and the time trend, are significant. However, the second-order interaction between the spatial coordinates is the most important component, as revealed by the estimated degrees of freedom, and explains most of the spatiotemporal variability of ageing over the sample period. The main function of time is nonlinear (5 degrees of freedom), but less important than the main functions of each spatial coordinate. This suggests us to focus on the spatial distribution rather than on the time trend in the interpretation of the spatiotemporal trend.

Table 2 – *Estimation results*

Effect	*Estimated degrees of freedom*	*F test*
f_t*(year)*	5.94	224.5***
f_1*(longitude)*	16.91	340.2***
f_2*(latitude)*	15.87	266.6***
$f_{1,2}$*(longitude, latitude)*	88.20	538.1***
$f_{1,t}$*(longitude, year)*	1.56	5.7**
$f_{2,t}$*(latitude, year)*	13.25	28.7***
$f_{1,2,t}$*(longitude, latitude, year)*	39.77	3.7

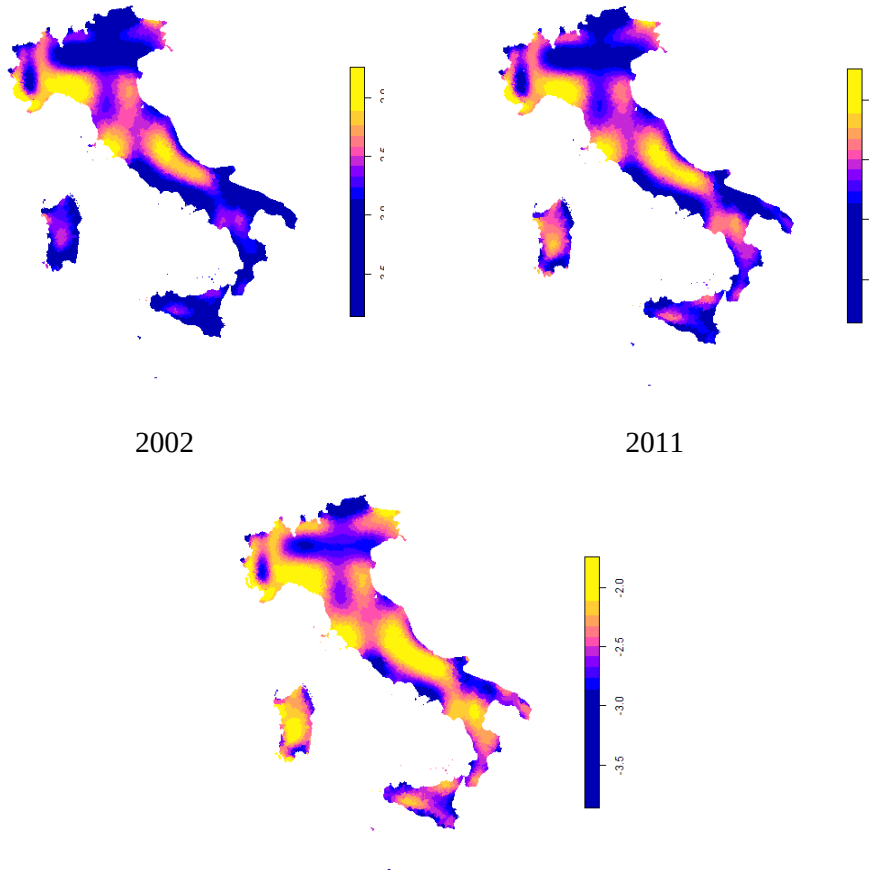
Source: Authors' calculation from ISTAT data.

Figure 3 reports the maps of the estimated spatial trend evaluated for three different years (2002, 2011, and 2019). Generally speaking, these maps confirm that the spatial distribution of the ageing index remains persistently characterized by a strong coastal-inland divide as a result of the complex interaction between demographic dynamics and local socio-economic contexts. As for its spatial pattern, at the beginning of the period (1.1.2002), the log of the ageing index recorded high values in the municipalities of the North-West and the Centre, while it was much lower in some municipalities of the North-East and in the Mezzogiorno (the South and Island). Areas in the North-West, especially the Liguria and lower Piedmont regions, have always been those with a particularly high level of ageing. These are the areas with the lowest fertility since the 1970s. The only areas with values below 100 are the northernmost part of the North-East (Bolzano province) and part of Campania (Naples and Salerno provinces), as well as small areas of Sicily: in all these areas, the average number of children per woman has always been above the national average.

Over time, however, many municipalities and areas in the Centre have also reached very high values of the ageing index: on 1.1.2011 the municipalities located along the Apennines[4] in the Centre and South Italy were among those with the highest values. In particular, there is a concentration of high values in some inner areas in the Centre of the Country (in particular in Abruzzo). In 2011, the index was also particularly high in some limited areas in the South of Italy, especially in Sardinia region. Since the 1990s, a depopulation process has been observed in the mountainous areas and in the interior of central and southern Italy, contributing to the subsequent increase of ageing population (Reynaud and Miccoli, 2018).

[4] The Apennines are a mountain system traversing several regions from the North to the South of Italy.

Figure 3 – *Smooth spatial trend evaluated in 2002, 2011, and 2019.*



Source: Authors' calculation from ISTAT data.

On 1.1.2019, ageing phenomenon is widespread in almost all Italian municipalities. As expected, the demographic dynamics are linked to the changing age structure of the population. On the one hand fertility rates continue to decline in all regions and on the other the women generation in mid-reproductive age are born during the baby-bust and less numerous of their mother generations. Over time, the ageing phenomenon spreads to other inner areas in the South, especially in Calabria and in Sardinia. On the other hand, Sicily, Puglia and the west coast in

the Centre show low values of ageing. However, some important deviations from this overall spatial pattern (i.e. the coastal-inland divide) do emerge. In particular, we can observe a concentration of high values of ageing in the North-West (Piemonte, Liguria and other coastal areas), while the lowest values are persistently shown in Trentino Alto Adige.

As mentioned above, these spatiotemporal dynamics could be greatly explained by typical determinants of ageing, such as the demographic dynamics (reduced fertility and death rates levelling off at low rates) and the dynamics of local socio-economic variables. In our research agenda, we will go beyond this simple exploratory analysis by carrying out a more complex econometric analysis which includes a large set of covariates to assess these hypotheses.

4. Discussion and conclusions

The phenomenon of ageing in Italy has become increasingly intense in recent years during which persons over the age of 65 have increased in absolute and relative numbers in most of the Italian territories. While the increase was slower in the early period, it became more intense in the subsequent years, mainly due to the drop in fertility and birth rates after the 2008 economic crisis, but also due to the decrease in women in the mid-reproductive ages. Even going down to a more detailed level of territorial analysis, such as that of the municipalities, the results of the analysis show how the phenomenon has grown throughout Italy, especially in recent years. Thus, a significant time effect allows us to define a very general trend (RQ1). With such a growth of ageing population, there are very few areas where the ageing is low.

The existence of municipalities where the number of elderly people is two or three times the number of young people poses a problem of sustainability of these administrative realities, not only from an economic point of view, but also from a political, social and cultural point of view. In some municipalities the population under 15 does not exist or is disappearing. A population is such when a generational turnover is ensured; therefore a population without young people and children, which does not guarantee this turnover, can hardly be considered a population in the original sense of the term. But the demographic characteristics of these municipalities must be analysed in the context in which they are embedded: the clusters of all very old municipalities are more problematic in governance than the clusters of municipalities with different levels of ageing. The spatial model applied for this analysis consider space (in this case, the context of the major socio-economic region) as a latent variable. The results demonstrate and underline the importance of the territorial context and the need to consider it in the analysis of

the demographic dynamics of the territories. A spatial model such as the one applied here plays a key role in the analysis of the relationship between territory and population ageing (RQ2). The spatial model also allows us to show that the two dynamics - space and time - are linked: it is possible to observe clusters of municipalities that have experienced the same increase over time in ageing indexes.

The spatial analysis conducted in this paper provides important elements that need to be considered. The spatial variability is very high not only within the major socio economic regions (NUTS-1), but also within regions (NUTS-2) or provinces (NUTS-3). Therefore, the spatial dimension cannot be considered a secondary element, and looking at the more detailed spatial units is crucial to investigate the spatial component in depth. The analysis of municipalities characteristics is also important as a tool to support the governance: municipalities constitute the level of administration that provides their citizens with the basic services they need and these can differ if the population is mainly elderly or young people.

This paper contributes to the deep knowledge of the phenomenon of population ageing in Italy by providing a spatial perspective. The consequences of this important demographic process in all Italian territories are and will be relevant. The knowledge of the territorial dynamics and space-time evolution of this phenomenon can help to the formulation and implementation of focused politics able to face this demographic challenge. Our results show that a continuous and slow increase of the populations ageing in inner territories has resulted in particularly aged territorial areas, especially in the mountainous or inner areas of the Mezzogiorno. High level of ageing seems to lead to unsustainable conditions for the populations of determined areas. The consequences of an ageing population will fall on the total population and the Country as a whole, but in certain areas the consequences may be more negative. For this reason, knowing the deep dynamics of this phenomenon is essential for managing the future.

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SUMMARY

Population ageing is one of the most relevant demographic phenomena of this century. Italy is one of the countries in the world where the phenomenon has been fastest and most intense. Indeed, it presents large differences with regard to population ageing, to the demographic factors behind it and to the economic and social contexts where this phenomenon develops and impacts. The spatial dimension is therefore extremely important when investigating this phenomenon in Italy.
This paper is part of the area of studies dealing with the analysis of demographic phenomena using both a spatial and a temporal perspective. The aim of the paper is to study population ageing in Italy by conducting a spatio-temporal analysis at a very fine territorial level. The data used for the analysis cover the period between 2002 and 2019 and refer to the Italian municipalities (LAU). The indicator of the age structure used is the ageing index, computed for each municipality and for each sample year. Beyond the descriptive analysis of the ageing levels and trends, we also estimate a simple nonparametric model.
The spatial distribution of the ageing index remains persistently characterized by a strong coastal-inland divide as a result of the complex interaction between demographic dynamics and local socio-economic contexts. The spatial model allows to show that the two dynamics - space and time - are linked; space cannot be considered a secondary element, and looking at the more detailed spatial units is crucial. The analysis of municipalities characteristics is also important as a tool to support the governance in facing future demographic challenges.

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