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Demographic sustainability in Italian territories: The link between depopulation and population ageing

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Abstract

Since the Second World War, Italy has experienced major demographic changes, including increasing survival, decreasing fertility and higher rates of immigration. These changes have silently and slowly led to important shifts in the structure and the territorial distribution of the population. Thus, like in many other European countries, population ageing and depopulation have become the most relevant demographic phenomena in Italy. In this paper, we studied the relationship between depopulation and ageing in Italian territories in the 1971–2019 period using the census data of the Italian municipalities and applying spatial techniques. We found that high levels of depopulation later result in high levels of population ageing, and that recent population ageing processes are also connected to ongoing depopulation processes, thereby creating a vicious circle.

Keywords: depopulation; population ageing; spatial analysis; Italy

1 Introduction

Depopulation, a process that shrinks a territory's population, and demographic ageing, defined as an increase in the number of older people in a population both in absolute terms and relative to the rest of the population, are two phenomena that are increasingly affecting large portions of Europe (Lutz and Gailey, 2020). These processes are mainly taking place in countries where fertility has reached very low levels, and where many sub-national areas have experienced very high levels of out-migration. This pattern can, for example, be observed in Spain

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(i.e., Alamá-Sabater et al., 2021), Italy (i.e., Reynaud and Miccoli, 2018) and many Eastern European countries (i.e., Lukic et al., 2012). Since the last century, various demographic changes have led to important variations in population growth, numbers and structure. As a result of these shifts, current populations, especially in certain areas, are characterised by a sharp decrease in growth and an intense ageing process. The Italian population is an interesting case to examine in the European context because it is among the populations experiencing the most intense population ageing and depopulation processes. Nonetheless, there has been relatively little research on the topic of depopulation in Italy (e.g., Reynaud and Miccoli, 2018; Rizzo, 2016), whereas it has attracted more attention in Spain and some Eastern European countries.

The similar dynamics of the depopulation processes – in particular the decline in fertility and the consequent negative natural balance – have caused and are causing a serious imbalance between the older and the younger generations in Italy, making the country's population one of the oldest in the world (Golini, 2000). These depopulation processes, which are also due to negative net migration, particularly among young people, are more widespread in rural areas, where significant ageing processes have taken place.

In Italy, depopulation is not a new or a recent phenomenon (Golini et al., 2000), as depopulation processes were occurring in specific territories in the early 1900s. However, over time, and especially since the 1970s, the demographic determinants of depopulation have changed, as new demographic and social processes have combined with depopulation processes. The areas affected by population decline have changed as well: new areas have begun to undergo depopulation, and are thus being added to the areas that were already experiencing this phenomenon; while other areas are no longer losing population, and are instead experiencing a new phase of demographic dynamism.

The aim of this work is therefore to examine the existing relationship between the two phenomena in Italian territories in the 1971–2019 period. Specifically, we are trying to understand whether and how population growth has affected the ageing levels in these territories, and whether and how having a large older population at a certain date has affected population growth.

The Italian context represents an interesting case for analysis because of its aforementioned demographic dynamics and the differences between its territories. Therefore, the analysis is carried out at a sub-national level by considering the lowest administrative level (Local Administrative Units, LAU), the Italian municipalities.[1] Furthermore, in the last considered period, in particular from 2011 onwards, the

[1] Italy is divided into five major socio-economic regions (NUTS 1, according to the Eurostat Nomenclature of Territorial Statistical Units): North-West, North-East, Centre, South and Islands. The country is composed of 20 regions (NUTS 2); 110 provinces (NUTS 3); and about 8000 municipalities (LAU), which are the low-level administrative divisions of the country. Throughout the paper, general reference will be made to the North, indicating the North-West and the North-East; and to the South, indicating both the South and the Islands.

effects of the economic crisis had an impact on demographic dynamics, which, in turn, exacerbated population ageing (Reynaud and Miccoli, 2019) and intensified depopulation processes. In this study, we consider the intercensal periods between the 1971 and 2019 census, and thus are able to take into account the period after 2011, when Italy was undergoing an acute demographic crisis. This approach provides us with recent insights into the relationship between the two phenomena. Unlike the previous study conducted on the subject (Reynaud and Miccoli, 2018), we add the last intercensal period, and apply the spatial model based on the assumption that one of the drivers of depopulation is the interdependence of neighbouring local units (Alamá-Sabater et al., 2021). We have chosen do so because previous studies have shown that when analysing demographic dynamics at a detailed territorial level, it is essential to take autocorrelation into account (Benassi et al., 2023; Matthews and Parker, 2013; Reynaud et al., 2018). The results of our previous paper may have been distorted by spatial autocorrelation.

The remainder of the article is organised as follows: Section 2 provides the theoretical background; Section 3 describes the research questions, data and methods used; Section 4 presents the results of the analysis, outlining first the descriptive results and then the results of the applied model; and, finally, Section 5 presents a discussion and the main conclusions of the study.

2 Theoretical background

Depopulation and population ageing are strongly connected (Díez Modino and Pardo Fanjul, 2020; Hospers and Reverda, 2014; Reynaud and Miccoli, 2018). The determinants that trigger depopulation processes are the same as those that cause population ageing, and the two phenomena influence each other. Low fertility and birth rates, together with emigration, cause both depopulation and ageing processes (Fihel et al., 2018; Hospers and Reverda, 2014). Indeed, a deficit of births over deaths implies that there are fewer babies, fewer younger people and more older people in the population (Kinsella and Phillips, 2005). The migration of young people (who are the most inclined to move and migrate) (Raymer et al., 2011) leads to a decrease in an important segment of the population: namely, young adults who are able to have children, and who are also more likely than older adults to contribute to the social and economic development of the society (Johnson and Winkler, 2015). On the other hand, ageing processes can cause further depopulation processes, because in contexts with older populations and fewer economic and social opportunities, the pressure on young people to emigrate to demographically and economically more dynamic areas becomes strong (Johnson and Lichter, 2019). These negative demographic processes – sharp declines in births and high levels of emigration, depopulation and ageing – can undermine the economic and social development of territories, resulting in a negative spiral of challenging demographic and social conditions.

Despite the close connection between depopulation and population ageing, there are no extensive studies in the scientific literature on the relationship between the

two demographic processes in recent decades. Several studies have highlighted how depopulation processes have resulted in an ageing of the population (Lukic et al., 2012; Viñas, 2019), while other studies have discussed the consequences of both processes in Spain (Pinilla and Sáez, 2021); in several Eastern European countries (Daugirdas and Pociūtė-Sereikienė, 2018; Vaishar et al., 2020); and in Japan, which has the oldest population in the world (Coulmas, 2007; Doo-Chul and Hye-Jin, 2009; Matanle, 2014). Wiśniewski et al. (2021) conducted a descriptive analysis of depopulation processes in combination with population ageing processes in Polish regions. Díez Modino and Pardo Fanjul (2020) examined the relationship between ageing and depopulation, but by considering ageing as a driver of depopulation. For Italy, studies have been conducted on depopulation and its consequences, and especially on past dynamics (e.g., Golini et al., 2000; Sonnino, 1979). Several recent studies have examined the depopulation processes in specific Italian areas by considering demographic and geomorphological factors (Reynaud et al., 2020), while other studies have focused on the effects of depopulation on specific areas or rural parts of Italy (e.g., Fantechi et al., 2020; Quaranta et al., 2020; Rizzo, 2016).

As was mentioned above, some Italian territories began to experience depopulation processes over the course of the 1900s. During the demographic transition process in Italy, which was characterised by decreasing mortality levels and stable fertility levels, population growth was not supported by a significant process of economic and industrial development, especially in certain areas, including in areas in the South. The demographic surplus therefore contributed to high levels of out-migration, which was seen as the only opportunity many individuals had to improve their living conditions, regardless of whether they were male or female, educated or uneducated, young or old (Bonifazi, 2013). These out-migrations from the most disadvantaged territories were to other Italian territories, as well as to other countries (Livi Bacci, 2020; Sonnino and Nobile, 1988). However, in the initial phase of this period of out-migration, the negative migration balance (in-migration minus out-migration) at both the national and the sub-national levels was counterbalanced by strong positive natural growth (births minus deaths). When fertility and births also began to decline, the natural balance in the areas already characterised by strong emigration decreased, which led to depopulation processes. Internal migration played an important role, contributing to the growth of certain territories, especially of cities, and to the depopulation of smaller and more isolated municipalities (Morettini, 2006). Depopulation was particularly likely to occur in territories that did not offer many opportunities due to their geographical and morphological characteristics, such as in mountainous areas or in areas with poor connections to the city (Birindelli, 1977). However, the depopulation phenomena that took place in sub-national territories at the beginning of the 20th century were embedded in a context characterised by the growth of the resident population in Italy as a whole (Sonnino, 1979).

In the 1970s, new depopulation processes began that were driven by new demographic dynamics. Since then, the continuous declines in fertility and birth rates have led to a significant decrease in the natural balance, which has, in turn, had a considerable impact on population growth rates at both the national and the

local levels. However, intense economic development, together with other socio-economic factors, have led to a reduction in emigration and to a subsequent increase of the inflow of immigrants from abroad (Bonifazi, 2013; Bonifazi et al., 2009). Particularly in the 1990s and 2000s, the positive and increasing migration balance helped to offset the negative natural balance, and thus contributed to a slowdown in the decline of growth rates, especially in areas in the North and the Centre. By contrast, in certain areas in the South, and particularly in the so-called inner areas, continuous outflows, low inflows from abroad and continuous declines in fertility have led to intense processes of population decline. During this period, the signing of the Schengen agreement and the substantial enlargement of the European Union that followed have profoundly changed, and are continuing to change, the system of international migration (Golini, 2005). Italy's entry into the Schengen area in 1997 may have facilitated the emigration of young people to more economically developed countries that were already destinations for Italian emigration, such as France and Germany. On the other hand, immigration flows were certainly facilitated by the Schengen agreement, as non-European people who were already present in one of the countries of the area could freely migrate to other countries of the area (Nikolić and Pevcin, 2022). Similarly, the entry of other European countries into the Schengen area, including Eastern European countries, has led to an increase in the number of European foreigners moving to Italy. However, migration flows to Italy have been decreasing for several years, and have not compensated for the imbalance between births and deaths, either nationally or in different local contexts. The economic differences between the various areas of the country – particularly between the North and the South, but also between cities and the countryside and between central and peripheral areas – are continuing to produce significant internal movements, albeit to a decreasing extent over time. These outflows from certain contexts have led to the abandonment, especially by younger people, of certain territories (Lasanta et al., 2017). Particularly in smaller areas, some sub-populations have either disappeared or shrunk significantly. Therefore, in recent years, depopulation has again become an important phenomenon in the Italian context, and is becoming increasingly widespread, as it is further accelerated by low fertility (Reynaud and Miccoli, 2016; Rizzo, 2016). Unlike the depopulation processes of the early 1900s, those that have taken place since the 1970s have occurred in a context characterised first by the slow growth of the resident population in Italy, then by a certain level of stability, and, finally, by a decrease in the population. In addition, current depopulation phenomena are combined with high levels of population ageing. In the 1970s and 1980s, emigration and the consequent depopulation process contributed to the intensification of the ageing process. However, in more recent decades, the high levels of ageing in some areas are contributing to further depopulation, which illustrates the vicious circle in which the two phenomena reinforce each other (Reynaud and Miccoli, 2018). The effects of the economic instability due to the economic crisis in 2008 are observable in the demographic dynamics, as they accelerated the process of population ageing in many areas of the country (De Rose and Strozza, 2015). While foreign immigration to European countries presents significant social challenges,

it appears to be necessary to ensure the demographic sustainability and economic development of these countries. Increasing depopulation and ageing levels therefore present not just demographic, but also social and economic challenges related to the demand for more immigration and the integration of foreign populations (Lutz, 2019).

Given the dynamics of the depopulation and ageing processes in Italy, this paper aims to demonstrate the theoretical existence of an association between depopulation and ageing by analysing the Italian context, in which the two phenomena are clearly present. Through a descriptive and a spatial analysis conducted at the municipal level for the 1971–2019 period, this study aims to contribute to a strand of research that remains underexplored, and to add empirical evidence to the theoretical background on this topic.

3 Research design, data and methods

With the general aim of studying and investigating the phenomena of depopulation and ageing in Italian territories, this work seeks to answer two research questions. The first question is whether there is a relationship between the variation in the population in a given period and the level of population ageing at the end of the same period, and how this relationship changed over time (RQ1). As was stated in the previous section, the emigration of young people leads not only to population decline, also to population ageing. Younger people may decide to emigrate because they need to find work, or, more generally, because they want to pursue life projects elsewhere. As the younger population tend to move to cities for work, emigration often takes the form of rural–urban migration (Lasanta et al., 2017). Furthermore, the emigration of young people also means that there will be fewer births or babies in the areas they left behind in subsequent years, as young people usually raise their families where they are working, or their babies emigrate with them. A decrease in births and a decline in the number of young people in an area can contribute to a decline in population, and to a change in the age structure of the population. We hypothesise that negative growth rates are related to subsequent population ageing, and that this association has been especially pronounced in recent years (H1). The second research question is whether there is a relationship between the level of population ageing at the beginning of a given period and the variation in population in the subsequent period, and how this relationship changed over time (RQ2). A high proportion of older people in a population contributes to a natural decrease in the population, because the higher the number of older people there are, the higher the number of deaths there are. Furthermore, young people tend to emigrate from areas characterised by population ageing, because these areas are often less dynamic from an economic and a social point of view. Therefore, we hypothesise that a high level of population ageing at a certain date corresponds to a subsequent population decline, and that this trend has been particularly strong in recent years (H2).

The data used for the analysis come from population censuses, and refer to Italian municipalities. Because there have been several changes in the boundaries and in the number of municipalities over the years, we have decided to consider the situations of the municipalities as of the 2011 census, when there were 8092 municipalities. We have harmonised the data accordingly. Data from seven censuses conducted between 1971 and 2019 are used. The latest census, for 2019, is not a traditional decennial census, but is a permanent census that was conducted with a new methodology (Istat, 2014). Although the methodology used in the latest census is different from that employed in previous censuses, the population census data for all the census years in Italy have legal value, and are comparable.

We calculate the intercensal population growth for all the municipalities for five periods (1971–1981, 1981–1991, 1991–2001, 2001–2011, 2011–2019) using the following equation:

$$r_{i(t,t+n)} = \frac{\ln(P_{i(t+n)}/P_{i(t)})}{n} \qquad i = 1, \ldots, 8092;\ t = 1971, 1981, 1991, 2001, 2011 \tag{1}$$

where P is the total population, i is the ith municipality, t represents the census data, n represents the number of years between two censuses, and $t + n$ represents the next census data.

We consider a negative growth rate in the intercensal period to be a measure of the depopulation process. In municipal territories, some of which are very small in terms of both square kilometres and population, a negative growth rate over a period of 8–10 years can be denoted as depopulation, and as a sign of significant demographic distress. We then calculate the proportion of people aged 65+ years in the census years in order to have a measure of population ageing at the beginning and at the end of the five intercensal periods.

First, we exploit a descriptive analysis of the depopulation process in the Italian municipalities for the intercensal periods from 1971 to 2019 and a descriptive analysis of population ageing in the census years in order to detect trends along the territories and to highlight changes over time. We then calculate Pearson's correlation coefficients for evaluating the association between depopulation and population ageing. In particular, we calculate the coefficients between intercensal growth rates in every period and the level of population ageing at the end of that period, and between the level of ageing at the beginning of the period and the subsequent growth rates. This enables us to provide an initial answer to our research questions, and to check whether our hypotheses are correct.

We then calculate Moran's index to verify the spatial autocorrelation of growth rates and the proportion of people aged 65+ years in the municipalities. To calculate this measure, a neighbouring structure defining the contiguity between locations is assigned to our data. In our case, two municipalities are considered as neighbouring if they share one boundary point (queen contiguity). After detecting the presence of spatial autocorrelation – meaning that space has had an influence on population growth – we apply a model that is able to take into account the spatial autocorrelation

(Ma and Hofmann, 2019) in order to investigate whether depopulation over a certain period is associated with population ageing at the beginning of that period. Then, considering that space has had an influence on the level of population ageing as well, we investigate whether population ageing at the end of a certain period is associated with depopulation in that period. This effect can be induced by several factors, and violates the assumption of independence common to many regression models (Chi and Zhu, 2008). To consider this autocorrelation, we apply a spatial panel data model with fixed effects, where the spatial autocorrelation is induced through the adjacency structure of the areal units (Lee, 2013; Millo and Piras, 2012)[2]. This model is implemented in R programming language through the "splm" package (Millo and Piras, 2012). This approach makes it possible to consider the influence that space has on unobserved variables by controlling for the influence of neighbouring spatial units.

Let y_{it} be the observations of dependent variables in every ith municipality in every time $t = 1, \ldots, T$, while X is the design matrix including the explanatory variables with parameter coefficients β, and ε is the independent error component. Following Millo and Piras (2012), a fixed effect spatial lag model can be written in stacked form as:

$$y = \rho(I_T \otimes W_N)y + X\beta + \varepsilon \tag{2}$$

where ρ is the spatial autoregressive coefficient and W is a non-stochastic spatial weight matrix. We explore two different models. In the first model, the dependent variable is the proportion of people aged 65+ years relative to the 8092 municipalities at the end of every intercensal period $[P_{65+}(t+n)]$, and the explanatory variable is the rate of population growth during that period $[r(t, t+n)]$. This allows us to examine how the population change over a certain period, expressed by the intercensal population growth rate $[r(t, t+n)]$, is related to the level of ageing at the end of the same period, expressed by the proportion of the proportion of people aged 65+ years at time $t+n$ $[P_{65+}(t+n)]$, in order to answer the first research question: namely, whether the decline in population is associated with an acceleration of the ageing process. In the second model, the dependent variable is the intercensal population growth rate in each of the 8092 municipalities during every considered period $[r(t, t+n)]$ and the explanatory variable is the population ageing at the beginning of the period $[P_{65+}(t)]$. This enables us to investigate the relationship between depopulation and ageing (i.e., the subject of the second research question) in greater depth. Specifically, we are examining whether population growth in a certain period $[r(t, t+n)]$ is dependent on the level of ageing at the beginning of the considered period, expressed by the proportion of people aged 65+ years at time t $[P_{65+}(t)]$.

[2] In the analysis phase, we tested the linear regression model and other spatial regression models (such as CAR) (Mingione et al., 2022). The outputs of these models allowed us to confirm the existence of a strong link between population ageing and depopulation. The results of the CAR model for each period confirmed the presence of spatial autocorrelation in each considered period.

4 Results

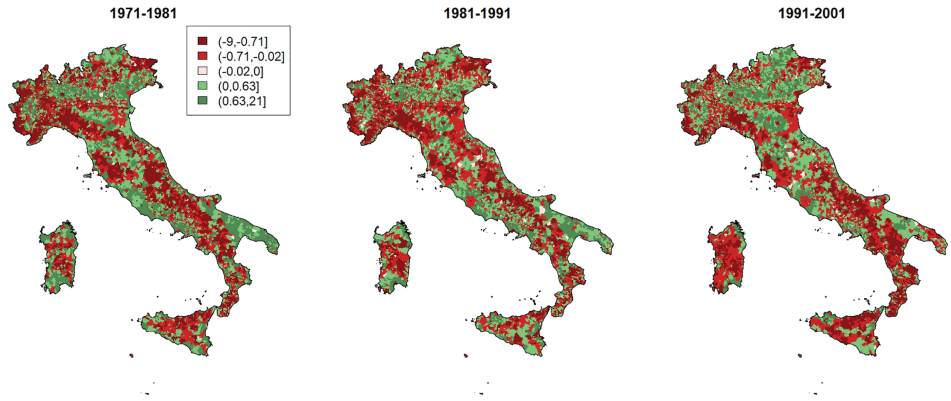
4.1 Descriptive results

The analysis of the growth rates in Italian municipalities for the first period (1971–1981) returned a pattern characterised by rather widespread depopulation processes throughout the country. Indeed, about 49% of Italian municipalities recorded a negative growth rate in this period, and thus experienced a process of depopulation. These municipalities were mostly located in rural and mountainous areas, and the decline was determined by significant emigration from these territories to large cities and, to some extent, abroad. Thus, it appears that even though the Italian population was growing at a rate of 0.6% in this period, depopulation was a rather widespread phenomenon at the municipal level (see Figure 1).

In the subsequent period from 1981 to 1991, the share of municipalities experiencing a decrease was very similar to that in the previous period, at about 48%. The situation was also rather similar to that in the previous decade (Figure 1). The decline at the municipal level can be linked to both the continuing emigration from rural areas (De Rubertis, 2019; Emanuel, 1997) and the movements that occurred from the major urban systems to the municipalities located around them (Dematteis, 1997).

In the 1991–2001 period, the proportion of municipalities with a negative growth rate dropped to 46%. This is the period in which internal migration flows were accompanied by immigrant flows from abroad, especially in the Centre–North. Thus, while some areas, particularly those in the North-East, experienced new

Figure 1:
Population growth rates (%) in the Italian municipalities for three periods: 1971–1981, 1981–1991 and 1991–2001



Source: Authors' calculation from ISTAT data.

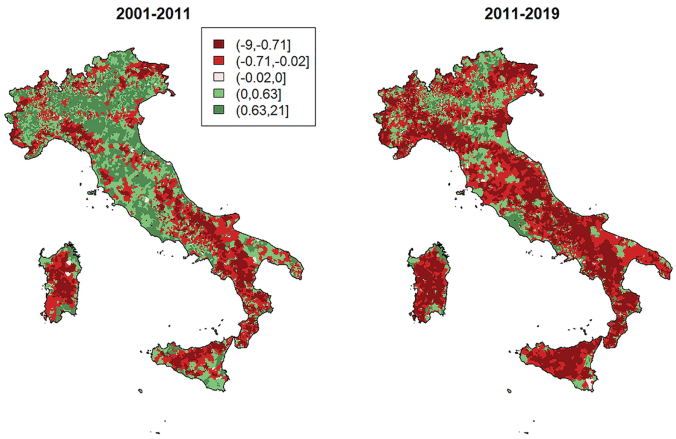
population growth, including in many previously shrinking municipalities, others continued to experience depopulation processes. For the first time, there was a barely noticeable dichotomy between the northern and the southern territories, with many municipalities experiencing negative rates (Figure 1). However, even in this decade, most of the municipalities with negative rates of increase were located in mountainous or inner areas.

In the following decade (2001–2011), the percentage of municipalities experiencing depopulation declined again to reach 40%. Immigration flows from abroad continued to be very strong until 2008, when, due to the economic crisis, the flows began to decrease. While foreigners were living all over Italy, most who were resident on a stable basis were living in the most productive areas of the country, and thus in the Centre–North. The effect of the depopulation phenomenon was strongest in the South of Italy, where the number of municipalities with a negative growth rate increased (Figure 2).

In the most recent period from 2011 to 2019, which was characterised by a decrease in migration dynamics, and in which, unlike in the past, there was no population growth, depopulation was once again a widespread phenomenon (see Figure 2). In this historical phase, the growth rate of the population resident in the country turned negative, and a new phase began in which depopulation at the municipal level occurred in a context characterised by population decline at the national level.

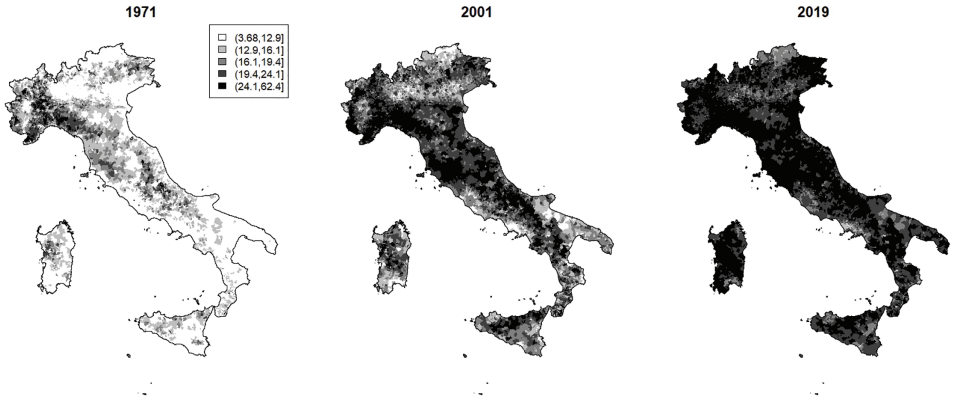
A descriptive analysis of the level of ageing in Italian municipalities in the census years returned a more linear profile (see Figure 3). The ageing process, which first

Figure 2:
Population growth rates (%) in the Italian municipalities for the last two periods: 2001–2011 and 2011–2019



Source: Authors' calculation from ISTAT data.

Figure 3:
Proportion (%) of people aged 65+ years in the Italian municipalities: Census data from 1971, 2001 and 2019



Source: Authors' calculation from ISTAT data.

began in the territories of northern Italy and then spread throughout the country, had become a phenomenon that was affecting the population as a whole as well as municipal sub-populations. In addition to being widespread throughout the country, this phenomenon was accelerating in areas where it started later, such as in areas of southern Italy (Figure 3).

The Pearson's correlation coefficient between population growth and subsequent population ageing was negative in every period considered, and was always statistically significant. The correlation was higher in the 2011–2019 period than in previous periods (Table 1). Higher levels of population growth were associated with lower levels of population ageing, as we hypothesised. Thus, population decrease in a certain period was strongly related to the level of ageing at the end of the same period. Moreover, our finding of a stronger correlation in the last period confirmed an important change in the relationship between these two phenomena, which were not only more intense than in the past, but were also more interconnected (H1).

The opposite correlation between the proportion of people aged 65+ years at the beginning of a given period and the intercensal population growth rate in the following intercensal period was also negative and was always statistically significant (Table 1). A higher level of population ageing in a certain year corresponded to a more negative growth rate, and thus often to depopulation in the subsequent period. This relationship was more intense in both the 2001–2011 and the 2011–2019 periods, when migration flows started to decrease and population ageing was more widespread among all municipalities, and was very intense compared to past periods. Thus, not only was depopulation always associated with the level of population ageing, but in the last period, this relationship became stronger, in line with our

Table 1:
Pearson's correlation coefficient between the intercensal population growth rate in the period $(t, t+n)$ $[r(t, t+n)]$ and the proportion of people aged 65+ years at the beginning of a given period (t) $[P_{65+}(t)]$ and between the intercensal population growth rate in the period $(t, t+n)$ and the proportion of people aged 65+ years at the end of a given period $(t+n)$ $[P_{65+}(t+n)]$

$r(t, t+n)$	$\%P_{65+}(t)$	Signif.	$\%P_{65+}(t+n)$	Signif.
1971–1981	−0.50	***	−0.64	***
1981–1991	−0.52	***	−0.63	***
1991–2001	−0.46	***	−0.62	***
2001–2011	−0.54	***	−0.61	***
2011–2019	−0.54	***	−0.67	***

Notes: *** $p < 0.001$.

Observations: 8092 municipalities.

Source: Authors' calculation from ISTAT data.

hypothesis (H2). These findings indicate that recent depopulation processes have different characteristics and drivers than those in the past, which merits further explorative analysis.

These correlations show the existence of a link between the values of the growth rate and the ageing index in Italian municipalities.[3] While this relationship may be determined by other potentially common factors, it is important to emphasise that it appears to be statistically significant.

4.2 Model results

From the descriptive analysis of the depopulation process it emerged that this phenomenon had become more widespread among the municipalities in recent periods. By applying Moran's index to the growth rates in the five considered periods, we verified whether there was a spatial autocorrelation of the phenomenon in space. Moran's index for the intercensal population growth rates was always positive and statistically significant, showing a moderate spatial autocorrelation. The index was 0.10 for the first period (1971–1981) and 0.15 for the last period (2011–2019). This means that municipalities with high growth rates were close to other municipalities with high growth rates, while municipalities with low growth rates were close to municipalities with low growth rates. The same pattern applied to the proportion of people aged 65+ years: Moran's index was always positive and

[3] There can be many potential explanatory factors of depopulation and population ageing related to economic, social and demographic conditions. It is not possible to observe all of these factors together over such a long period of time, or at such a detailed territorial level.

statistically significant, and was increasing over time. The value of the index for the two measures indicates the importance of the space effect, and the need to take into account spatial autocorrelation in the model when analysing depopulation and population ageing at a detailed territorial level.

To investigate the relationship between depopulation and ageing more deeply, we decided to account for spatial autocorrelation by applying the spatial panel data model. As was previously mentioned, in the first step we used the proportion of people aged 65+ years at the end of the period $[P_{65+}(t + 10)]$ as the dependent variable and the intercensal population growth rate in the period $(t, t + 10)$ as the explanatory variable. In the second step, we used the variation in population in the intercensal period as the dependent variable and the proportion of people aged 65+ years at the beginning of the period as the explanatory variable. Although the models were very simple, they were essential for investigating the relationship between depopulation and the level of population ageing, while also taking into account non-visible spatial effects. We were aware that other factors could be associated with the evolution of the two phenomena, and might have an influence on the demographic determinants of the two phenomena. We wanted to observe to what extent, net of the spatial latent variable, a high level of ageing was associated with a lower subsequent level of growth, and to what extent the rate of population growth was associated with the subsequent level of ageing.

The model results (Table 2) demonstrated than an increase in growth rates in a certain period corresponded to a low level of population ageing at the end of the period. The coefficients were always negative and had a high level of significance. The proportion of people aged 65+ years in the considered periods always increased, on average, as the estimated coefficients were increasingly higher compared to the baseline period: from 1.750 in the 1981–1991 period up to 8.245 in the last considered period. The relationship between the rate of population growth and the percentage of older people was as expected: for the baseline period of 1971–1981, an increase of one in the rate of population growth corresponded, on average, to a 63% decrease in the old age index at the end of the period. This relationship was even stronger in the 1991–2001 period, as the differential coefficient for this period was −88.747. This means that depopulation in a period (i.e., a negative growth rate) was linked to a high level of population ageing at the end of the period. The association between the growth rate and the proportion of people aged 65+ years at the end of the period was lower, especially in the period between 2001 and 2011, when, as was already mentioned, migration flows from abroad were larger, and the foreign population had a strong impact on the change in the population size, although not as strong as on the age structure.

The results for the second model (in which the dependent variable was the population growth rate and the explanatory variable was population ageing at the beginning of the period) showed that the rate of population growth was, on average, increasingly negative. Specifically, the results demonstrated that a higher proportion of people aged 65+ years at the beginning of the period corresponded to a lower growth rate during the period: a one per cent increase in the proportion of people

Table 2:
Parameter estimates of the spatial panel data model wherein the proportion of people aged 65+ years at the end of the period is the dependent variable [$\%P_{65+}(t+n)$]

Name of variable	Variable	Estimate	Std. error	Signif.
The intercensal population growth rate	$r(t,t+n)$	−63.280	1.942	***
The intercensal periods	1981–1991	1.750	0.034	***
	1991–2001	4.776	0.034	***
	2001–2011	6.444	0.034	***
	2011–2019	8.245	0.037	***
The interaction between the intercensal population growth rate and the intercensal period	$r(t,t+n) \times$ (1981–1991)	−36.645	2.707	***
	$r(t,t+n) \times$ (1991–2001)	−88.747	2.912	***
	$r(t,t+n) \times$ (2001–2011)	−74.128	2.775	***
	$r(t,t+n) \times$ (2011–2019)	−57.303	3.193	***

Notes: '***' denotes statistical significance at <0.001.

Observations: 8092 municipalities.

Source: Authors' calculation from ISTAT data.

aged 65+ years in the population corresponded, on average, to a six per thousand decrease in the rate of population growth in the subsequent period. The coefficient of the proportion of people aged 65+ years in the population increased for the second period and the third period. Furthermore, the coefficient of the period between 2001 and 2011 was smaller than the previous one (between 2001 and 2011, migratory flows from abroad slowed down the ageing and depopulation processes), but the coefficient increased again in the last period (Table 3). This coefficient was highest in the last period, which shows that a high level of ageing influenced negative growth rates even more in this period than it did in past periods.

The spatial autoregressive coefficient ρ was significant in both models. This means that the demographic changes that occurred in the various periods were also affected by the spatial autocorrelation effect.

5 Discussion and conclusions

The end of the demographic transition has led to significant demographic changes in most European countries. In the second half of the 20th century, the natural balance, which had previously been the main driver of population trends, became negative for the first time in history not because of diseases, wars or other catastrophic events, but mainly as a result of individual fertility choices. Migration has therefore become the main driver of population growth in many European populations (van Nimwegen and Van der Erf, 2010). Moreover, when we look at sub-national areas, we can see that population growth did not occur everywhere, and that many areas of the continent

Table 3:
Parameter estimates of the spatial panel data model, wherein the population growth in period t, $t + n$ is the dependent variable [$r(t, t + n)$]

Name of variable	Variable	Estimate	Std. error	Signif.
The proportion of people aged 65+ years at time t	$\%P_{65+}(t)$	−0.00065	0.222	***
The intercensal periods	1981–1991	−0.00771	3.145	***
	1991–2001	−0.01333	3.253	***
	2001–2011	−0.01111	3.566	***
	2011–2019	−0.02268	4.036	***
The interaction between the proportion of people aged 65+ years at time t and the intercensal period	$\%P_{65+}(t) \times$ (1981–1991)	−0.00056	0.198	***
	$\%P_{65+}(t) \times$ (1991–2001)	−0.00090	0.197	***
	$\%P_{65+}(t) \times$ (2001–2011)	−0.00086	0.199	***
	$\%P_{65+}(t) \times$ (2011–2019)	−0.00101	0.210	***

Notes: '***' denotes statistical significance at <0.001.

Observations: 8092 municipalities.
Source: Authors' calculation from ISTAT data.

have been experiencing depopulation processes (Newsham and Rowe, 2022). At the same time, declining fertility and progressively increasing survival have led to high levels of ageing in these populations (Christensen et al., 2009). At the theoretical level, the relationship between depopulation and population ageing seems clear, as the two processes have very similar determinants: falling birth rates and directly or indirectly increasing life expectancy and the emigration of young people. As we observed in the introduction, a decline in births leads to a decrease in the population size and an acceleration of the ageing process; an increase in life expectancy implies an increase in the number of older people in the population, which means that the level of population ageing is higher but the chances of population growth are lower; and emigration by young people is one of main determinants of depopulation in many historical periods, but it can also intensify population ageing. Our aim was to verify the theoretical relationship between depopulation and population ageing by looking at a long period that also includes the most recent years.

The Italian population has been undergoing the most pronounced ageing process in Europe for decades. For the first time, Italy has seen the size of its population decline in the last 10 years, including at the national level. Furthermore, many areas of Italy have experienced depopulation in the past, including at the beginning of the 20th century, and have recently experienced it again. In the last decade (which we did not consider in the previous paper on depopulation and ageing), the depopulation process became more intense and widespread in many areas of the country. Therefore, Italy can be considered a relevant case for analysing the theoretical interplay between depopulation and ageing. There is also political interest in depopulated areas, which are often located in the inner regions of the country (Barca et al., 2014; Espon,

2017). In these areas, public services are provided to a small number of people, and therefore represent a significant cost for political actors (Pinilla and Sáez, 2021; Syssner, 2020). The lack of political interest in these areas can lead to problems, such as underserved populations and abandoned land (Syssner, 2020). Furthermore, in Italy, the abandonment of territories can mean the loss of important forms of cultural heritage, which are often associated with a strong sense of territorial identity (Dell'Ovo et al., 2022).

By using data on municipalities (the lowest administrative territorial level) and considering the importance of spatial autocorrelation in our models, it was possible to support such observations with results that were not biased by spatial autocorrelation. Indeed, taking spatial autocorrelation into account is crucial in analyses conducted at a detailed territorial level, and particularly when investigating depopulation, due to the political as well as the demographic implications of this process. When considering depopulated areas, analyses conducted at a more aggregated territorial level, such as at the level of provinces (NUTS 3) or regions (NUTS 2), are not effective because population trends can be determined by the larger population size. For example, it is likely that more people are living in the larger cities than in the other administrative units of the territory. On the other hand, Italian municipalities should be able to provide their citizens with basic services that reinforce the demographic dynamics, beyond the economic and social environment. Therefore, providing a picture at the municipal territorial level also means supporting a political response.

We showed that the depopulation processes that occurred in Italy during the 1971–2019 period decreased slightly at first and then increased consistently in terms of both the intensity of the growth rates and the number of municipalities involved. Thus, population ageing in municipalities went from being a phenomenon concentrated in some areas in the North to being a generalised phenomenon throughout Italy.

From the analyses we carried out, it appeared that the relationship between these two phenomena was statistically validated: i.e., the correlation coefficients between the population growth rate and the proportion of people aged 65+ years showed a significant and negative relationship. Thus, in the areas where the population increased, ageing decreased. This relationship could also be interpreted negatively: i.e., in the areas where depopulation took place, ageing increased. These findings confirmed our hypothesis that a decrease in the size of the population would be accompanied by an increase in the level of population ageing (H1). Population decline can be due to a negative natural balance (i.e., fewer births than deaths), a negative net migration balance (i.e., more out-migrations than in-migrations) or a combination of the two. When the natural balance has been negative over time, the age structure changes, with more people remaining in the population and the number of new-borns decreasing. When net migration is negative, the emigrants are predominantly young people who, by leaving, reinforce the ageing of the population in their place of origin, especially if the area already has an older population, as is the case for most Italian municipalities.

On the other hand, we found that in areas where the level of population ageing was higher, the level of depopulation was also higher, which confirmed our second hypothesis (H2). Areas where the proportion of older people in the population was high often had a higher number of deaths, as in a country like Italy, most deaths occur at older ages. In addition, in areas with a high proportion of elderly people in the population, proportionally fewer young people were having children. Furthermore, in areas with high levels of ageing that were also economically less competitive, young people tended to out-migrate to look for employment and for an environment that was more dynamic not just economically, but also culturally and socially. Our results confirmed the existence of an important connection in Italy between ageing and depopulation, which could, in certain areas, feed off each other. Our finding that this relationship existed did not take causality into account, but simply showed that the two phenomena were linked. Our work could be further developed by applying a spatial autoregressive model to attempt to prove that the influence of ageing on depopulation and the influence of depopulation on ageing were not independent of each other. While the determinants of the two phenomena were similar from a demographic point of view, many other economic and social aspects may have influenced the demographic determinants over time. Another potential development of our findings would be to consider the determinants of these processes.

Although the effects of demographic factors were taken into account in the theoretical background, they were not formally included in the model in this study. These effects can, of course, be investigated in future works that are more focused on understanding the various determinants of these processes. Despite these limitations, this paper provides a useful background for further in-depth analyses of the relationship between depopulation and ageing.

This paper has highlighted aspects that are useful to consider when investigating why demographic changes seem to lead to a vicious circle in which depopulation leads to accelerated ageing, and the ageing process, in turn, leads to further depopulation. These processes typically originate in areas that are in a demographically unsustainable condition, which can, in turn, lead to economic decline and environmental fragility (Collantes and Pinilla, 2004). As the populations living in these areas lose access to public and private services, the economic and social conditions in these places become less sustainable over time (Fernandes, 2019; Syssner, 2020).

Thus, the results of our study, which was conducted at a very detailed territorial level for the whole of Italy, can be useful to national and local policymakers who are seeking to implement policies aimed at counteracting the effects of depopulation and ageing, and at addressing the factors that cause the vicious circle triggered by these effects. Without political intervention, the current demographic dynamics in Italy will lead to economic and social sustainability problems across the country, with the number of abandoned areas increasing and population ageing occurring at a rapid rate in many territories.

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