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RESEARCH PAPER

Depopulation in the Central Apennines in the Twentieth Century: An Empirical Investigation

Riccardo Lucchetti[1] · Gabriele Morettini[1]

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Abstract
We propose an empirical investigation of the population dynamics between 1931 and 2011 in a mountain area in Italy. The main novelty of our work is the usage of sub-municipal data, which makes it possible to disentangle several drivers of the overall depopulation trend. All these factors had been considered previously by separate strands of literature, but never jointly, as we do. One of our most interesting results is that different factors operate in different historical periods. Therefore, we use a flexible strategy by which we divide the sample in four different 20-year spans and adopt a different statistical model for each. Another notable result is that an appropriate quantitative description of the phenomenon must take into account the disappearance of inhabited centres separately from their size in terms on inhabitants. Consequently, the concept of local community is crucial for a systematic understanding of population change and "place-sensitive" policies in remote mountain areas.

Keywords Rural settlements · Depopulation · Local community

JEL Classification J11 · N94 · R23

1 Introduction

Natural disasters are recently increasing in frequency and intensity (Zobel and Baghersad 2020; Lima and Barbosa 2019) all over the world. Such catastrophic events result in huge human and financial losses and raise the issue of reconstruction (Marin et al. 2021; Modica et al. 2021). An efficient recovery policy must take into account current socio-economic backgrounds and trends. In spite of the conventional wisdom, natural disasters are almost never "cathartic" (see Placanica 1985), but they consolidate and accelerate ongoing structural processes. They thus penalise mountainous rural areas, more exposed to geological disasters (Jiang et al. 2016) and particularly vulnerable to exogenous shocks (Whittaker et al. 2012) because of resource shortages (Irvine and

✉ Gabriele Morettini
g.morettini@univpm.it

1 DISES, Università Politecnica delle Marche, Ancona, Italy

Anderson 2004), infrastructural deficiency and social and economic fragility (Bonfiglio et al. 2021).

In these contexts, natural hazards exacerbate cultural discomfort (Bryant et al. 2011), socio-economic divides (Barone and Mocetti 2014; Geipel 2012) and long-term shrinkage (Collantes 2009). Catastrophic events can even trigger a downward spiral characterised by population decrease, loss of economic functions (Leetmaa et al. 2015), withdrawal of public and commercial services (Rizzo 2016), and more housing vacancies (Franklin and van Leeuwen 2018). These intertwined processes can become irreversible beyond a critical threshold and may lead to territorial abandonment (McLeman 2011), fraught with dramatic social and environmental implications, as already occurred in the US Great Plains, where "many small towns are emptying and ageing at an all-time high rate, and some are dying" (Popper and Popper 1987, p. 14).

This unprecedented large-scale desertion is a key social issue for the twenty-first century (Reher 2007), when demographic projections boost concerns about an increasingly territorial polarisation, between crowded cities and wide inhabited lands. Rising regional inequalities represent a major challenge for many developed countries, whose democratic institutions are frequently threatened by the discontent of "left-behind places", expressed by voting populist or anti-system parties (McCann 2020; Rodríguez-Pose 2018). Insecurity, resentment and anxiety for the future of places suffering a prolonged and intense shrinkage (Dijkstra et al. 2020; Ford and Goodwin 2014); could be mitigated through the design of effective policies addressing depopulation. In this regard, a proper management of disaster recovery plays a key role.

Scholars and policymakers debate on whether, how and where to rebuild settlements, and several strategies have been discussed (see Clemente and Salvati 2017; Pereira and Navarro 2015; Orcao and Cornago 2007; García-Ruiz et al. 2020; Peters et al. 2018). However, effective policies for tackling rural abandonment are context-dependent (van der Zanden et al. 2017) and require an understanding of the current scenario and of the forces shaping it. This is a very complex issue, because massive depopulation arises from a long-term, multistage process (Beresford and St Joseph 1979; Chi and Ventura 2011) driven by heterogeneous factors, often operating at local level in polycentric settlements (Di Méo 1991; Ciuffetti 2019).

Therefore, it is indispensable to clarify the nature and the drivers of the population reduction (Bucher and Mai 2005; Johnson and Lichter 2019). Depopulation also calls for place- and time-specific research (Sánchez-Zamora et al. 2014). Greater attention must be placed on the selection of an appropriate spatial unit able to measure the size, dynamics and the pace of the shrinkage (Franklin and van Leeuwen 2018). The village is the basis of the upland settlement (Di Méo 1991); it is the framework within which policies are effectively implemented and where people forge shared memories and a collective identity (Banini 2017), and therefore provides a valid viewpoint to observe a prolonged demographic decline still rarely explored at detailed scale for large regions (Reynaud and Miccoli 2019). A further shortcoming in previous studies is the scant attention given to the temporal profile of depopulation. The scarcity of longitudinal data and the change in the local boundaries over time have steered the research towards short-term analysis which, however, cannot comprehensively reconstruct the dynamics underlying the shrinking and peripheralisation processes (Kühn 2015).

Under these premises, this article provides a theoretical framework for tackling the complexity of population trends from an empirical point of view. We systematically examine a large sub-municipal dataset in order to analyse long-period population shrinkage in a remote mountain context. The adoption of different metrics allows for a comprehensive quantification of depopulation patterns, both at municipal and sub-municipal levels. This descriptive part is complemented by an empirical inquiry aimed at exploring the diverse drivers of population changes between 1931 and 2011. The main purpose of this paper is to establish an empirical strategy to identify determinants of population change. However, our results also have strong policy implications, since they provide a foundation for designing proper place-sensitive policies to curb abandonment (Iammarino et al. 2019; Modica et al. 2021).

Our study area is the portion of Italian Apennines hit by the 2016–2017 earthquakes, that we consider a paradigmatic case of slow-burn changes (Pike et al. 2010) in mountain contexts, especially across the Mediterranean countries (Collantes 2009; Pinilla et al. 2008). We remind the reader that the Apennines, due to their considerable latitude extension, include very different territories in terms of bioclimatic aspects and must be divided into at least three macro-areas, characterised by marked heterogeneity of settlement, agricultural, and social systems. As a confirmation, the depopulation process occurred at different times and intensities in the various parts of this mountain range: it emerged in the early 1900s in the Northern Apennines, extended to the Central Apennines after the Second World War, and only later affected the southern slope (Golini et al. 1976).

Our paper focuses on the Central Apennines, where a unique civilisation emerged, characterised by cultural, historical, geographical, and settlement homogeneity (Ciuffetti 2019). The area indeed exhibits remoteness and high ruggedness, polycentric settlement on small villages, prevalence of agricultural activities, and limited provision of services. These specific orographic, economic, and social characteristics represent structural delays in the process of industrialisation, compounded by episodic shocks, such as the repeated earthquakes that have plagued one of the most seismic areas in Europe (Zullo et al. 2020). Moreover, the earthquakes in 2016–2017 have put many centres at risk of permanent abandonment (Dottori 2024).

We focus on the mountain municipalities included in the so-called "seismic crater", which encompasses the most severely damaged settlements. This area has reserved funds, peculiar needs, opportunities and risks related to the unclear, lengthy and expensive reconstruction process. In this context, demographic trends are a key, but yet underappreciated issue that should be examined through suitable methods so as to uncover the long run patterns (Kilkenny 2010).

We provide several original results. First, we empirically assess the diverse characters of the depopulation process, which involves settlement hollowing as well as population loss. At close scrutiny, the Central Apennines display diverse population trends, with substantial differences even within municipal borders. Thus, sub-municipal settlements, identified by local communities, constitute a suitable spatial scale for tackling population change in mountain regions, characterised by polycentrism in small villages. We also find striking evidence that depopulation stems from a broad set of socioeconomic, demographic and institutional drivers, rather than from sudden natural disasters. These structural factors operate at multiple scales, engaged according to the place and the period under consideration. At a theoretical level, our paper shows the effectiveness of a comprehensive approach to complex processes of population change. Our multidisciplinary, quantitative investigation at sub-municipal scale allows to disentangle the multiple trends and drivers of long-term depopulation in the Central Apennines.

The paper contains six sections. The next one explores the main issues debated in the related literature. The empirical analysis is organised into stages. First, we present the data and clarify the two different metrics (Sect. 3) we use to assess depopulation; Sect. 4 describes the methods we use, while Sect. 5 discusses the main empirical results and the last one (Sect. 6) provides a conclusion.

2 Literature Review

Permanent depopulation of large areas is usually considered the unavoidable and often neglected consequence of a global scenario marked by rushing agglomeration economies, massive migratory flows, sectoral economic shifts and sudden crises, which exacerbate the vulnerabilities of marginal contexts (Elshof et al. 2014). The structural decay of peripheral settings has been amplified by major shocks such as the Great Recession, natural disasters and the recent COVID-19 pandemic. Adverse events mark significant turning points in development trajectories since they broaden territorial gaps (Fratesi and Perucca 2018) and accelerate ageing (Reynaud and Miccoli 2019).

However, settlement abandonment hardly ever stems from a sudden natural shock, but it rather arises as the terminal stage of a prolonged population decline (Di Figlia 2016; McLeman 2011), often triggered by disruptive technological innovations (Kemeny et al. 2022). Industrialisation and urbanisation processes have brought about population shrinkage in peripheral spaces in the US, Eastern Asia and Europe (Johnson and Lichter 2019). In France (Mathieu 2000) and the United Kingdom (Saville 1957) depopulation began at the end of the 19th century whereas in Southern Europe (Collantes 2009) massive emigration from rural areas has risen since the second half of the 20th century.

Such concerns are particularly relevant in Italy, which is characterised by both scattered settlements and large, deep-rooted regional disparities. The issue of territorial imbalances was stifled for a long time by the “southern question” (Felice 2015), although some have made important distinctions; for example, the INEA report of 1938, describing the harsh living standard in the mountains, or Rossi Doria (1958), who focused on the differences between “pulp and bone”. The demographic decline was a matter of “the mountain and the plain” rather than of the North–South divide, claimed as early as 1902 by Luchino Dal Verme, a member of the Italian Parliament. The shrinkage of the uplands goes back to the end of nineteenth century (Bonelli 1967) but it increased its pace and magnitude with the industrialisation occurred during the so-called Italy’s “economic miracle”. Since the 1950s the Apennines were particularly exposed to a demographic decrease that was fast, virulent and widespread (Tino 2002). In the early 21th century, Italy became a laboratory to design original policies, such as the “National Strategy for Inner Areas” (NSIA) (Barca et al. 2014), aimed at tackling the apparently unavoidable depopulation of peripheral settings.

Despite their importance (Modica et al. 2021), inner areas have often been downplayed because of misleading statistics, that underestimate or trivialise their potential (Sisson 2021). Several scholars call for innovative theoretical and methodological approaches to unravel the complexity of population change (Milbourne 2007). The first misunderstanding arises from the use of the number of inhabitants as the main (often the only) indicator of shrinkage that, instead, also entails a structural crisis of settlement patterns (Sousa and Pinho 2015). INEA already observed in the 1930s that population reduction deserves "the more comprehensive and appropriate name of demographic crisis" (INEA 1938, p. 4) whereas the term "depopulation" refers to the spatial events, such as land or hamlet abandonment, thus revealing the pathological characters of the exodus from the uplands (INEA 1938, p. 4). Those issues are not always correlated, so there might be demographic reduction without depopulation or vice versa (INEA 1938, p. 144). However, few studies jointly consider the twofold nature of shrinkage.

Previous literature also failed to grasp the interplay of various drivers of shrinkage (Wang et al. 2020). The adoption of a specific disciplinary perspective may steer the analysis of rural settlements into a specific direction, while in fact they evolve under the influence of formal and informal institutions (De Blasio and Nuzzo 2010), historical legacies (D'Adda and De Blasio 2017), relations with nearby urban centres (Veneri and Ruiz 2016), geographical endowment (Albalate et al. 2022). A holistic view of population change thus requires a multidimensional approach (Chi and Ventura 2011).

Moreover, a diachronic overview is necessary to describe different population dynamics and the underlying drivers, that may be changing over time (McManus et al. 2012). The longitudinal perspective blends the local level with broader socio-economic changes: except for sudden and catastrophic events, village abandonment has been a gradual process, either in ancient times (Beresford and St Joseph 1979) and in the present age (Di Figlia 2016). In spite of this, most of the research has not adopted a long-term view, mainly because of data scarcity (Milbourne 2007) and the ingrained (as much as unwarranted) Braudel's assertion that uplands "have no history".

3 Case Study

The study area is located in central Italy (Fig. 1), in the mountain municipalities[1] included in the so-called "seismic crater" of the 2016–2017 earthquakes (the portion most affected by seismic events). The sample appears to be the quintessence of Italian rural inner areas, which are distant from urban centres and geographically dominated by sparsely populated uplands, with just over 27 inhabitants per square kilometre (in 2011). Morphological constraints, harsh climate, scarcity of fertile soil and poor communication infrastructure are among the ingredients that have generated structural decay, chronic shrinkage and ageing in these territories. The continual exposure to seismic hazard has exacerbated the vulnerability of this "slow burn" setting (Pike et al. 2010), where no less than four ruinous earthquakes occurred in the 1997–2016

[1] According to article 1 of the Italian law 991/1952, the identification of mountain municipality is based on both geo-morphological (at least 80% of the areas higher than 600 ms or a vertical drop more than 600 ms) and economic (average taxable income for hectare lower than 2.400 lyres) criteria.

Fig. 1 The study area

Table 1 Municipalities by number of centres, 1931–2011

	Municipalities	% on total
1	22	16.058
2–4	39	28.467
5–9	35	25.547
10–19	22	16.058
20 or more	19	13.869

period only (Zullo et al. 2020). The seismic crater is the core of the reconstruction: the substantial availability of public funds granted here calls for a specific analysis in order to plan effective recovery strategies from a disastrous earthquake that has threatened the very survival of several settlements.

Local society transcends administrative borders and is characterised by geographical consistency, settlement model and cultural homogeneity (Phythian-Adams 1993). Space is organised around a network of small and scattered villages, where local resources are carefully managed so as to preserve a fragile environment. Upland villages have a long tradition of self-government, dating back to the XII-XIII centuries (Di Méo 1991), when a dense set of localities (towns, castles, villages, hamlets, abbeys) was created in the Central Apennines. In this settlement pattern, boundary changes are much rarer than in hills and plain systems.

With regard to the territorial unit, we operate on 1016 "inhabited centres", which belong to 105 municipalities (see Fig. 1), with an average of 9.68 centres per municipality. The precise definition of an "inhabited centre", as well as the rationale why we chose this as the basic spatial unit for our empirical analysis, is given below in Sect. 3.1. The majority of municipalities contain a small number of centres, while 16.1% of municipalities include one centre only. On the other hand, 19 municipalities contain 20 or more centres.

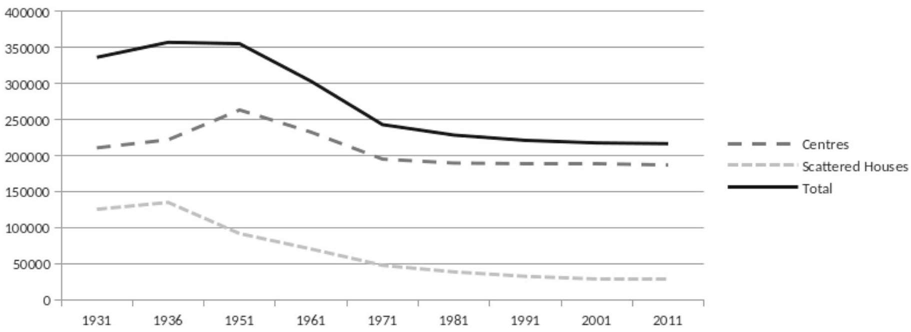

Fig. 2 Population between 1931 and 2011

Since these units have remained stably defined over time, we were able to put together a consistent longitudinal dataset of demographic data between 1931 and 2011 (the last census year). 1931 is the first year in which Italian National Institute of Statistics (ISTAT), alongside with the best Italian geographers of the time, provided an official, reliable and comprehensive list of inhabited centres in conformity with uniform standards (ISTAT 1935). The year also marks the peak of centuries-old population in the Central Apennines. Earlier historical chronicles report several settlement crises due to earthquakes, starvation, epidemics or wars but strong depopulation was confined to few remote, rugged territories, affected by natural catastrophes (Bonelli 1967). The 1930s were a turning point in the direction, purpose and cadence of mobility, which became more domestic, permanent and selective (Gallo 2012). The interwar period was marked by both the Fascist regime and the Great Depression, which prompted underemployment and rising gaps among the Italian farming systems (Chiapparino and Morettini 2018). Out-migration from the uplands, despite the mobility constraints imposed by the regime (Treves 1976) could thus be considered the outcome of the crisis of subsistence mountain economies (Federico 2005), settled in sparse and self-sufficient communities (Collantes 2009). Large scale settlement decline occurred in the second half of the 20th century; the 1931–2011 bout therefore embeds the whole period in which the shrinking process of the area starts, spreads and exacerbates.

From simple descriptive statistics, two main results emerge. The municipal time-series shows a significant population decrease, mostly in the 1951–1971 period (Fig. 2). Most of the shrinkage affected scattered houses whereas for the inhabited centres, in the long term, “we cannot strictly speak of depopulation, because mountain setting seems initially to have absorbed and then allocated the overpopulation left by demographic transition” (Sori 2004, p. 31).

The number of centres, conversely, dropped substantially—from 949 (1931) to 436 (2011), with a decrease of 513 units (54%), as can be seen in Fig. 3. In the period under review, 67 new centres were created but 580 ceased to exist. The disappearance of inhabited centres peaked between 1951 and 1981, with the negative trend continuing in the following decades, which we take as sign of a structural process. This aspect is of crucial importance and will be further discussed in the next subsection.

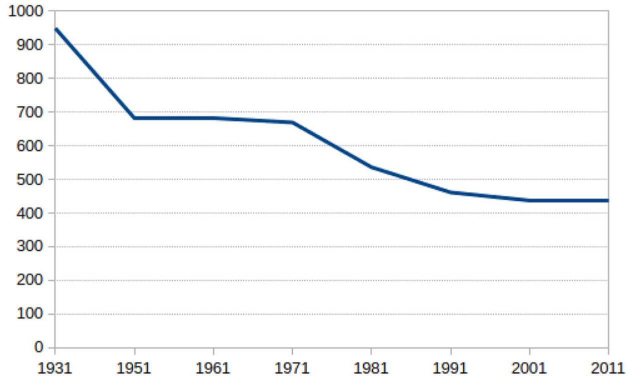

Fig. 3 Inhabited centres between 1931 and 2011

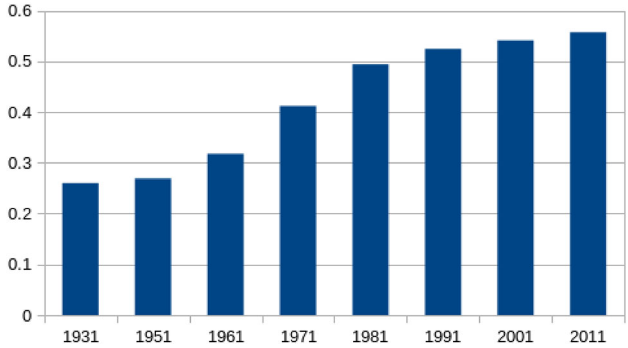

Fig. 4 Population share in municipal seats

The uplands experienced a dramatic shift in the settlement pattern rather than just a population loss; this transformation can be properly described only by adopting a twofold metric, both at the municipal and the centre levels. The longitudinal investigation clearly highlights a sharp dichotomy between the growth in size of some centres and the substantial shrinkage of many others. Local population moves into larger centres or somewhere close to the main roads at the expense of remote villages, often located on steep slopes or isolated highlands. Between 1931 and 2011, the share of population living in municipal seats grew from 28% to 56% (Fig. 4). Concentration and abandonment are the most visible outcomes of a settlement polarisation that endangers the social biodiversity of a sparsely populated area.

As an example of the dissolution of a dense network of meeting points, which used to be a traditional, essential feature of uplands, take the iconic town of Norcia, where the growth of the municipal capital (from 2682 to 2964 inhabitants) appears to be in stark contrast with the collapse of the other 23 inhabited centres (from 4547 to 1069 inhabitants). The town of Amatrice provides another example[2] of how demographic dynamics have undermined its peculiar polycentric settlement, where many small

[2] Amatrice is the hardest hit municipality by the 2016–2017 earthquakes, in terms of human lives (239 deaths on a total of 299) and buildings destroyed.

villages gravitate around the main centre. In the 1931–2011 period, the municipal seat recorded only a small population decline (from 1411 to 1046 people), compared to the other 49 inhabited centres existing in 1931 (with 4890 inhabitants), that dropped to just 5 (with only 304 residents) in 2011.

In short, the community perspective reveals a widespread settlement vulnerability, which cannot be detected either by municipal data or by a single case study. Population change is the result of many different dynamics, both infra- and intra-municipal. The large decrease in inhabited centres is a worrying sign of local shrinkage which is often overlooked. The loss of many meeting spaces deprives territories of their vital nodes, that provide a resilience (or development) factor for places where community has traditionally played a key role (Ciuffetti 2019).

3.1 The Inhabited Centre

The adoption of a sub-municipal scale is a key novelty of this paper. The literature has seldom focused on the local level, which more properly describes the scattered settlements of mountain settings (Collantes 2009), characterised by many small villages endowed with their own identity (Ciuffetti 2019). In order to show how misleading the municipal level can be, consider the case of Amatrice, Cascia and Acquasanta Terme. In 1931 these municipalities included 50, 35 and 32 inhabited centres, respectively. These hamlets are often separated by a few kilometres but also by a centuries-long delay in lifestyle: in some cases, the time seems to “stand still in the Middle Ages or in the eve of Hesiod or Virgil” (Desplanques 1969). Such organisations have played a primary and persistent role over time: the villas imposed demographic control, determined the management of the local resources, exert some local powers (Gobbi 2004) to the extent that several municipal capitals cannot be distinguished from the neighbouring hamlets (INEA 1938).

Nevertheless, very few studies have ventured beyond the municipal level so far and some scholars have been complaining for a long time about “the absence of systematic investigation on villages, despite its potential interest” (INEA 1938). Municipal figures are insufficient to describe the way population has changed over the dense network of village, hamlets and communities: secondary centres are often located in remote places, whose decay is offset by the demographic increase of the municipal seat or other villages at the valley floor (INEA 1938). Municipal indicators tend to overlook short-distance re-locations (Stockdale 2016), although these account for most of the mobility in rural settings (Walford 2007).

The major obstacle is scarcity of sub-municipal data. A few studies filled this gap by collecting data on parishes (Sørensen 2018), enumeration districts in Wales (Walford 2001) or villages (Chi and Ventura 2011; Wang et al. 2020). Unfortunately, Italian statistical sources ignore the concept of “village”. A plausible local unit to collect official, detailed, reliable and standardised information might be the fraction,[3] with data available since 1871, but building consistent time series is made difficult by frequent and considerable re-drawing of administrative boundaries. A fraction often

[3] Fractions are administrative partitions of the municipal territory.

includes other inhabited localities. Among these, the “inhabited centre” provides an adequate meaningful spatial unit for long-term analysis in many respects.

The concept of an inhabited centre was defined in 1931 by ISTAT, and a full description was provided in 1958 as “an aggregate of contiguous or close dwellings [...] characterised by the availability of facilities or public places (i.e. church, school, railway station, public office, drug-store, shop, public market...) that identify a gathering place, also for residents in nearby places, and where a shape of social life emerges, coordinated by the same centre” (ISTAT 1958). This definition leaves out groups of houses lacking public services (therefore without interactions among people) but also railway stations, churches, shops spread in the countryside or on the road, because of the absence of an aggregated social life. Population size is a relevant but not exclusive determinant for the identification of the inhabited centre; the distinctive feature is the existence of a gathering place where a local community of people meets. Therefore, the concept of an “inhabited centre” properly captures a relational space that embraces productive relations and social interactions, of both material and symbolic dimensions (Di Méo 1991; Capello 2019).

In our view, inhabited centres identify local communities, whose size may change over time but that still maintain their identity as a gathering place (unlike other spatial statistical units such as the fraction). The inhabited centre is therefore a dynamic concept that allows to observe the continual reset of the territory (Teti 2004) by incorporating new areas, downgrading or vanishing due to the desertion or absorption of other settlements. Such variations do not hinder the study of local settlements, that involve melting and abandonment processes. The loss of status of inhabited centre does not imply the complete abandonment of the village, in any case very rare (McLeman 2011), but it is a sign of outbreak of local community; conversely, an extension of the centre implies a widening of the community space. The inhabited centre thus provides an operational tool for long term population studies at a fine spatial scale because it satisfies objective, official and time-consistent criteria.

That said, the village remains a suitable unit of investigation for making broad comparisons (Braudel 1985), but research has so far focused only on a small number of cases, limited in scale and devoid of an organic view of the territory. The complexity of the depopulation process can only be understood by incorporating the local dimension within large, quantitative datasets. The method proposed here pursues a detailed and systematic insight of the settlement patterns in the selected area. As we will explain in detail in Sect. 4, we adopt a twofold metric (municipal and inhabited centre) for a more comprehensive assessment of population decline which occurs at multiple spatial-scale levels (Bontje and Musterd 2012) but has not been investigated empirically yet.

4 Empirical Methods

4.1 Dataset Limitations

Given the nature of the issue at hand, we analyse the dynamics of population in the area of interest across 20-year spans,[4] starting from 1931–1951 to 1991–2011, by using ISTAT census data, supplemented by other sources. Unfortunately, sub-municipal data sources are very few, which prevents us from employing many other potentially interesting variables, such as for example infrastructural data, that are only available at the provincial or regional level.

More importantly, the unavailability of several variables for some time periods prevents us from setting up a truly longitudinal study. These data gaps occur in terms of available variables (by column) and in terms of observable centres (by row). Table 2, where a tick mark indicates the availability of a variable in a sub-period, displays the situation. As can be seen, only a handful of indicators are available for all periods; notably, a number of variables which describe quality and quantity of the facilities available in each centre are only observed in 1951 (ISTAT 1957).

While most variables in Table 2 are obvious, we believe a few words are necessary to define the "collective ownership" variable: collective ownership can be defined as the common inalienable and indivisible property of a certain stretch of land which a specific number of families enjoy collectively according to mutually agreed rules and methods (Jacini 1884, p. 487). Such assets can be exploited individually or jointly among all the entitled persons. Collective ownership is generally found in marginal areas or uplands unsuitable for intensive agricultural practices; it mainly consists of woods, forests, pastures whose use is potentially for everyone (for walking, picking hay, mushrooms or wood, grazing livestock, skiing).

In parallel, only a minority of centres remain observable for the whole period from 1931 to 2011. Many of the original ones disappear, and a few appear. Table 3 summarises the appearance and disappearance of centres across our four 20-year spans.

As can be seen from Table 3, the figures for the four sub-periods we analyse are quite different from one another. The column labelled "start" indicates how many centres existed at the beginning of the period; "in" and "out" hold the number of centres that appeared and disappeared, respectively, so that the column "survivors", with the difference between "start" and "out", contains the number of centres existing from the beginning to the end of the 20-year span. The rightmost column, "rel. Δ", indicates the percentage change in population in the surviving centres.

In the 1931–1951 and 1971–1991 periods, the number of centres shrank dramatically, but population grew. On the contrary, centres were stable in the 1971–1991 period, but population declined. Finally, there was very little change in the final period. This evidence is hardly surprising, considering that those four periods are very different from each other from a historical perspective: at first (31–51), the Fascist regime fostered a policy of self-sufficiency, with massive state intervention in agriculture

[4] Shorter time spans have not been considered mostly on account of two reasons: first, World War II would represent an almost insurmountable obstacle. Moreover, we believe that the structural effects we are considering here are best represented using time spans that broadly overlap with generations.

Table 2 Gaps in the dataset

Code	Variable	1931	1951	1971	1991	2011
a	Altitude[a]	✓	✓	✓	✓	✓
Pop	Population[a]	✓	✓	✓	✓	✓
cap	Municipal capital[a]	✓	✓	✓	✓	✓
pres	Present/resident ratio[a]	✓	✓	✓	✓	✓
Walls	Walled settlements[a]	✓	✓	✓	✓	✓
Alt_dist	Altitude gap with municipal seat[a]	✓	✓	✓	✓	✓
Inactive	Inactivity ratio[a]					✓
elderdep	Elderly dependency ratio[a]					✓
Age 0–15	Population aged 0–15 years[a]					✓
Age6575	Population aged 65–75 years[a]					✓
Ageover75	Population over 75 years[a]					✓
pcoll	Collective ownership[b]		✓		✓	
Quake	Struck by earthquakes[c]			✓	✓	
Road	Road access[d]		✓			
Local road	Road access (only local road)[d]		✓			
B-road	Road access (only B-road)[d]		✓			
A-road	Road access (only A-road)[d]		✓			
Train station	Train station[d]		✓			
Post Office	Distance from nearest one[d]		✓			
Telegraph	Distance from nearest one[d]		✓			
Telephone	Distance from nearest one[d]		✓			
Permanent hotels	Permanent hotels[d]		✓			
Seasonal hotels	Seasonal hotels[d]		✓			
Inns	Inns[d]		✓			
Restaurants	Restaurants[d]		✓			
Bank branches	Bank branches[d]		✓			
Aqueduct	Aqueduct[d]		✓			
Sewers (partial)	Sewers (partial)[d]		✓			
Sewers	Sewers[d]		✓			
Doctor	Doctor[d]		✓			
Midwife	Midwife[d]		✓			
Chemist	Chemist[d]		✓			
Hospital	Hospital[d]		✓			
Municipal hospital	Municipal hospital[d]		✓			

Table 2 continued

Code	Variable	1931	1951	1971	1991	2011
Primary school	Primary school[d]		✓			
Middle school	Middle school[d]		✓			
Church	Church[d]		✓			
Parish	Parish[d]		✓			
Cathedral	Cathedral[d]		✓			

Source legend: [a]population censuses; [b]Turbati (1947) and De Sanctis (1983); [c]Decreto Pres. del Consiglio (1979); Decreto regionale (1997); [d]ISTAT (1957)

Table 3 Number of centres, 1931–2011

Period	start	out	survivors	in	rel. Δ
1931–1951	949	309	640	41	5.65
1951–1971	681	33	648	21	−17.93
1971–1991	669	221	448	13	7.23
1991–2011	461	26	436	1	1.77

and constraints on population mobility which increased demographic pressure on the mountain areas. After World War II, Italy experienced the so-called "economic miracle" (1951–1971) and a large rise of industrialisation, which was fuelled by labour force emigrating from the uplands. This golden age ended with the productivity slowdown, that started a complex path of restoration and economic relaunch (1971–1991). The substantial fall in mobility slowed down the out-migration by inner areas but they did not halt it. The last period (1991–2011) is marked by European integration and declining competitiveness. Large waves of foreign immigrants counterbalanced the population decline of the natives. Depopulation continued in the uplands, which are penalised by ageing and low fertility.

In short: a fully longitudinal model would have to be based on a limited set of variables, and would have to take into account the issue of sample attrition between periods. Moreover, as we will show below, coercing population dynamics and centre survival into a time-invariant model would overlook a number of important empirical and historical features, that are typical of each particular period. In the light of all the above, we will analyse the change in population using different models for each period.

Unfortunately, the impossibility of setting up a fully-featured longitudinal model prevents us from carrying out a formal hypothesis test of model structural stability across periods, although the closest possible approximation to such a test is presented in Sect. 5.1 below. However, our findings lend themselves to a very natural interpretation so that model stability across periods can be safely ruled out by a qualitative argument.

Table 4 Descriptive statistics

	Mean	Median	S.D	Min	Max
1931 (949 centres) altitude	711	710	228.3	194	1452
population	221.9	121	484.3	16	10,965
1951 (681 centres) altitude	691.6	676	239.6	194	1452
population	289.9	155	629.8	15	12,400
1971 (669 centres) altitude	682.8	667	241.8	46	1452
population	241	92	859	2	18,355
1991 (461 centres) altitude	663.5	647	243.1	194	1452
population	344.6	98	1237	8	21,172
2011 (436 centres) altitude	659.7	637.5	243.8	194	1452
population	366.3	90	1367	7	23,230

4.2 Econometric Methods

The framework we use can generally be described as

$$\Delta n_{i,t} = \boldsymbol{\beta}'\mathbf{x}_{i,t-1} + \varepsilon_i \tag{1}$$

where $n_{i,t} = log(N_{i,t})$ is the natural logarithm of the population of centre i at time t (where $t = 1931, 1951, \ldots, 2011$) and $\mathbf{x}_{i,t-1}$ is a suitable set of explanatory variables, as observed at the beginning of each period.[5] Of course, in this context the most obvious characteristics to include among the explanatory variables $\mathbf{x}_i$ are altitude and population size, and in fact we will show in the next section that these two variables play a key role, especially in the earlier sub-periods. Table 4 provides some descriptive statistics, relative to the centres existing at each point in time.

The first issue to consider is the fact that centres appear and disappear at different rates, in the different sub-periods we consider (see Table 3). Therefore, apart from estimating an equation like (1), we also set up a binary model aimed at describing the factors that make a centre more or less likely to survive at the end of each 20-year period:

$$s_i^* = \boldsymbol{\gamma}'\mathbf{z}_i + u_i \tag{2}$$

$$s_i = 1 \iff s_i^* > 0 \tag{3}$$

In other words, equation (2) is used to determine the probability that centre i survives as such at the end of the 20-year span: while equation (1) describes the drivers of population dynamics, (2) describes the drivers that explain why a centre may remain active, or disappear. Of course, some of the factors may be the same and affect the

5 We also tried defining the dependent variable as percent change rather than Δ log. We found that adopting the alternative definition produced no substantial changes in the results, which are available upon request. Moreover, in some periods variations in some of the centres are rather large, and the Δ log method generates a dependent variable whose distribution is more regular, symmetric and with fewer outliers.

two phenomena in different ways; or some factor may enter one equation but not the other.

Naturally, these auxiliary models for centre survival may be considered superfluous for periods such as 1951–1971 or 1991–2011, when very little change was observed. However, the issue of sample selection has to be considered: if the two error terms ε_i and u_i are correlated, OLS estimation of equation (1) on the sole sample of surviving centres will yield biased estimates. Put differently: if the unobservable factors that account for population movement also influence the probability of a centre to remain active (as is possible), then a model that describes population change using the data on surviving centres is going to give misleading indications. Therefore, equation (1) should, in principle, be estimated by taking properly into account that we only observe centres that have survived.

Therefore, we decided to estimate jointly the two equations (1) and (2) for each period by using Heckman's sample selection model. However, we found that the correlation between ε_i and u_i was never significant in any of the four periods. We take this to mean that the information set we have for each period is large enough to rule out the possibility of having neglected some unobserved factor, relevant for both the population dynamics of a centre and its survival chances. Therefore, we only report the result of the separate models. Of course, we do not claim our models provide a comprehensive description of the population dynamics. In fact, in several cases idiosyncratic factors seem to dominate: in most of the models we estimate, the R^2 is rather low; what we claim is that the observable explanatory variables we employ contain an information set that is rich enough to shield us from "survivor bias".

Another potential problem with equation (1) is heteroskedasticity: since the dependent variable is a relative rate of change, it may be surmised that larger centres should exhibit figures that are less prone to be contaminated by idiosyncratic factors than smaller ones (for example: if a whole family decides to migrate for some random reason, this would affect a centre with 50 inhabitants to a much larger extent than one with 1000). This was confirmed, in most cases, by running standard heteroskedasticity tests on the OLS estimates. As a consequence, to mitigate this effect, we decided to employ weighted least squares for the estimation of (1), using $\sqrt{N_i}$ as weighting variable. Statistically, this can be considered optimal if the variance of ε_i was inversely proportional to the population size of centre i at the start of the period. For the sake of robustness, we experimented with different solutions and obtained qualitatively similar results as those reported. Notably, one of the alternatives we explored was weighting by N_i instead of $\sqrt{N_i}$. This choice, however, amounts to postulating that the variance is proportional to the *square* of the initial population, which seems rather extreme to us, and makes observations on very small centres practically irrelevant.

5 Results

In this section, we discuss the results for the different models that we estimated for each 20-year span. These are provided in separate subsections: as we argued in Sect. 4.1, a longitudinal approach to estimation is in our case both infeasible and undesirable. It is also worth recalling that in no case a selection effect was found to be significant, and therefore we estimated two separate models for centre persistence and population variation. Before doing so, however, we briefly show a pooled estimate, mainly to motivate the analysis that follows.

5.1 Pooled Estimate

In this subsection, we produce the results for a pooled estimation procedure, whose main purpose is to show the reader its untenability and provide a formal justification for the empirical strategy we follow (namely, estimating separate sub-models for each 20-year span). We estimated equations (1) and (2) by using the whole dataset using the methods described in Sect. 4.2. The results are shown in Table 5.

As can be seen, results are rather unsurprising, given the conventional narration on depopulation of rural areas. The effect of altitude is convex in both equations, reaching a minimum around 1000 ms. On the other hand, the effect of the centre size in terms of population seems much less clear: in the selection equation, a test for the joint significance of all variables associated with population fails to reject the null (p-value = 8.8%), while in the main equation there is, again, a marked convex effect, with smallest centres suffering harder population decline. As for the other explanatory variables, we refrain from commenting their coefficient in the light of the considerations below.

The most important result from the above model, however, is a formal test for poolability that was run for both equations, by adding to the specification above the interactions between all explanatory variables and three dummies for 1951, 1971 and 1991, respectively. The poolability hypothesis was then tested by checking whether the added regressors were jointly significant, by means of a Wald test. The results are unambiguous: the poolability test for the probit model for centre survival yields 128.75, which is equivalent, with 27 degrees of freedom to a p-value of 3.23969e$-$15. The rejection for the WLS model is even stronger: the test statistic is 855.98, for a p-value of 5.92925e$-$160 (31 degrees of freedom).

This implies that the factors considered above play different roles, with different intensities in each of the sub-periods we consider: while this result could be largely anticipated on account of the enormous historical, social and economic differences between sub-periods, some readers may find it reassuring that this intuition was confirmed by a formal statistical test.

In short: the very reason for setting up separate models for each of our 20-year spans is that that there are dramatic differences that set each period apart from one another. Therefore, we used separate specifications for each sub-period, without resorting to formal methods of variable selection such as information criteria, stepwise addition/elimination or regularised least squares techniques, but opted for a qualitative approach in which we also took into account the possible nonlinear effect of some of the explanatory variables. Moreover, as we argued earlier (see Table 2) data for some of these variables are available for some sub-periods only, so we were forced to omit those in some of the models.

Table 5 Estimates for the whole dataset

	Coeff	*t* ratio	*p*-value
Population change			
Const	0.5628	1.682	0.0927
Altitude	−0.8027	−2.293	0.0218
Altitude^2	0.4272	2.981	0.0029
log(pop)	−0.06245	−0.7838	0.4331
log(pop)^2	0.006742	1.334	0.1823
log(pop) × altitude	−0.02188	−0.565	0.5721
Pres. pop. ratio	−0.2811	−3.996	0.0001
Municipal capital	0.2443	7.895	0.0000
Walled settlement	−0.02854	−1.142	0.2533
Temp	−0.3892	−2.333	0.0196
Quake	0.00751	0.3087	0.7576
n. obs	1882	R^2	0.166075
Sum of sq. resid	4235.72	(unweighted)	350.211
$\hat{\sigma}$	1.50462	(unweighted)	0.432641
Centre persistence			
Const	−0.06909	−0.04743	0.9622
Altitude	−2.625	−1.703	0.0885
Altitude^2	1.111	1.639	0.1012
log(pop)	−0.2156	−0.4401	0.6598
log(pop)^2	0.09705	1.905	0.0567
log(pop) × altitude	0.1756	0.7504	0.4530
Pres. pop. ratio	0.3655	0.6725	0.5013
Municipal capital	6.203	0.002519	0.9980
Walled settlement	0.1621	1.67	0.0950
Temp	0.5579	0.8322	0.4053
Quake	0.5974	4.877	0.0000
n. obs	2287	McFadden R^2	0.215552
Log-likelihood	−837.722	Correct predictions	NA%

5.2 The 1931–1951 Span

The model for survival of inhabited centres between 1931 and 1951 features predominantly population size and altitude, the latter with a quadratic effect such that mid-altitude, small centres are the most likely to disappear. By using information on the concavity, we estimate the elevation at which a centre is least likely to persist as such at around 730 ms. This finding is strikingly consistent with Vitte (1995), who argues from a purely qualitative standpoint that depopulation in the Central Apennines started in the medium-altitude villages, clinging to steep slopes, without the fertile soils of the valley floor or the lush pastures at greater altitudes.

Table 6 Estimates for the 1931–1951 span

	Coeff	*t* ratio	*p*-value
Population change			
Const	2.207	4.605	0.0000
Altitude	−1.037	−2.753	0.0059
Altitude^2	0.3168	2.032	0.0422
log(pop)	−0.4048	−3.097	0.0020
log(pop)^2	0.0275	3.038	0.0024
log(pop) × altitude	0.0657	1.442	0.1492
Pres. pop. ratio	−0.59	−5.825	0.0000
Municipal capital	0.191	5.145	0.0000
Walled settlement	−0.09646	−2.718	0.0066
n. obs	571	R^2	0.134152
Sum of sq. resid	685.544	(unweighted)	59.2984
$\hat{\sigma}$	1.10446	(unweighted)	0.324828
Centre persistence			
Const	−2.675	−4.468	0.0000
Altitude	−5.378	−3.791	0.0001
Altitude^2	3.68	3.807	0.0001
log(pop)	1.039	13.02	0.0000
n. obs	949	McFadden R^2	0.21011
Log-likelihood	−473.018	Correct predictions	74.60%

Population changes are also driven by altitude and scale (see Table 6). These variables capture, to some extent, the standard of living for a village and its link to the demographic pressure on the available resources. Altitude, in fact, provides a proxy for several factors, such as remoteness, economic backwardness, poor endowment of resources, harsh climate and the persistence of traditional agricultural practices.

Nonlinear effects for size and altitude are substantial. Negative changes mostly occur in mid-sized, high elevation centres. In order to give the reader an immediate idea of the implications of the estimates, we show in Fig. 5 a heatmap of the combined effect of size (on the x-axis, in logs) and altitude (on the y-axis) on population change. Red and blue denote population increase/decrease, respectively.

The period is marked by the Great Depression, starvation and World War II. The deterioration of living conditions, however, did not bring about massive depopulation of the uplands, as the Fascist regime discouraged long-range mobility. In fact, in the 1930s, the Central Apennines recorded their all-time high in population density (Bonelli 1967), but people reallocated within the area, so as to ease demographic pressure on the overcrowded, fragile settings, where all suitable lands were cultivated, even on very steep slopes. The low productivity of mountain farming encouraged many to seek some kind of additional income via seasonal mobility, transhumance and collective ownership (INEA 1937).

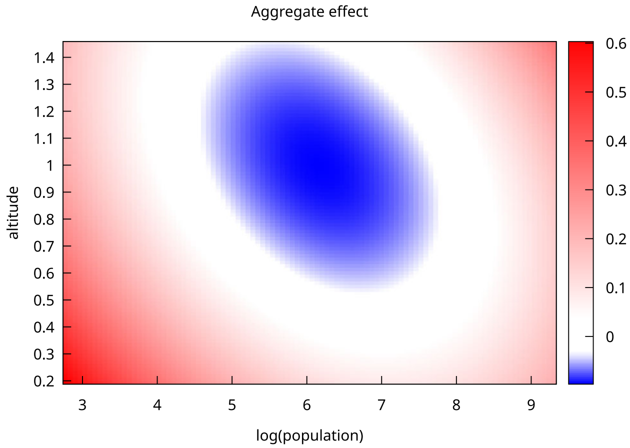

Fig. 5 Combined population/altitude effect: the 1931–1951 span

As a proxy for temporary migration we use the present/resident population ratio, which takes a negative sign: in a context of out-migration, a lower ratio means higher temporary mobility. Our interpretation is that between 1931 and 1951 temporary emigration did not undermine the local community: on the contrary, migrants acted as a welfare hedge for the village, by providing remittance inflow and reducing the demographic pressure on the scant local resources. A contemporary official survey emphasises that villages with large migratory flows enjoyed better life conditions than neighbouring areas (INEA 1937).

The two dummy variables "municipal capital" and "walled settlement" confirm the importance of short-distance movements. The period marks the beginning of an agglomeration process within the municipal border that was bound to continue in the following years. Until the 1930s, the municipal capital was quite indistinguishable from the other settlements (INEA 1937). Agglomeration forces led to settlement restructuring, with new municipal hierarchies taking shape in a context that was still polycentric. This process can be observed in the lower demographic trend of walled settlements (*terra*, *civitas* and *castrum*) compared to open villages (where buildings are interspersed with cultivated fields). Such a discrepancy is firstly related to the severe economic crisis of the 1930s, which mostly affected centres that were dependent on other villages for their agricultural supply. In addition, several craft activities, hitherto concentrated in castles, moved to bigger centres or the municipal capital in search of broader markets. This displacement reflects the decline of the pluri-activity model, supplanted by a pattern of growing job specialisation.

Table 7 Estimates for the 1951–1971 span

	Coeff	*t* ratio	*p*-value
Population change			
Const	−0.5413	−0.9203	0.3574
Altitude	−0.3149	−0.656	0.5118
Altitude^2	0.6508	3.12	0.0018
log(pop)	0.04066	0.2376	0.8122
log(pop)^2	0.0002082	0.01587	0.9873
log(pop) × altitude	−0.1584	−2.538	0.0111
Pres. pop. ratio	0.2794	2.325	0.0201
Municipal capital	0.1818	2.84	0.0045
Coll. ownership	−0.0964	−2.93	0.0034
servizi1	0.01047	2.077	0.0378
servizi2	0.01204	2.245	0.0248
n. obs	591	R^2	0.386788
Sum of sq. resid	1131.05	(unweighted)	85.3328
$\hat{\sigma}$	1.39646	(unweighted)	0.383569

5.3 The 1951–1971 Span

Between the 1950s and the 1960s, a new lifestyle broke into the Apennines. In this period, Southern Europe recorded the collapse of mountain economies based on traditional, no longer profitable activities, such as agriculture and sheep farming (Collantes 2009).

The number of inhabited centres remained remarkably stable (see Table 3), so we do not report the corresponding probit model. Conversely, depopulation occurred almost everywhere, but mainly from high-altitude centres (Table 7). Interestingly, settlement size plays a marginal role in the great exodus from the Central Apennines, and does so only jointly with altitude. Figure 6 shows their combined effect: the difference between Figs. 5 and 6 is striking, and shows not only the dramatic change between the two periods in terms of overall depopulation, but also that the different role played by size and altitude in the two sub-periods.

Migration effects, measured by the present population ratio, are significant but, again, with an opposite sign compared to the previous time span: centres with a higher share of residents working somewhere else experience a greater population loss. In our interpretation, demographic decline is linked to the shift from temporary to permanent emigration, that brings about a sizeable loss of labour and local social capital (McLeman 2011). This tendency had a devastating effect on the fragile economy of the mountain settings, which largely relied on pluri-activity and external resources.

Depopulation is stronger for centres where collective ownership is more common. This form of property is a traditional response to lack of arable areas (Vitte 1995, see p. 201) and is usually associated with woods and grazing. Therefore, we use collective ownership as a proxy for the presence of marginal lands, unsuitable for farming.

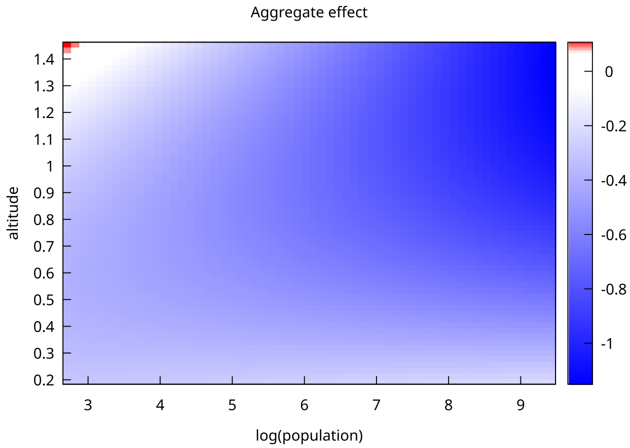

Fig. 6 Combined population/altitude effect: the 1951–1971 span

A very interesting feature of the data for this time span is that rich information is available on a wide set of services in 1951 (ISTAT 1957); descriptive statistics for the original variables are provided in Table 8. In order to incorporate it into our model for population change, we summarised several variables via a Principal Component Analysis and we used the first two principal components, whose percentage of retained variance is 38.2%. In fact, the mechanical application of the information criteria by Ahn and Horenstein (2013) would indicate one factor only, which accounts for 29.1% of total variability. However, the inclusion of a second factor is rather natural, given the interpretation of the loadings that emerges from applying the varimax rotation technique: the loadings are reported in the two rightmost columns of Table 8.

Figure 7 shows a scatter plot of our two composite indicators versus population in 1951 and versus each other. As can be seen, correlation is unsurprisingly positive, but far from perfect. Factor one is mostly associated with the availability of "basic" services (post office, telephone and basic health, such as a chemist or a midwife). Factor 2, instead, describes the availability of more "advanced" services, such as hotels, bank branches, or the presence of a cathedral. It is interesting to note that there is a marked nonlinear relationship between the two. We find that both our proxies (despite being only an imperfect measure of service availability) exert a very strong counter-effect to depopulation, as expected (Wang et al. 2020).

The process of industrialisation and urbanisation in Italy between 1951 and 1971 led to rising living standards, both in the economic and the social dimensions. Rural population strove for the modern, comfortable, vibrant lifestyle of the city promoted by mass media or newly-built motorway construction (Di Figlia 2016; Rizzo 2016). The lack of facilities such as healthcare, education and shops has not only practical implications, but also a symbolic meaning for the communities which were progressively pervaded by a sense of remoteness and backwardness (Christiaanse and Haartsen 2017). Lowe and Ward (2009) report a similar phenomenon for Wales, where physical remoteness and poor infrastructure explain some of the situation as well as population mobility to the municipal capital, where services were increasingly available.

Table 8 Variables used in the PCA analysis, descriptive statistics and loadings

	Mean	Median	S.D	Min	Max	Load1	Load2
Road	0.8342	1.000	0.3721	0.000	1.000	0.4069	−0.0676
local road	0.4948	0.000	0.5003	0.000	1.000	−0.1333	−0.3193
B-road	0.2513	0.000	0.4340	0.000	1.000	0.3732	0.1602
A-road	0.08808	0.000	0.2836	0.000	1.000	0.1979	0.2294
Train station	0.03109	0.000	0.1737	0.000	1.000	0.1327	0.4697
Post Office	0.3381	0.000	0.4734	0.000	1.000	0.8459	0.1345
(Distance from nearest)	3.041	2.500	3.183	0.000	18.00	−0.706	−0.0443
Telegraph	0.2759	0.000	0.4473	0.000	1.000	0.8197	0.2195
(Distance from nearest)	4.183	3.500	3.985	0.000	20.00	−0.6201	−0.1151
Telephone	0.4339	0.000	0.4959	0.000	1.000	0.7644	0.072
(Distance from nearest)	2.778	1.350	3.651	0.000	25.00	−0.6378	0.0098
Permanent hotels	0.04016	0.000	0.2436	0.000	3.000	0.1313	0.7033
Seasonal hotels	0.01943	0.000	0.2712	0.000	4.000	0.1112	0.2011
Inns	0.07513	0.000	0.2638	0.000	1.000	0.3459	0.5645
Restaurants	0.1723	0.000	0.3779	0.000	1.000	0.463	0.4385
Bank branches	0.1308	0.000	0.4882	0.000	6.000	0.3261	0.7695
Aqueduct	0.7189	1.000	0.4498	0.000	1.000	0.3184	0.044
Sewers (partial)	0.2915	0.000	0.4547	0.000	1.000	0.4353	0.2738
Sewers	0.06477	0.000	0.2463	0.000	1.000	0.2894	0.3997
Doctor	0.2176	0.000	0.4129	0.000	1.000	0.7638	0.3062
Midwife	0.1930	0.000	0.3949	0.000	1.000	0.7455	0.3695
Chemist	0.1606	0.000	0.3674	0.000	1.000	0.6877	0.4364
Hospital	0.03886	0.000	0.1934	0.000	1.000	0.2213	0.7183
Municipal hospital	0.2733	0.000	0.4460	0.000	1.000	−0.1301	−0.1732
Primary school	0.9106	1.000	0.2855	0.000	1.000	0.2441	−0.0137
Middle school	0.04793	0.000	0.2138	0.000	1.000	0.2691	0.7563
Church	0.09585	0.000	0.2946	0.000	1.000	−0.2812	0.0931
Parish	0.7966	1.000	0.4028	0.000	1.000	0.3138	−0.3267
Cathedral	0.01554	0.000	0.1238	0.000	1.000	0.0351	0.7697

5.4 The 1971–1991 Span

This period is more akin to 1931–1951 than the next one: total population remained relatively stable but many centres ceased to exist as such. The empirical regularities that describe both phenomena, however, are quite different: as can be seen in Table 9, the main empirical drivers of this phenomenon are altitude, population in 1971 (with the expected signs) and the `quake` dummy, which identifies the centres affected by a strong earthquake in 1979. For the Probit model, this variable has a positive effect. Although this finding could be considered surprising at first sight, it should be considered that natural disasters call for the maintenance of gathering places for people

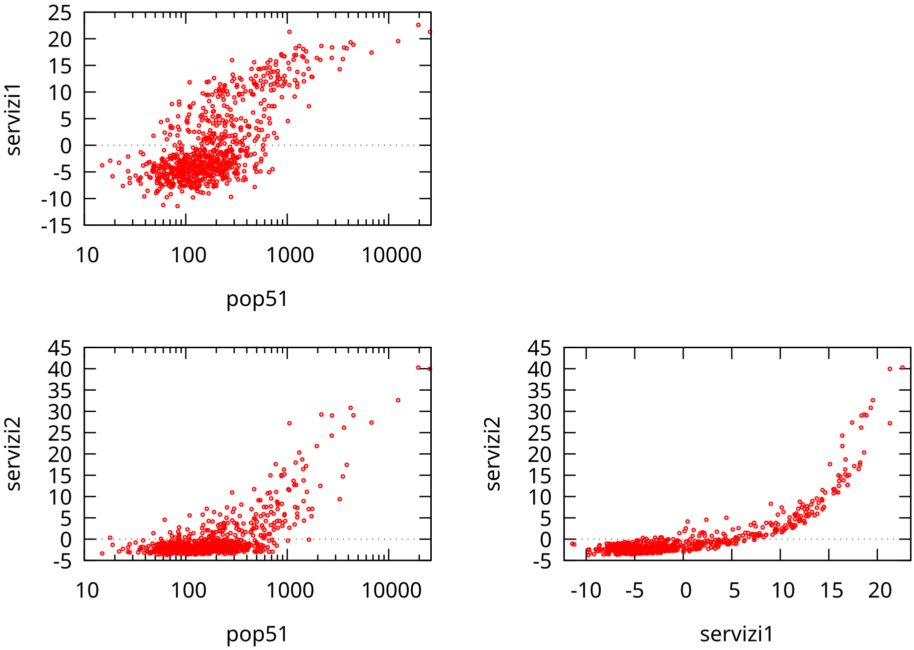

Fig. 7 Services composite indicators vs centre size

and public operators working on the recovery; these efforts, however, failed to reverse the prolonged, preexisting demographic decline, as confirmed by the regression on population change. The area keeps losing inhabitants, albeit at a slower pace than the 1951–1971 period.

As for population change, nonlinear effects are insignificant, and therefore the traditional interpretation, whereby depopulation is a simple outcome of altitude and size, is warranted here. Shrinkage is particularly strong in the high-altitude settlements, where inhabitants suffer most from the increasing remoteness and the lack of services. Mountain areas are divided between shrinking villages depleted by long and short mobility, and the capital town or nearby villages, which are the destination of local migrations.

5.5 The 1991–2011 Span

This period is remarkably static, both in the number of the inhabited centres and in the demographic size. Population mostly drops at higher altitudes, whereas centre size is not significant; municipal capitals are less affected by depopulation. Despite the cuts to local services, the spread of ICT and the arrival of lifestyle migrants, the growth of settlement polarisation confirms the relevance of low scale mobility towards the municipal capitals.

We accounted for the 1997 earthquake by considering a dummy variable equal to 1 in the settlements where more than 20% of the building stock was severely

Table 9 Estimates for the 1971–1991 span

	Coeff	*t* ratio	*p*-value
Population change			
Const	−0.1179	−0.233	0.8157
Altitude	−1.01	−1.933	0.0533
Altitude^2	0.08424	0.3824	0.7022
log(pop)	0.09145	0.6772	0.4983
log(pop)^2	−0.005635	−0.6533	0.5136
log(pop) × altitude	0.05759	0.8311	0.4059
Municipal capital	0.1568	3.221	0.0013
Quake	−0.02555	−0.5554	0.5786
Coll. ownership	−0.03518	−0.8414	0.4001
n. obs	448	R^2	0.309298
Sum of sq. resid	797.669	(unweighted)	77.2366
$\hat{\sigma}$	1.34797	(unweighted)	0.419449
Centre persistence			
Const	−3.846	−9.382	0.0000
Altitude	−0.548	−2.108	0.0350
log(pop)	1.023	12.09	0.0000
Quake	0.6594	4.437	0.0000
n. obs	669	McFadden R^2	0.278422
Log-likelihood	−306.258	Correct predictions	80.12%

damaged. Data on building conditions are provided by official sources (Ministry of Interior, Marche and Umbria regions) aimed to limit the reconstruction benefits to the municipalities worst hit by the earthquake. This variable, turned out to be insignificant but we included it in Table 10 anyway. It is also important to consider that the policy response to the 1997 earthquake resulted in a substantial amount of funds to be used in a relatively small area. Therefore, reconstruction efforts involved almost all the affected settlements and buildings, and the conscious choice was made not to relocate the population from the villages, even in the immediate aftermath of the event. Decisions such as these are would nowadays be considered impractical on account of to the vast extent of the seismic crater, the state of ruin of some centres, and increased constraints on public finances.

In addition to these usual drivers, population dynamics is influenced by demography, for which we use the variables described in Table 11. In this period, the age structure of the population matters more than the size of the settlement. The nature of depopulation has changed substantially, going from out-migration to natural decline, induced by unbalanced age structure. Shrinkage is fuelled by endogenous cumulative effects started in the previous decades that are difficult to reverse (Bucher and Mai 2005; Rizzo 2016).

Table 10 Estimates for the 1991–2011 span

	Coeff	t ratio	p-value
Population change			
Const	0.9301	4.472	0.0000
Altitude	−0.3088	−4.54	0.0000
log(pop)	−0.0008173	−0.05855	0.9533
Municipal capital	0.07056	1.775	0.0758
Quake	0.03734	1.052	0.2926
Inactive	−1.077	−4.237	0.0000
elderdep	4.265	2.552	0.0107
age6575	−8.249	−3.538	0.0004
ageover75	−6.722	−2.699	0.0070
n. obs	435	R^2	0.208934
Sum of sq. resid	529.019	(unweighted)	57.1172
$\hat{\sigma}$	1.11437	(unweighted)	0.366167

Table 11 Demographic indicators

		Mean	S.D	Min	Max
`inactive`	Share of inactive population over 15	0.6459	0.08127	0.4	0.92
`elderdep`	Elderly dependency rate: $\frac{n_{64+}}{n_{15-54}}$	0.1251	0.05907	0	0.67
`age6575`	$\frac{n_{65-75}}{n_{tot}}$	0.0572	0.02881	0	0.22
`ageover75`	$\frac{n_{75+}}{n_{tot}}$	0.03907	0.02753	0	0.22

6 Conclusions, Policy Indications and Ideas for Further Research

Our paper adds to the theoretical debate by introducing a conceptual model that is tested using long-term longitudinal data from a sample of mountain settlements in Central Italy.

The main findings of our study can be summarised as follows. First, a proper quantitative analysis of long-term population change in the Apennines requires two separate dimensions: the number of villages and their size. Moreover, the most appropriate geographical unit for tackling an empirical analysis of depopulation in a mountain setting has to be sub-municipal. This led us to use the concept of “inhabited centre”, as described in Sect. 3.1. This twofold metric allows for a more comprehensive assessment of a multifaceted depopulation process that involves a shift in the settlement pattern rather than just a population loss. This perspective reconciles the discrepancy between scholars who think, based on municipal data, that the depopulation in the Apennines has come to a halt (Sori 2004) and those who worry about the abandonment of many villages (Teti 2004). The settlement hollowing shows a neglected but dramatic facet of depopulation which is also boosted by the agglomeration effect within the municipal borders. The concentration of residents in the municipal capital or the valley floor (Sørensen 2018) deconstructs the centuries-old polycentric settlement of mountain areas.

Second, our analysis poses the issue of the intra-rural divide. We found ample evidence of local redistribution of inhabitants within municipal settlements, often due to local mobility (Milbourne 2007; Han et al. 2016). Despite a relative lack of attention, short-distance relocation is a consolidated practice in rural settings, that are "at least as mobile as the urban, if not more so" (Bell and Osti 2010, p. 199).

Third, the complexity of population change can only be addressed by considering the joint interdependence of a variety of social, economic, cultural, institutional and environmental factors operating at multiple scales (Beresford and St Joseph 1979). "None of the factors can individually determine the direction and magnitude of population change" (Chi and Ventura 2011, p. 12). In our empirical model, we strive to combine these elements by using the widest possible data array in order to achieve a comprehensive understanding of the mechanisms driving rural shrinkage.

Fourth, depopulation is a multistage, cumulative process of increasing vulnerability, decline, and self-reinforcing decay (Wang et al. 2020; McLeman 2011; Di Figlia 2016). Population fall has manifold manifestations and causes, engaged according to the place and the period under consideration: "one important factor in a certain time period may become unimportant in another, and vice versa" (Chi and Ventura 2011, p. 2). Some drivers, such as temporary migration and elevation, affect in a different manner each specific phase of the village depopulation. Although we cannot provide a formal test, for the reasons outlined in Sect. 4, we believe that the evidence is striking.

Fifth, despite mountain settlements having been described as "a thin and rudimentary canvas, which could tear at each unusual natural event" (Gambi 1972, p. 19), we find that catastrophic events play only a minor role in a population decline driven by structural socioeconomic and demographic processes that are difficult to reverse (ageing, low population density, de-natality etc.). The 2016–2017 earthquakes, however, could have had particularly harmful consequences because of the extension of the affected area, the adverse economic conjuncture, the constraints of public spending, and the discourage brought by repeated, violent tremors. Such concerns are corroborated by a recent study which assesses significant additional population losses in the seismic crater of Central Italy after the earthquake (Dottori 2024). Many settlements, exhausted by prolonged shrinkage, economic downturns, social exclusion and recurring natural disasters are close to a point of no return.

Further research should be extended to a long-term analysis of inhabited centres in other mountain areas either in Italy or elsewhere. In addition, the set of variables used in the paper may be further identified and improved. For instance, we do not consider the spillover effects on neighbour settlements (Chi and Ventura 2011; Han et al. 2016).

As for the policy implications of our findings, we argue that the recovery policies for the mountain cannot embrace an emergency logic, especially in settings with recurrent natural disasters. On the contrary, exploring the trends and drivers of population change allows for planning credible development policies addressed to settings in slow burn decline. In this perspective, the 2016–2017 earthquake has only consolidated and accelerated processes already underway, such as the decline and aging of the population (Dottori 2024) that slowly erodes the resilience of places.

The adoption of a long-term, multidisciplinary, quantitative approach at submunicipal scale provides a holistic insight of population dynamics, which can be interpreted through the lens of the peripheralization process (Kühn 2015). This perspective allows to avoid both the anachronism and anatopism which often plague development policies for uplands. Ignoring the history of local communities perpetuates the stereotype of the mountain as empty of resources, opportunities and people. Regeneration of mountain contexts needs the recognition of a local identity that is often denied or trivialised, and the understanding of the path that has led to the marginalisation.

It must be remarked that there is not yet a scientific consensus on the optimal strategy to confront this unprecedented village abandonment. Several recovery strategies are discussed: from the return to the past settlement (Clemente and Salvati 2017) to "rewilding", i.e. complete human abandonment (Pereira and Navarro 2015); from organised depopulation of some villages (Orcao and Cornago 2007) to the restoring of the traditional landscape (García-Ruiz et al. 2020) or smart shrinkage (Peters et al. 2018). The different standpoints relate to the sharp discussion between space-blind and place-based regional policies (Barca et al. 2012). If some kind of policy to manage the depopulation process is deemed desirable, then our paper proves that demographic trends depend on many diverse drivers, which are space and time contingent.

In the future, shrinkage will be inevitable. However, not all shrinkage is decline (Peters et al. 2018), and population drop could be properly managed in order to guarantee social equity and a better life quality. Successful smart shrinkage needs stronger social ties, significant civic engagement, shared values and mutual trust. Local community may therefore be an engine of resilience or endogenous development (McManus et al. 2012) which must be recognised and strengthened (Imperiale and Vanclay 2016). In this view, regeneration of communities entails reactivation of relationships, a productive and cultural re-functionalisation, the exploitation of territorial capital, often ignored or underutilised, in innovative and sustainable forms. It is therefore necessary to pursue the re-functionalisation of the enormous stock of redundant and abandoned buildings and uncultivated fields, the appropriate enhancement of endogenous resources (housing, landscape, tourism, historical-cultural, natural) and of common water and forest goods.

Therefore, the concept of local community lies at the core of our work. The term "place" often recurs in public policies, namely for inclusive and sustainable place sensitive policies aimed at addressing the under-utilisation of people and resources (Iammarino et al. 2019). The concept of place identifies a space for living; it is meant to be inhabited and brings about a rediscovery of the meaning of history, which is essential to recover the reasons and events that led to an ancient and widespread anthropisation. The reconstruction of long-term demographic dynamics helps trace paths of sustainable future for territories often conceived only with respect to the environmental (rewilding) or recreational needs of the cities.

Both alternatives are unfit to the history of the Central Apennines, that have never been "wild" (whatever that may mean), but rather an ecosystem shaped by the co-evolution between anthropic and natural elements. The mountain settlements should become a place on a human scale, in which to reside in an innovative way, combining development and conservation. An effective development strategy must act on several spatial scales, creating a multi-level governance in the allocation of services or participation in calls for proposals that require size and capacity absent in a single municipality. On the other hand, public planners cannot ignore the sub-municipal scale, which underpins the settlement system of the central Apennines. The reconnection of the territory requires a strengthening of digital networks in order to enhance the creation of community hubs for functional areas (i.e. telemedicine) and new relational forms. In this regard, policy efforts should focus on selected local centres that may trigger some kind of agglomeration economies. Mountain areas, for example, must be provided with a bundle of public services (healthcare, education, etc.) so as to meet the basic needs of the population; at the same time, their inhabitants "could be financially compensated for ecosystem services provision" (De Toni et al. 2021).

However, we should be aware that not every settlement can be inhabited, and very few as before, but that we must get used to recovery, innovations and new ways to live on the mountains. In our view, the abandonment of traditional former villages undermines the historical memory of the places; it brings about a waste of cultural heritage and land resources (Wang et al. 2020), a loss of aesthetic and tourist values, biodiversity, environmental protection and ecosystem services (García-Ruiz et al. 2020). The safeguard of mountain settlements is not only a cultural need but also a pressing political issue. The growing gap between urban and rural areas has amplified economic, social and political instability in the EU and forged the rise of populist waves in recent political elections (Rodríguez-Pose 2018; McCann 2020). The ruins of the Basilica of St. Benedict, the patron of Europe, in Norcia remind us that the original spirit of the European Union, constantly on the edge between competitiveness and cohesiveness goals, calls for the protection and the effective, sustainable recovery of mountain settlements.

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Data Availability Data and other replication material is available at the link below.

Declarations

Conflict of interest No conflict of interest to declare.

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