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RESEARCH NOTE

Local-Scale Fertility Variations in a Low-Fertility Country: Evidence from Spain (2002–2017)

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Abstract
Since the early 1990s, persistently low fertility in Mediterranean countries has attracted the interest of empirical research aimed at identifying factors associated with demographic change in what were traditionally high-fertility contexts. Most of these studies have been carried out at the national scale, while spatial analyses of sub-national patterns remain mostly absent. The present study aims to fill this gap, investigating the spatio-temporal changes in local fertility in Spanish municipalities over a 16-year period that covers consecutive waves of economic expansion (2002–2009) and recession (2010–2017). The analytical framework is grounded on descriptive statistics, spatial statistics (that is, Global Moran's I and Local Indicators of Spatial Association) and non-parametric inference testing the pair-wise correlations between fertility levels and contextual variables (including population density, topography, accessibility and distance from central locations). Results of this study reveal a fertility decline in most areas of the country—especially in depopulated districts. The highest fertility is observed in Southern Spain, along the Mediterranean coast, and around the main cities. With recession, spatial heterogeneity emerges as the main trend characterizing regional fertility—a finding in line with research from other Mediterranean countries. Local fertility rates were less spatially clustered in the recession than in the expansion period, with a progressive shrinkage of high-fertility districts. A persistent decline in local fertility may be considered an early-warning indicator of depopulation in Spain's rural districts and can be used to delineate demographically fragile areas.

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Résumé
Depuis le début des années 1990, une fécondité toujours faible dans les pays méditerranéens a suscité l'intérêt des chercheurs visant à identifier les facteurs associés au changement démographique dans des contextes traditionnellement à forte fécondité. La plupart de ces études ont été menées à l'échelle nationale et des analyses explicitement spatiales étaient partielles ou absentes. La présente étude vise à combler ce manque de connaissances en examinant l'évolution spatio-temporelle de la fécondité dans les municipalités espagnoles sur une période de seize ans qui couvre une phase d'expansion economique (2002–2009) et de récession (2010–2017). Le cadre analytique est fondé sur des statistiques descriptives, le I de Global Moran, les indicateurs locaux de l'association spatiale (LISA) et l'inférence non paramétrique testant les corrélations par paires entre les niveaux de fécondité et les variables contextuelles (y compris la densité de population). Les résultats de cette étude montrent une tendance à la baisse de la fécondité dans la plupart des régions du pays - en particulier dans les districts dépeuplés. La plus forte fécondité est observée dans le sud de l'Espagne, le long de la côte méditerranéenne et autour des principales villes. Avec la récession, l'hétérogénéité spatiale apparaît comme la principale tendance caractérisant la fécondité régionale de l'Espagne - une constatation conforme aux recherches dans d'autres pays méditerranéens. Les taux de fécondité locaux étaient moins homogènes pendant la récession que pendant la période d'expansion, quand il y eu une réduction progressive des districts à forte fécondité. Une baisse persistante de la fécondité locale peut être considérée comme un indicateur d'alerte précoce du dépeuplement dans les districts ruraux et peut être utilisée pour délimiter les zones démographiquement fragiles.

Keywords Total fertility rate · Urban-rural gradient · Accessibility · Depopulation · Municipality · Spain

1 Introduction

Advanced societies report very low fertility, with rates persistently close to one (Frejka et al. 2010; Galor 2011; Zaidi and Morgan 2017). Scholarship on fertility and the population dynamics of the second demographic transition (SDT) has expanded rapidly in the 30 years since the seminal work of Van De Kaa (1987). This literature includes work that seeks to explore the factors that shape fertility at multiple social and geographic levels. In this context, Balbo et al. (2013) identified and grouped factors shaping fertility at the micro-, meso- and macro-scale. Micro-level factors include fertility intentions, fertility preferences, partner and partnership relations, division of labour, individual and family income, education, and employment uncertainty, the socioeconomic status and cultural context of the family, transmission of values and behaviours and bio-demography of fertility. Meso-level forces are those that are mainly focused on social interaction, place of residence and social capital at the same level. Finally, macro-level drivers include local, regional, and national economic trends, (un)employment rates, policy measures, welfare regimes, aggregate change in values and attitudes, contraceptive and reproductive technologies, broad historical and cultural settings as well as policy endogeneity (Adsera 2006a, 2006b; Wachter 2005; Frejka and Sobotka 2008).

Earlier studies have frequently documented the importance of social contexts and economic downturns in shaping specific regional trends of fertility rates (Muniz 2009; Vitali and Billari 2017; Tragaki and Bagavos 2019). While strongly embedded in a macro-scale analysis of demographic patterns and processes, this kind of studies may reveal—better than other approaches—the linkages between socioeconomic forces regulating (directly or indirectly) fertility across spatial scales, from regional to local. Recent developments in spatial data availability and spatial analysis tools provide a powerful opportunity to examine and interpret demographic processes, such as fertility, at multiple spatio-temporal scales (Morgan 2003 Gil-Alonso et al. 2017; Evans and Gray, 2018). Based on this rationale, and considering the wealth of recent studies focusing on the micro-level determinants of fertility levels in different socioeconomic contexts (that is, urban, suburban, rural) of both advanced countries and emerging economies, the present study focuses on meso- and macro-level factors shaping local fertility in Spain. The temporal coverage of the study includes periods of economic expansion (2002–2009) and recession (2010–2017) in Spain. Our study hypothesises that economic expansion and recession influence both the overall level of fertility and the spatial regime of fertility rates, following Salvati et al. (2020). Specifically, we assume that a generalised economic expansion may reflect a growth of long-term birth rates, intensifying the eventual divide in high-fertility and low-fertility areas mediated by socioeconomic differences at the regional scale. We also assume that an intense recession may result in a spatially heterogeneous reduction of birth rates, that are influenced by the intrinsic role of locally specific, contextual forces (Gavalas et al. 2014).

Processes linking economic downturns with regional and local fertility levels include the effects of job uncertainty, instability or unemployment as well as volatility in housing markets. Since sequential economic downturns are assumed to increase spatial complexity of fertility dynamics, a more heterogeneous distribution of birth rates over time and space may reflect new family relations, less (and later) marriage or cohabitation, childbearing postponement and smaller households. When investigating such issues, European countries and, more specifically, Mediterranean regions are paradigmatic cases of low-fertility and the emergence of intense demographic spatial divides (Salvati et al. 2019), which deserve further investigation.

2 Peculiarities of Regional Fertility Dynamics in European Mediterranean Countries

The total fertility rate (TFR) in Europe decreased from 5.7 in 1960 to 2.8 in 1990. Since the late 1990s, low fertility was particularly evident across the continent, when 25 out of 39 countries had a period TFR below 1.5, and of these 16 countries were below 1.3 (Frejka and Sobotka 2008). During this period of decline, fertility levels in Europe also became increasingly spatially heterogeneous. For instance, Norway, France and the Netherlands had comparably high birth rates, while fertility in Germany and Austria was low. In post-1980s, Eastern Europe fertility was persistently very low, under 1.3 children per woman (Kohler et al. 2002). The lowest-low fertility on the continent was observed in Mediterranean countries with strong family traditions, specifically Italy, Spain and Greece (Arpino and Patrício Tavares, 2013). Indeed, Southern Europe provides a paradigmatic example of transitional fertility, shifting rapidly from the highest rates on the continent in the 1950s and 1960s to the lowest rates by the 1990s. It is worth noting that fertility decline was more pronounced than changes in mortality or mobility patterns. This extreme low fertility has now been observed for over two decades in Southern Europe (Cabré 2003).

Although studies on regional fertility in European Mediterranean countries have emerged during the last 30 years, investigations of spatio-temporal population dynamics at local scales (i.e. the municipality level) have been relatively rare. Relatedly, their geographical coverage was incomplete or fragmented. Among Mediterranean countries, Spain has experienced one of the most rapid declines in fertility (Leasure 1963; Livi Bacci 1968; Baizán 2009): from 2.8 children per woman in 1970 to 1.2 in the 1990s. Indeed, Spain's fertility was the lowest in the world for that period (Cabré 2003). However, not all Spanish regions had the same fertility: fertility was particularly low (< 1 child per woman) during the 1990s in Asturias, Cantabria, Galicia and the Basque country and, on average, Southern Spain had a higher fertility than Northern Spain (Bernardi and Roquena 2003).

Conditions mixing lowest-low birth rates at the national scale and important divides in regional fertility that persist over several decades are uncommon in other large European countries—apart from Italy and, to a lesser extent, Germany (Rodriguez-Rodriguez 2000). In the published literature, factors underlying these regional conditions are interpreted using traditional paradigms such as modernisation, gender equality, rising life expectancy or new parent-child relationships (Brodmann et al. 2007; Bledsoe et al. 2007; Cooke 2009). In contrast, the lowest-low fertility observed in Spain seems to have a closer relation with the imbalance amongst social institutions, that also emerged in recent decades, and that accompanied the changes associated with the rapid and spatially varying demographic transition (Coppola and Di Cesare 2008; Delgado et al. 2008; Davia and Legazpe 2013; Lesthaeghe and Lopez-Gay 2013).

Earlier studies of regional fertility in Spain were carried out at intermediate territorial levels (i.e. autonomous communities or provinces), and without using spatial analysis (Gil-Alonso et al. 2017, but see also Lesthaeghe and Lopez-Gay, 2013, and Sabater and Graham 2019). The present study proposes a comprehensive analysis of Spanish fertility at finer level of analysis, the level of local area unit (LAU) municipalities (hereafter municipalities) using spatial approaches. Specifically, we use exploratory spatial data analysis and statistical methods that help identify patterns and trends toward spatial clustering (or heterogeneity) over a sufficiently long time interval that encompasses periods of both economic expansion (2002–2009) and recession (2010–2017). Assuming fertility is a spatially varying demographic phenomenon, as our literature review suggests, a spatial analysis of change in regional fertility regimes may lead to a more precise interpretation of population dynamics in Spain. An identification of the socioeconomic forces underlying demographic changes may inform—both directly and indirectly—more effective developmental policies that support fertility in specific regions and types of place (i.e. urban and rural municipalities).

3 Methodology

3.1 Study Area

Spain is a country located in South Western Europe and includes land on the Iberian Peninsula, the Balearic Islands and the Canary Islands. With an average elevation of 660 m above sea level, Spain has an undulated topography and represents the second most mountainous country in Europe behind Switzerland (Appendix Fig. 4). The Spanish territory is partitioned into 17 regions (autonomous communities), 50 provinces and more than 8000 municipalities. In 2017, Spain's population was approximately 46.7 million, with the majority settling in large cities. Only 5% of the population resides in half of the country's territory, a strong indication of uneven and potentially serious demographic problems such as low fertility and rural depopulation (Gil-Alonso et al. 2017).

3.2 Data and Indicators

This study focused on period fertility using a generalised indicator derived from the computation of the total number of births observed at a given time point (e.g. year or time interval) and the number of women of reproductive age (15–49 years) at the same location and time. Official statistics of births and population gender and age structure at a given time (year) and location (municipalities) have been obtained from the Spanish National Institute of Statistics (INE) for all years between 2002 and 2017.

Mapping and spatial analysis were performed using shapefiles and raster files provided by the Spanish National Geographical Institute (IGN), including a Digital Elevation model with 90-m spatial resolution. The number of municipalities was quite stable over time with just 20 of the 8000 cancelled or created ex-novo, mainly in rural and marginal districts. The fertility rate for the 20 municipal boundaries that changed was estimated as the average rate of the 5 surrounding municipalities, assuming spatial similarity of demographic behaviours at this local scale. This is a plausible assumption especially in rural and marginal contexts with low population density.

To estimate crude fertility rates with missing data of births or population structure, specific rules were followed: (i) for some municipalities where the amount of women of reproductive age was missing for 2002, population structure of 2003 was considered based on the assumption that any variation would be minimal from year to year; (ii) some (localised) missing data on births for specific years were estimated by averaging the number of births in both the previous and the subsequent year (e.g. if 2016 was missing we used 2015 and 2017 values); and (iii) for new municipalities resulting from administrative division changes, as well as for municipalities that were combined, fertility rates were estimated proportional to the population and births before any change.

3.3 Statistical Analysis

Fertility rates were estimated at two-time intervals of equal duration representing economic expansion (2002–2009) and recession (2010–2017). Using average rates over time generates fertility time series data that are more consistent and stable at the municipal scale. Specifically, averaging reduces the impact of random factors on municipal birth rates and population structures by age and gender (Muniz 2009). Thematic maps illustrating the spatial distribution of fertility rates in the two time periods were created.

3.3.1 Spatial Analysis

Spatial analysis as applied to demographic processes can be defined as a series of spatial statistical techniques aimed at explaining or predicting changes in a specific demographic outcome within a set of geographically bound regions (Wachter 2005). Specifically, the spatial statistical methods leverage information on location (e.g. a municipality or area) and relative location (the relative positioning of municipalities or districts within a study area, focusing on adjacency, proximity and distance metrics). Moreover, linking location to the attributes of places (i.e. of municipalities or districts) such as the fertility rate and factors potentially associated with fertility allows researchers to examine the role of space and spatial processes (Castro 2007). Spatially informed demographic research seeks to examine whether and how geographical environments directly affect outcomes such as fertility (Delgado et al., 2008; Vitali and Billari 2017; Lerch 2019).

Based on this framework, we used information on relative location of municipalities to create a set of eleven distance-based spatial weights matrices. Spatial weights matrices are required for the application of global and local measures of spatial autocorrelation.[1] Global measurements of spatial autocorrelation provide one set of values that reflects the extent of spatial autocorrelation across the entire study area. Spatial weights matrices based on eleven different Euclidean distance bandwidths were created at 10, 25, 50, 75, 100, 125, 150, 175, 200, 250 and 300 km (e.g. Guilmoto and Rajan 2001).

These spatial weights were used for the calculation of the global Moran's I. In the case of the local indicator of spatial association (Local Moran), maps corresponding to four bandwidths (25, 100, 200 and 300 km) have been prepared for each time interval, testing for the null hypothesis of spatial independence. Based on the local Moran's coefficient at each location, municipalities were classified as (i) High-High (HH) hot spots (high fertility value with similar values among neighbouring municipalities), (ii)

[1] Global and local spatial autocorrelation coefficients provide a comprehensive analysis of the spatial behaviour of a given variable at various territorial scales, moving from the whole study area (global indexes) to the most elementary spatial unit (local indexes). Global measures generate a single metric of overall spatial autocorrelation, whereas local measures draw on a subset of data and are useful for identifying clusters and specific types of clusters (identifying clusters of high values of fertility in adjacent municipalities or "hot spots", as well as clusters of low values of fertility in adjacent municipalities or "cold spots"). Significant and non-significant coefficients respectively indicate the level of spatial clustering and randomness. Use of multiple bandwidths in global analysis identifies specific spatial patterns and regularities at varying ranges, from small-range to large-range similarities in demographic behaviours.

Low-Low (LL) cold spots (low fertility value with similar values among neighbouring municipalities), (iii) High-Low (HL) potential spatial outliers (high fertility values with low fertility values among neighbouring municipalities), (iv) Low-High (LH) potential spatial outliers (low values with high fertility values among neighbouring municipalities) or finally, (v) units spatially uncorrelated with neighbours.

3.3.2 Correlating Local Fertility Rates with the Socioeconomic Context

Ecological variables were calculated for each municipality in the study area. We generated data on (i) population density (inhabitants/km^2), (ii) average municipal elevation (m), (iii) proximity to the sea coast (a dummy variable indicating coastal or inland municipalities), (iv) accessibility (presence/absence of a highway in each municipal area), (v) linear distance (km) to Madrid (the Spanish capital city) and the respective (vi) regional and (vii) provincial head towns. A pair-wise Spearman rank correlation analysis was carried out with the aim to identify the variables associated with the spatial variability of local fertility during economic expansion and recession. Significance was tested at $p < 0.05$ after Bonferroni's correction for multiple comparisons.

4 Results

4.1 Descriptive Analysis

Comparing the periods of economic expansion and recession, a moderate decrease of fertility was observed at the country scale (from 1.5 to 1.4 children per woman) and in all Spanish regions except three low-fertility areas: Asturias (from 1.0 to 1.1), Basque Country (from 1.3 to 1.4) and Galicia (1.1 to 1.2). Melilla fertility increased from 2.2 to 2.6 children per woman, being the Spanish district with the highest birth rate (Appendix Table 2) and driven in part by the large influx of native Moroccans settling in the area and contributing to high fertility. Consistently, Ceuta—another Spanish enclave in North Africa—was the second most fertile district in the country, moving from 2.0 to 1.9 children per woman over the study period. Fertility decline was more evident in the Balearic Islands (from 1.5 to 1.3 children per woman), Andalusia (from 1.6 to 1.4) and the Canarias Islands (from 1.3 to 1.1).

The spatial distribution of local fertility in Spain was assessed using thematic maps (Fig. 1, left). The most evident change between the first and the second time period was the increase of municipalities with a fertility rate < 1 children per woman and the consequent decrease of municipalities with rates > 2. More than half municipalities (4558 out of a total of 8115 or 56%) experienced a decrease in their period fertility rate during the recession. High-fertility municipalities (> 2 children per woman) were concentrated in Southern Spain, around the main cities such as Madrid, Barcelona, Valencia and Seville, along the Mediterranean Sea coast, in the Ebro valley, and in the Basque country. During 2010–2017, 3716 municipalities (46% of the total) recorded fertility rates < 1.These very low fertility municipalities are at an average elevation of 872 m above the sea level and an average population density of 21 inhabitants/km^2 in 2017. Many of these municipalities were concentrated in sparsely populated areas of

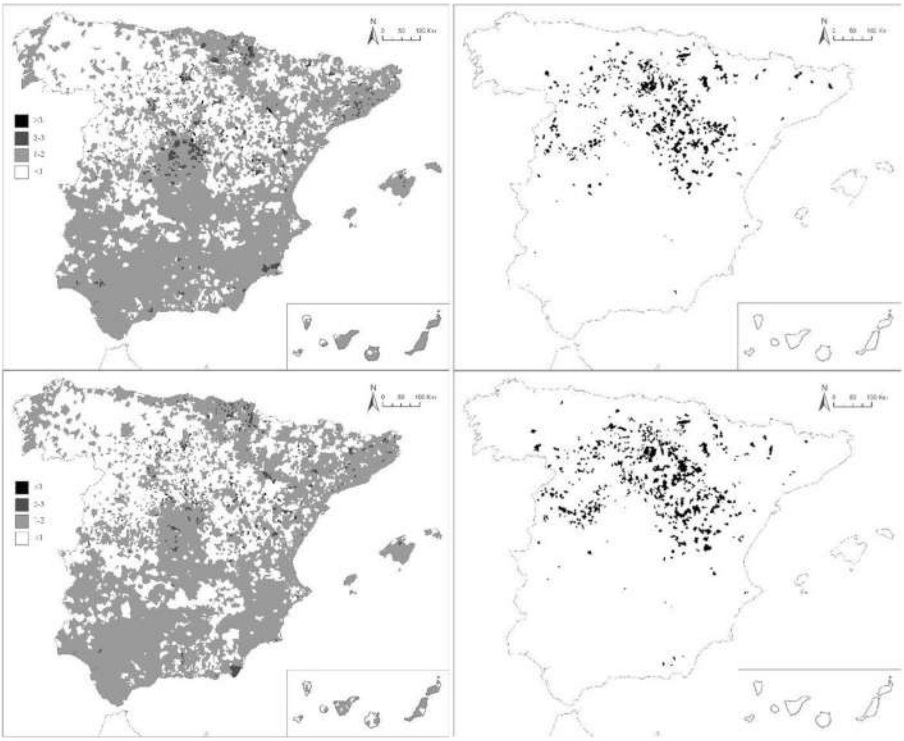


Fig. 1 Total Fertility Rate in Spanish municipalities, 2002–2009 (upper left map) and 2010–2017 (lower left map), and Spanish municipalities where no births were recorded during 2002–2009 (upper right map) and 2010–2017 (lower right map)

Spain, with less than 12 inhabitants/km^2, where the low level of births is associated with depopulation and ageing.

The number of Spanish municipalities where no births were recorded during 2010–2017 increased from 573 to 745 (Fig. 1, right). Most of these municipalities (59.7%) were located in Serranía Celtibérica, the least populated territory in Spain, with an area of 69,875 km^2 and a total population density of 7 inhabitants/km^2. A total of 338 municipalities with no births at both the first and the second time intervals were also identified. These municipalities have an average elevation of 1053 m above the sea level and an average population density of 2 inhabitants/km^2 in 2017. In this set of municipalities, ageing and depopulation processes are the most pronounced in Spain.

4.2 Spatial Autocorrelation Analysis of Local Fertility Rates

The Global Moran's index of spatial autocorrelation of local fertility rates (z scores) is illustrated in Fig. 2 for the 11 bandwidths. A systematic decrease over time in the Moran's index was observed for all bandwidths, outlining a more heterogeneous spatial distribution of local fertility rates during the recession. Local Moran's indexes of spatial autocorrelation in fertility rates were calculated separately for two time intervals (2002–2009 and 2010–2017) and four bandwidths (25, 100, 200 and 300 km). Briefly, high

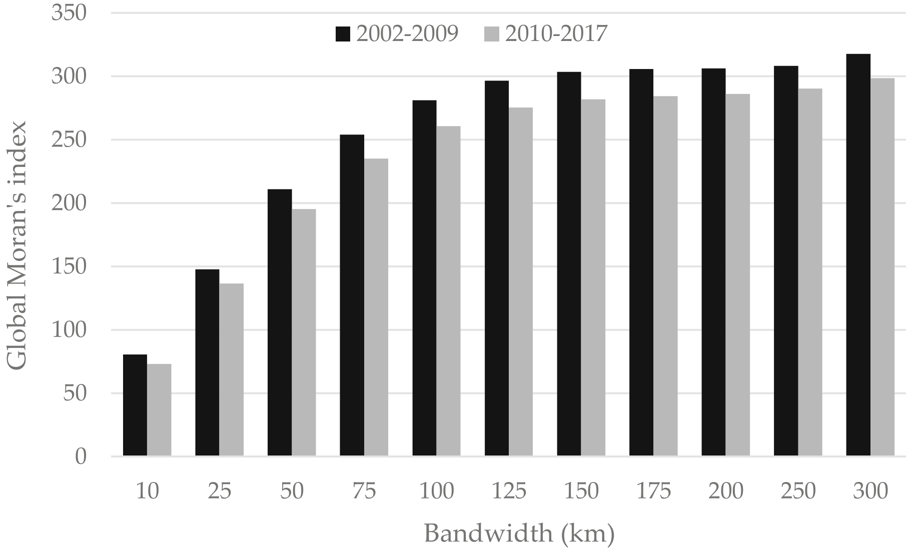


Fig. 2 Global Moran's index of spatial autocorrelation of fertility rates in Spanish municipalities by time interval and bandwidth

fertility clusters were observed around Madrid, along the Mediterranean Sea coast, in Catalonia, Basque Country, Balearic Islands, Murcia and Andalusia (Fig. 3). Low fertility clusters are concentrated in Northern and North-Western Spain (Castilla and León, Galicia, Asturias, Cantabría, La Rioja and the Western part of Aragon).

4.3 The Influence of the Territorial Context on Local Fertility

Results of a non-parametric Spearman correlation analysis highlight the importance of elevation in the spatial distribution of fertility rates in Spain (Table 1). Flat, low lying municipalities had systematically higher fertility rates than mountainous and upland areas in both observation periods. Fertility increased significantly in those municipalities with medium and high population densities and positive rates of population growth. Conversely, fertility levels decreased in districts with limited accessibility to the provincial capital city and the capital of the related administrative region. Proximity to the sea coast was a non-significant factor in the spatial variability of fertility levels in Spain.

5 Discussion

Our descriptive analysis of birth rates provides a refined outline of changes in the local demographic context during periods of both economic expansion and recession, and sheds light on the latent linkage between fertility and depopulation in rural municipalities (Delgado et al. 2006). We have identified areas with persistently low fertility (< 1 children per woman) and municipalities with no births (Gil-Alonso et al. 2017), irrespective of the economic cycle. As expected, these low-fertility municipalities correspond to rural (< 50 inhabitants/km^2) or hyper-rural (< 10 inhabitants/km^2)

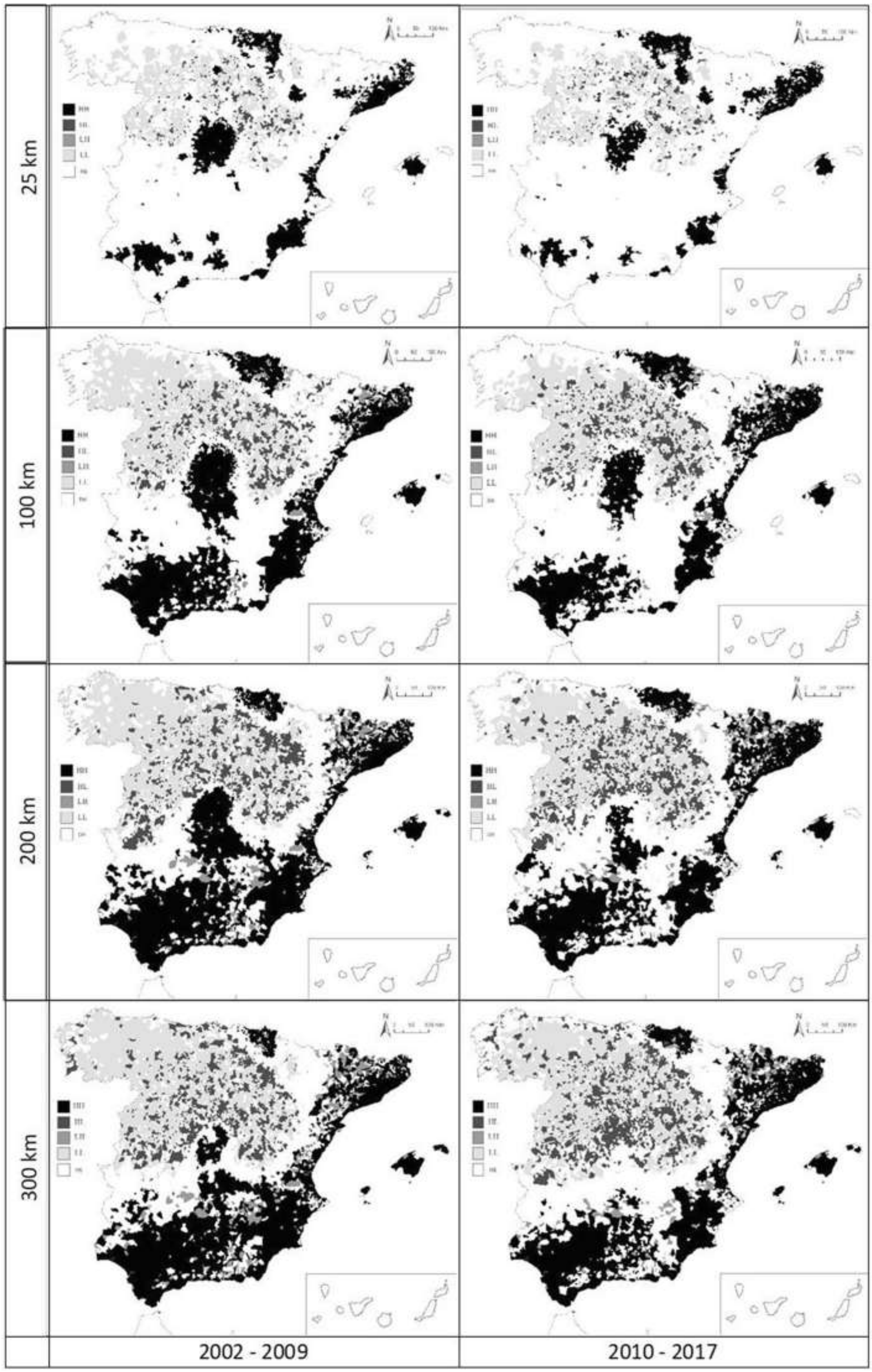


Fig. 3 Local Moran's spatial autocorrelation coefficients of fertility rate in Spanish municipalities by clustering typology (High-High, High-Low, Low-High and Low-Low), time period and bandwidth

Table 1 Pair-wise Spearman non-parametric correlation coefficients between local fertility rate by time period and contextual variables measured at the municipal scale in Spain (italic indicates significant coefficients at $p < 0.05$ after Bonferroni's correction for multiple comparisons)

Variable	2002–2009	2010–2017
Population density	*0.53*	*0.50*
Population growth rate	*0.64*	*0.53*
Elevation	*− 0.39*	*− 0.40*
Proximity to the sea coast	0.14	0.12
Road accessibility	0.12	0.14
Distance from Madrid	*0.24*	*0.27*
Distance from regional head town	*− 0.23*	*− 0.22*
Distance from provincial head town	*− 0.23*	*− 0.24*

locations and are characterised by limited road accessibility, demographic ageing, land abandonment and intense population decline.

Internal migration to urban centres—especially in the 1960s and the 1970s, and less evidently in the subsequent decades—has exacerbated the fragile demographic context of many rural districts, including areas with multiple compositional changes in the resident population (e.g. by age, sex, educational attainment and employment status; Rodriguez-Rodriguez, 2000). A moderate fertility decline observed in Spain during the most recent decade provides additional context (Bernardi and Roquena 2003), reflecting only marginally the impact of the 2007 recession.

In this context, several macro-level factors contributed to the decline in fertility in Spain. Some of these macro-level factors likely played a similar role during periods of expansion and recession. Rising women's education and participation in the job market were recognised as key drivers of childbearing postponement (Adsera, 2006a; Rosti and Chelli 2012; Lesthaeghe and Lopez-Gay 2013; Baizán 2009; Vitali and Billari 2017). Women's access to education has major implications for work, marriage (or cohabitation) timing and childbearing (Van Bavel 2012). In addition, factors such as greater participation in and the lengthening of university study over time was particularly intense in Southern Europe (Billari et al. 2007; Chelli et al. 2009; Carlucci et al. 2018). As in other Mediterranean countries, having secure employment, an adequate income level and owning a home are frequently seen as a pre-requisites before considering childbearing (Martín García, 1992, 2010; Mills et al. 2011; Rosti and Chelli 2009). Childbearing postponement in Spain was also associated with social and psychological factors such as religious attitudes, having been born in a city or in a rural area and family status (Reher and Iriso-Napal 1989; Chelli and Rosti 2002; Oinonen 2004; Lesthaeghe and Lopez-Gay 2013; Martin-Garcia and Castro-Martín, 2013). Although in most recent times the role of assisted reproduction—which is allowed in Spain for both married and single women—rose rapidly, children generated through this technique have increased only slightly from 2.5% of the total births in 1996 to 4.1% in 2011 (Melo-Martín 2009), contributing to total fertility but negligibly.

However, the Great Recession, as experienced in Spain, intensified job shortages and increased poverty in both urban and rural areas (Roig and Castro Martín, 2007). Similarly, the recession influenced net migration in Spain (Baizán 2009), boosting emigration abroad and reducing immigration and, thereby, also fertility (Sabater and Graham 2019). These results contrast with the empirical evidence found in earlier studies and indicate a slight fertility recovery starting in 2000—a period corresponding with intense economic expansion reflected in the housing bubble typical of urban areas and coastal districts—reinforced by an accelerated flow of high-fertility immigrants from developing countries (Reher and Sanz-Gimeno 2007; Cooke 2009; Requena and Salazar 2014). The contribution of non-native women to Spanish fertility grew from 1.6% in 1998 to 12.2% in 2010 (Roig and Castro Martín 2007), although the absolute level of TFR increased about 0.08 children per woman during the same period (Castro-Martín and Rosero-Bixby 2011).

While differences in the level of fertility were relatively small between economic expansion and recession at the local scale, changes in the spatial regime observed for local fertility rates were evident in the two time periods. Indeed, the moderate recovery in fertility observed during the 2000s economic expansion coincided with a particularly clustered distribution of births. This pattern was quite stable across spatial scales, being observed at higher, more aggregate levels than reported here (Ciommi et al. 2018). More specifically, the Local Moran clusters showed a polarised fertility regime, with a pronounced divide between Northern and Southern Spain, and including more evident local-scale differentiations. These findings highlight the influence of urban gradients in both high-fertility regions (e.g. Madrid, Catalonia and Andalusia) and the rest of the country. With recession, fertility decline at the country scale coincided with a lower spatial polarisation on a regional scale and greater heterogeneity on a local scale. Increasing spatial heterogeneity of local fertility is consistent with findings from other Mediterranean countries (Ciommi et al. 2019). Although the most significant factors shaping spatial variability of fertility levels were associated with urban-rural and the coastal-inland gradients, the statistical association with fertility rates decreased during the recession period. Additionally, Local Moran's coefficients have demonstrated the existence of a significant regime of spatial autocorrelation characterising local fertility in specific areas of Spain, with a progressive decline of high-fertility districts (Gil-Alonso et al. 2017). Taken together, these results indicate a greater spatial diversification of demographic behaviours during recession, being progressively decoupled from the socioeconomic characteristics of the local context and likely more influenced by multi-scaled (i.e. regional and national-level) exogenous factors, mostly of economic origin (Tragaki and Bagavos 2019). Although in line with earlier results from Italy (Salvati et al. 2020), this interpretation needs comparative empirical verification in other country contexts with similar economic dynamics (e.g. Greece, Portugal or, even, France).

Irrespective of economic downturns, a persistent decline of local fertility may be considered an early-warning indicator of depopulation in rural districts and can be used to delineate demographically fragile areas (Reynaud et al. 2020). A time horizon of about 10 years was considered a sufficiently long period to investigate persistence (or change) in a given demographic regime on a local scale (Salvati et al., 2019). In this study, spanning 16 years, the number of municipalities with zero fertility was relatively high in Spain and grew substantially with the economic crisis (e.g. Salvati and Carlucci 2017). This underlines a process of spatial fragmentation that may be driven by changes in local socioeconomic contexts, embedded within regional and national systems (Ciommi et al. 2017).

The increased unpredictability of spatio-temporal changes in small-scale fertility rates makes it difficult to estimate the contribution of different spatial trends to fertility rates on a national scale. At the local scale, a persistently low fertility level can be considered a proxy of shrinking populations, anticipating ageing and related social problems (from consolidation/closing of schools to improved health care services' needs). These results inform more specific (and context-based) development policies that might support population stability in hyper-rural districts and contribute to seeking to maintain birth rates in the most accessible rural locations (Bernardi 2005; Delgado et al. 2006; Kalwij 2010; Gigliarano and Chelli, 2016).

All of this confirm the existence in Spain of an emerging issue related to demographically fragile regions and spatially unbalanced development. On a broader scale, this is a key issue on which the European Union (EU) has worked since the early 1990s. Within the EU, depopulated territories and shrinking regions lead to uneven spatial development and this could undermine the socioeconomic cohesion of individual countries and supranational areas like the EU (European Commission, 1999; Espon 2017). From this perspective, it is critical to know and understand the demographic drivers of local territorial 'vitality' to devise appropriate policy and interventions that might mitigate spatial demographic disequilibrium. Just 20 years ago, at the beginning of globalisation process, the EU commission stated that a balanced spatial distribution of the population must be the goal of the EU (European Commission, 1999).

The original contribution of this study lies in the spatial analysis of fertility observed at a granular, detailed level (i.e. municipality) within Spain over periods of economic expansion and recession. This allows a thorough understanding of global and local fertility patterns and reveals increased spatial heterogeneity in fertility rates over time. The empirical evidence describing subnational patterns and trends can be useful in designing targeted development policies within a national framework, customizing needs to specific contexts such as urban, suburban, and rural municipalities. In this regard, spatial analysis can shed light on the latent relationship between patterns and the processes generating those patterns at the local level and at the regional and national levels. In doing so, spatial analysis may reveal and thus improve our knowledge of complex multi-scale processes within and across spatial scales. By identifying areas with persistent population decline (low fertility and ageing during both economic expansion and recession), we contribute to identify demographically dynamic and fragile areas. Developmental policies may indirectly benefit from this territorial classification. Place-specific measures promoting a spatially balanced development are particularly required in low-fertility, heterogeneous social contexts, since demographically fragile districts are likely to be more at risk when exposed to exogenous shocks and less resilient to economic crises. Further investigation of the main socioeconomic determinants of local fertility is required through the use of dedicated techniques including spatial regime models or multi-scale Geographically Weighted Regressions (Fotheringham et al., 2017).

6 Conclusion

A comprehensive analysis of Spanish fertility at the municipal scale outlines location and extent of depopulation processes in economically marginal areas. Our analysis indicates that high fertility clusters were progressively restricted to suburban districts and highly accessible rural areas, providing the highest contribution to Spanish fertility. A spatial analysis of local fertility along sequential economic downturns is appropriate to identify areas structurally affected by specific demographic problems (e.g. depopulation and ageing in economically marginal districts) and to inform development policies supporting population stability (or growth) in rural (or hyper-rural) districts and simultaneously the maintenance of high birth rates in more accessible (suburban or urban) locations.

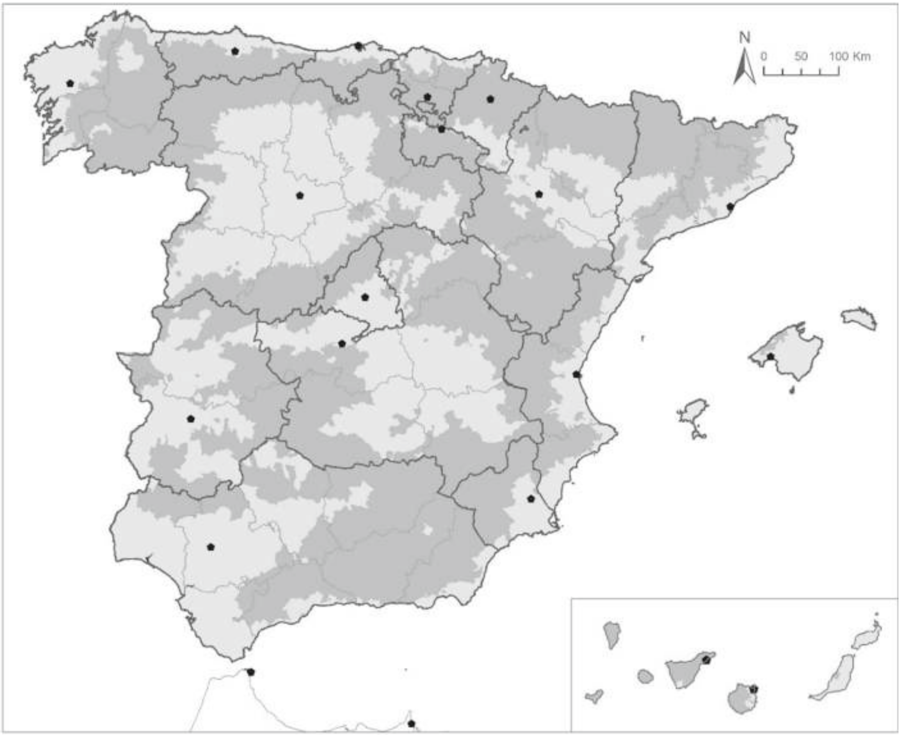
Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Research Involving Human Participants and/or Animals No humans or animals involved.

Informed Consent All authors agree with this submission.

Appendix



Legend: Black stars indicate the location of regional head towns. Dark grey areas represent mountain municipalities.

Fig. 4 Map of Spain with delimitation of regional authorities (Comunidades Autonomas) and provinces

Table 2 Total Fertility Rate in Spanish regions by time period

Region	2002–2009	2010–2017
Andalucía	1.6	1.4
Aragón	1.4	1.4
Principado de Asturias	1.0	1.1
Islas Baleares	1.5	1.3
Canarias	1.3	1.1
Cantabria	1.3	1.3
Castilla and León	1.2	1.2
Castilla-La Mancha	1.5	1.4
Cataluña	1.6	1.5
Comunidad Valenciana	1.5	1.4
Extremadura	1.3	1.3
Galicia	1.1	1.2
Comunidad de Madrid	1.5	1.5
Región de Murcia	1.7	1.6
Comunidad Foral de Navarra	1.5	1.5
Basque Country	1.3	1.4
La Rioja	1.5	1.4
Ceuta	2.0	1.9
Melilla	2.2	2.6
Spain	1.5	1.4

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