


Article

Population Trends and Urbanization: Simulating Density Effects Using a Local Regression Approach

Gloria Polinesi ¹, Maria Cristina Recchioni ¹, Rosario Turco ², Luca Salvati ^{3,*}, Kostas Rontos ⁴, Jesús Rodrigo-Comino ^{5,6}  and Federico Benassi ⁷

¹ Department of Economic and Social Science, Polytechnic University of Marche, Piazza Martelli 8, I-60121 Ancona, Italy; g.polinesi@univpm.it (G.P.); m.c.recchioni@univpm.it (M.C.R.)

² Council for Agricultural Research and Economics (CREA), Viale Santa Margherita 80, I-52100 Arezzo, Italy; rosario.turco@crea.gov.it

³ Department of Economics and Law, University of Macerata, Via Armaroli 43, I-62100 Macerata, Italy

⁴ Department of Sociology, University of the Aegean, EL-81100 Mytilene, Greece; k.rontos@soc.aegean.gr

⁵ Physical Geography, Trier University, 54286 Trier, Germany; rodrigo-comino@uma.es

⁶ Soil Erosion and Degradation Research Group, Department of Geography, University of Valencia, 46010 Valencia, Spain

⁷ Italian National Institute of Statistics (ISTAT), Piazza G. Marconi 44, I-00144 Rome, Italy; benassi@istat.it

* Correspondence: luca.salvati@unimc.it

Received: 23 June 2020; Accepted: 17 July 2020; Published: 18 July 2020



Abstract: Density-dependent population growth regulates long-term urban expansion and shapes distinctive socioeconomic trends. Despite a marked heterogeneity in the spatial distribution of the resident population, Mediterranean European countries are considered more homogeneous than countries in other European regions as far as settlement structure and processes of metropolitan growth are concerned. However, rising socioeconomic inequalities among Southern European regions reflect latent demographic and territorial transformations that require further investigation. An integrated assessment of the spatio-temporal distribution of resident populations in more than 1000 municipalities (1961–2011) was carried out in this study to characterize density-dependent processes of metropolitan growth in Greece. Using geographically weighted regressions, the results of our study identified distinctive local relationships between population density and growth rates over time. Our results demonstrate that demographic growth rates were non-linearly correlated with other variables, such as population density, with positive and negative impacts during the first (1961–1971) and the last (2001–2011) observation decade, respectively. These findings outline a progressive shift over time from density-dependent processes of population growth, reflecting a rapid development of large metropolitan regions (Athens, Thessaloniki) in the 1960s, to density-dependent processes more evident in medium-sized cities and accessible rural regions in the 2000s. Density-independent processes of population growth have been detected in the intermediate study period (1971–2001). This work finally discusses how a long-term analysis of demographic growth, testing for density-dependent mechanisms, may clarify the intrinsic role of population concentration and dispersion in different phases of the metropolitan cycle in Mediterranean Europe.

Keywords: density-dependent population growth; urban indicators; metropolitan cycles; socioeconomic change; Greece

1. Introduction

Socioeconomic transformations and demographic transitions stimulate (or slow down) urbanization, leveraging differential mechanisms of metropolitan growth and rural development [1–4]. In this perspective, population density is a pivotal dimension shaping the demographic growth

(or decline) of small to large areas [5–11]. Being intimately associated, a comprehensive understanding of local development and demographic dynamics requires long-term investigations that may clarify the role of changing socioeconomic contexts [12–16]. Population concentration is one of the most powerful factors of demographic growth, summarizing the impact of different forces that modify economic structures and promote social change [17–19]. Human population dynamics are associated with density-independent or density-dependent mechanisms [20]. While the former models hypothesize that population growth rates are dependent on the environment—with density independence being a time-invariant property of a given socioeconomic system—the latter models represent quite common processes in specific local contexts. Such mechanisms are usually analyzed considering changes in density over time and population growth rates together [21–23]. Assuming growth rate as a (linear or non-linear) density function, density-dependent mechanisms of population growth show differences considering the impacts, causes, reactions, dynamics and severity of change [24]. On the one hand, positive density dependence delineates a context where demographic expansion is accelerated in contexts with high population density [25]. On the other hand, negative density dependence processes depict a local context where population concentration limits demographic growth [26].

Density-dependent processes regulating population growth are considered as factors at the base of regional development and economic dynamics. When extensively studied in non-human populations [27], density-dependent mechanisms of population increase (or decrease) show complex regulatory processes at the local scale [28–30]. Earlier studies demonstrated that the density-dependent regulation of demographic dynamics is a particularly complex process because of the inherent variability and diversity and the multiple impacts of socioeconomic forces and territorial (or normative) constraints affecting settlement density, economic development, social change and demographic dynamics [31–34].

The aim of this research, considering population growth rate as a density-dependent variable, is to assess the intrinsic linkage between population growth and demographic density. Assuming the complex spatial association between demographic density and population growth [26,35,36] as an intrinsic property of local communities, non-linear mechanisms of population regulation reflect feedback impacts on socioeconomic contexts at large [3,37,38]. For instance, population growth was demonstrated to intensify with urban concentration up to a specific density amount [39], declining at higher levels of population concentration (e.g., displaying the negative externalities of over-crowding). This assumption may reinforce models simulating urban expansion with agglomeration benefits or negative impacts of metropolitan congestion (e.g., [1,7,40]). Focusing on the identification of density-dependent processes of population growth, this study represents a quantitative approach with some novelties in comparison with earlier research. The main difference is in the adoption of a local regression model when analyzing density-dependent (or density-independent) mechanisms of population growth at a sufficiently disaggregated spatial scale. Local regressions provide a unique opportunity to reliably estimate the local-scale relationships of density dependence in demographic dynamics. Thanks to geo-information approaches, passing from global to local spatial approaches may advance regional economics and spatial demography.

Density-Dependent Mechanisms of Population Growth in Europe

In recent decades, population increase and metropolitan expansion became progressively more heterogeneous and less predictable over space, with depopulation being a common trend in advanced economies. This is especially relevant in long-established rural territories. At the same time, detecting the most evident demographic dynamics in specific socioeconomic contexts at low and very low population densities [41–44], Alados and coworkers [45] compared the empirical evidence from density-independent and density-dependent models in advanced economies of Europe. They found that some areas showed density-dependent (positive) feedback from 1960 to 2010. The interplay between agricultural activities and population size was demonstrated to be at the base of such long-term trends. In the coming future, this may result in a strong modification of population structures and demographic dynamics driven by (i) a latent shrinkage of rural communities and (ii) intense

mobility to peri-urban districts, suggesting how population collapses are associated with abrupt territorial transformations [46,47]. As a result, complex socio-ecological systems are molded by strong feedback mechanisms (e.g., [48]) and non-linear interactions among the constituting elements [37], fixing, or even perturbing, their intrinsic regulation [49]. In this regard, the negative impact of population concentration has been widely investigated [50–54]. This impact may lead to settlement dispersion [55], determining (i) population shrinkage (which hardly reverts to demographic stability) or (ii) irreversible processes of extinction in a certain location [55]. Conversely, positive density-dependent effects were regarded as explosive, and therefore unstable and less predictable [41,54]. To date, studies of density-dependent mechanisms in human populations have mainly been carried out over a broad geographical coverage, using low- or intermediate-resolution elementary analysis spatial units (e.g., regions within the same country or continent). Some authors compared local-scale population changes under similar (or specific) socioeconomic contexts and their results depicted key forces delineating latent mechanisms at the base of population growth [56–60]. While being informative at aggregated spatial scales, the local assessment and empirical testing of demographic dynamics along urban–rural gradients are fragmented and partial in many European countries [40,51,57,61]. If we consider urban and rural demographic trends during sufficiently long time windows, these results may illustrate latent socioeconomic transformations better than other indicators [13,62–64].

Multiple key drivers were recognized as influencing the spatial distribution of European resident populations from low to high density [65–69]. Metropolitan development has been associated with increasing population densities [70–73]. At the same time, dispersed urbanization took place in mixed, peri-urban locations [74–77]. Subsequently, some authors argued that suburbanization has been extensively molded by metropolitan structures and socioeconomic functions at large, leveraging population decreases in large cities and unexpected growth in peripheral areas [6,37,65,78–81]. Given the pervasiveness of recent metropolitan transformations [57,74,82], density-dependent population growth has been less investigated in Southern Europe than in other European regions, considering urban–rural demographic dynamics in only a few cases [15]. At the same time, the Mediterranean belt is well recognized as a paradigmatic region displaying quite homogeneous demographic trends and compact–dense urban structures [83]. In this regard, the spatial analysis of demographic dynamics may clarify the role of agglomeration factors in settlement consolidation, especially in countries (or regions) experiencing “urbanization without industrialization”, such as Greece, Southern Italy, rural Spain and some parts of Portugal. Despite regional differentiation, these territories showed similar demographic dynamics after World War II [84,85]. In such contexts, new studies developing a spatially explicit analysis of population distribution may better delineate factors affecting local-scale demographic expansion along specific density gradients.

A comparative assessment of five time steps encompassing a range of 50 years could enhance the detection of intrinsic drivers, leveraging a given settlement model and the potential factors that affect territorial imbalances at the same time (e.g., [86,87]). Based on spatially explicit local regressions, the results of the empirical analysis identified districts with positive (or negative) density-dependent mechanisms of population growth. These results contribute to the inference of density levels that could evidence a turnaround from a positive to a negative (or vice versa) influence in areas with high (or low) settlement concentrations [54,86,87]. The spatially explicit approach implemented in this study—based on geographically weighted regression models—evaluates the impact of both urban concentration and rural depopulation in Greece, a country that had differentiated population trends in the decades immediately following World War II [88–90]. With homogeneous databases and statistical data at a sufficiently disaggregated spatial scale being scarce or partial, and often needing standardization, validation and control checks [64,67,91], a within-region test for density-dependent population growth in Southern European countries would significantly benefit from classifications referring to the Nomenclature of Territorial Statistical Units system (EUROSTAT). More specifically, from official data collected at the spatial level of municipalities, EUROSTAT published long-term, stabilized demographic data derived from national censuses of populations and households (1961–2011). This allows a

comparative analysis of demographic dynamics to investigate the latent effect of density-dependent mechanisms of population expansion (or decline). We consider that local-scale population growth rates are associated with some intrinsic properties of local systems that include urban concentration or rural depopulation. In our study, intensity and spatial trends in both urban concentration and rural depopulation will be considered as a result of local-scale population trends, whose knowledge would help to inform strategies of regional management in adapting to multifaceted local contexts [8,66,92–95].

2. Methodology

2.1. Study Area

Greece extends across 131,957 km² in Southeastern Europe, with 13 administrative regions, nearly 50 prefectures (Figure 1) and more than 1000 municipalities.



Figure 1. An administrative map illustrating regions and prefectures of Greece.

Long-term population growth in this country has been particularly heterogeneous over time (Figure 2), rising slowly between 1821 and 1907, and increasing more rapidly between 1907 and 1951, mostly because of refugee immigration from Asia Minor and high fertility. Since 1951, the resident population grew in a rather linear fashion, passing from 8 million inhabitants in 1951 to nearly 11 million inhabitants in 2001, and declining slowly in the subsequent two decades. Based on this evidence, the present study evaluates demographic trends in Greece during a period characterized by continuous and mostly linear population growth. Despite some regional differences, post-war population trends were exemplifications of demographic dynamics typical of Southern Europe. While displaying heterogeneous demographic trends at the regional and local scales, overall population

density in Greece was rather low (less than 100 inhabitants/km²), with the highest value observed in 2000.

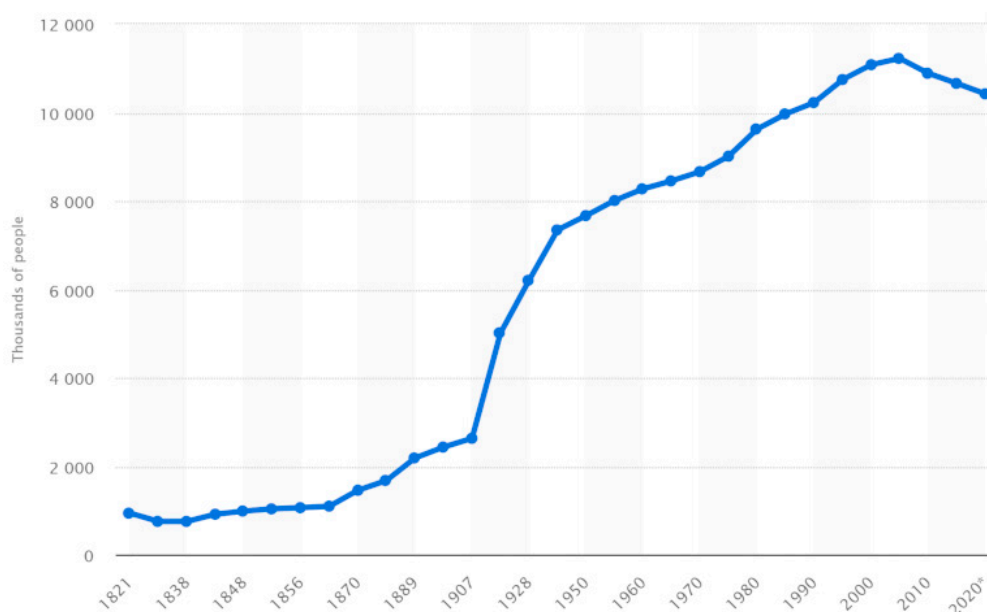


Figure 2. Total population growth since the unification of the Greek state (* 2020 estimate).

The population is concentrated in a few urban areas (Table 1). Considering a time window between 1955 and 2019, positive population growth rates were observed continuously over the period 1955–2000. The urban population amounted to 54% of the total population in 1955, growing to up to 84% in 2019. Similar to other Mediterranean countries, population aging was likely the most relevant characteristic of the post-war demographic transition in Greece: the median age of the population increased from 27 to 44 years between 1955 and 2019. Conversely, the total fertility rate has halved over less than 50 years (1955–2000), recovering slightly in 2010 (1.42) and decreasing to 1.34 in 2019.

Table 1. The evolution of selected demographic indicators over time in Greece.

Year	Total Population (Inhabitants)	Annual Rate of Change (%)	Population Density (Inhabitants/km ²)	Urban Population (%)	Median Age (Years)	Total Fertility Rate
1955	8,011,124	0.88	62	54.1	26.9	2.48
1960	8,273,629	0.65	64	55.9	28.3	2.42
1970	8,663,571	0.49	67	64.2	32.2	2.55
1980	9,627,002	1.32	75	69.4	33	2.42
1990	10,225,992	0.51	79	71.6	35.1	1.53
2000	11,082,104	0.62	86	73.1	38	1.31
2010	10,887,637	−0.61	84	80.2	41.1	1.42
2015	10,659,750	−0.42	83	82.1	43.4	1.34
2019	10,473,455	−0.46	81	84.3	43.8	1.34

Greek urban settlements are mostly polarized and divided, with an intrinsically dense metropolitan system centered on the capital city region (Athens, Attica), hosting more than 30% of the total population residing in the country. Municipal boundaries and the spatial location of settlements are illustrated in Figure 3, outlining an asymmetric distribution of the population in 1961. A slightly more balanced settlement structure was observed in 2011. Maps of the annual rate of population increase (%) for selected, representative decades illustrate three diverging settlement models: (i) a centralized population increase concentrated in Athens (Attica) and Thessaloniki (Central Macedonia) between 1961 and 1971, (ii) a more diffused population growth over the whole country, especially in highly

dynamic rural areas between 1981 and 1991 and (iii) a decentralized growth of medium-sized cities, coastal districts and more accessible rural districts.

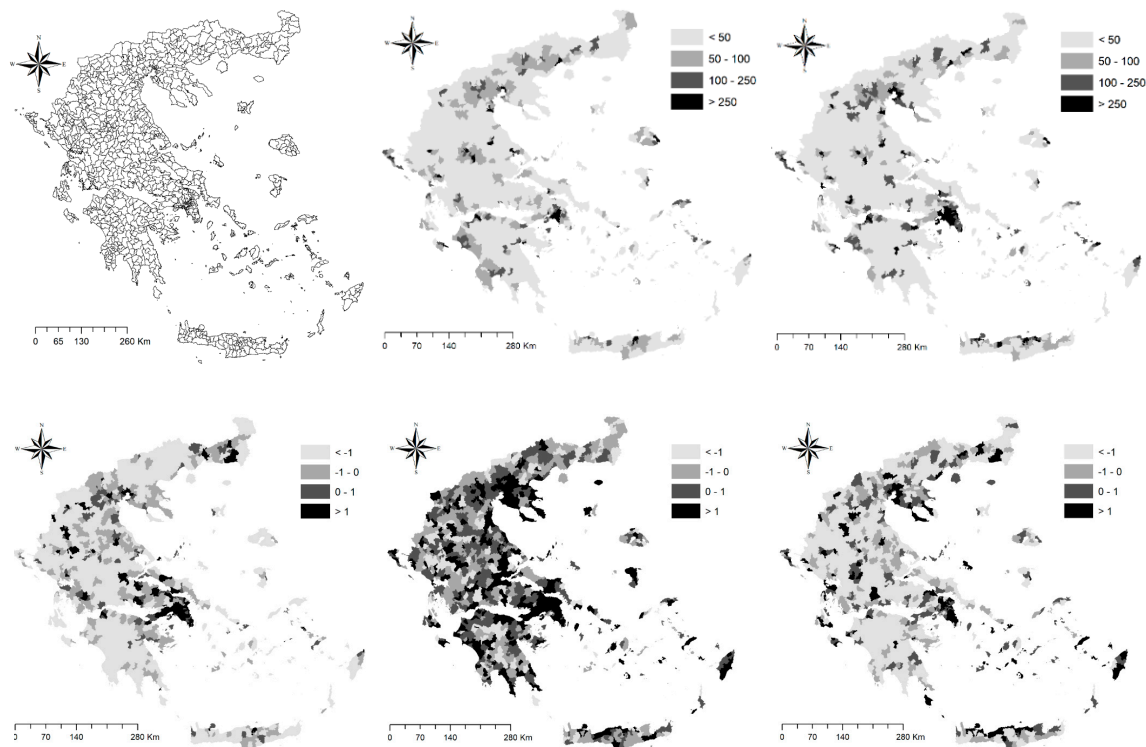


Figure 3. Maps illustrating Greek municipalities (upper left), population density (inhabitants/km²) for 1961 and 2011 (upper middle and upper right) and population growth rate (%) over three decades (1961–1971: lower left; 1981–1991: lower middle; 2001–2011: lower right).

2.2. Data Sources and Demographic Variables

This study adopted local administrative units (LAUs) as the elementary spatial domain of the Nomenclature of Territorial Statistical Units (NUTS). They are mostly homogeneous local communities from the socioeconomic and territorial perspective. Being administered by homogeneous local authorities, LAUs play a role in official statistics thanks to the extensive availability of census data with a regular acquisition/publication schedule (10 years) and relevance for both positive approaches and normative analysis/implementation. In this line of thinking, EUROSTAT, the Statistical Office of the European Commission, provided a homogeneous set of spatial units and boundaries for the country, and a comprehensive sample of demographic data obtained from census sources for every LAU-1 unit (1961, 1971, 1981, 1991, 2001 and 2011). The present study made extensive use of such a data source for Greece, following the specific indications provided by EUROSTAT (<https://ec.europa.eu/eurostat/web/nuts/local-administrative-units#:~:text=The%20spatial%20level%20of%20detail,Turkey%20have%20LAU%2D1%20coverage>).

Based on earlier research [3,9,10,24,45], the present study was grounded in a spatially explicit analysis of two variables (demographic density and the annual rate of population growth) at the spatial level mentioned above. Population density (resident population per municipal area in inhabitants/km²) and per cent annual rate of population growth at five different intervals (1961–1971, 1971–1981, 1981–1991, 1991–2001, 2001–2011) were estimated for each spatial unit. Data were processed and analyzed with spreadsheets and mapped in ArcMap release 10.5 (ESRI, Redlands, CA, USA) using a shapefile of Greek municipalities. Spatial autocorrelation analyses of spatial dependence and heterogeneity, based on global and local Moran's coefficients and a local regression approach

(geographically weighted regression) controlling for spatial structures separately for each time point, were adopted in this study and are described extensively in the following section.

2.3. Statistical Analysis

Considering the above-mentioned municipal-level data, (global and local), Moran's spatial autocorrelation coefficients (z-scores of the Moran's I) were calculated for population density at the beginning (1961) and the end (2011) of the study period. Global Moran's spatial autocorrelation coefficients of population growth rates were tested for significance at $p < 0.001$ separately for five time intervals (1961–1971, 1971–1981, 1981–1991, 1991–2001, 2001–2011). A significant global Moran's coefficient at a given bandwidth indicated spatial dependence at the country scale [96]. A comprehensive analysis of variations in the global Moran's coefficients for five bandwidths (10, 25, 50, 100 and 150 km) quantified spatial interactions in the studied variable across a broad scale range, from local (10 km) to regional (150 km).

To study spatial structures of population distribution (e.g., clustering or random location), Moran's local coefficients of spatial autocorrelation were also computed for the same time schedule for each elementary analysis unit (municipalities) and were tested for significance at $p < 0.001$. Significant coefficients indicate spatial clustering of the studied variable [80]. Four spatial autocorrelation regimes were classified for each time point based on significant Moran's z-scores: clusters of municipalities with homogeneous population dynamics and (i) positive spatial auto-correlations (High–High clusters, "HH") or (ii) negative spatial auto-correlations (Low–Low clusters, "LL"), and clusters of municipalities with heterogeneous population dynamics forming transitional spatial gradients from (iii) high to low rates of population growth (High–Low clusters, "HL") and (iv) from low to high rates of population growth (Low–High clusters, "LH").

The local-scale relationship between population density at time t (dependent variable) and population growth rate between t and $t+x$ time points (independent variable) was analyzed separately for five time windows using (i) three correlation coefficients that separately explore a linear linkage (Pearson moment-product) and non-linear associations (Spearman rank and Kendall co-graduation) and (ii) three global, aspatial regression models testing (a) a linear structure reflecting the effect of population density on demographic trends along the urban gradient, (b) a quadratic shape considering a divergent (positive or negative) effect of urban concentration on growth rates depending on a given density threshold and (c) a cubic equation considering a divergent impact of settlement concentration on growth rates depending on two thresholds. These forms were evaluated as the best-fit estimation of equations (a–c) adopting empirical data with an adjusted R^2 . Regressions were then separately applied for each study period. The population density was log-transformed before analysis.

The results of the aspatial models were refined, adopting a geographically weighted regression (GWR) strategy controlling for population distribution over space. According to Fotheringham et al. [96], GWR identifies local-scale variability in population dynamics, assessing the contribution of demographic density to total population growth at a municipal scale [96]. By implementing a kernel filter to estimate local regression coefficients, the GWR model can be modeled, as follows, at each point $s = 1, \dots, n$:

$$Y(s) = X(s)B(s) + e(s)$$

where $Y(s)$ represents the dependent variable at each location s (population growth rate) and $X(s)$ indicates the independent variables at location s (population density). $B(s)$ is the column vector of regression coefficients at each location s . Finally, $e(s)$ identifies the model residual at each location s . Regression coefficients work as a function of s , covering the whole study area [e.g., 50].

Global adjusted R^2 values were used to compare the GWR performances with those of aspatial models. Local adjusted R^2 (municipal level) values were used to estimate stability over time, internal coherence and the reliability of the GWR model [97]. While it is an appropriate methodology for controlling for spatial dependence and heterogeneity [98], the limits of the use of GWR are intrinsically linked with the difficult interpretation of extreme regression coefficients, and how to draw conclusions

based on restricted sample sizes. The extensive sample size in our case justifies the use of such a methodology, which remains one of the most widely adopted in social science. The results of the GWR provide, for each municipality, an estimation of the local connections between the dependent variable and the predictor, evidencing (i) a local impact of density on population growth (local regression slope and intercept), (ii) the model's local uncertainty (regression residual) and (iii) the model's fit (local adjusted R^2). The results of the GWR are illustrated through maps representing the spatial distribution of regression coefficients (i–iii).

3. Results

3.1. Analysis of Spatial Auto-Correlation Regimes of Population Growth

Moran's global coefficients of spatial autocorrelations provide an overview of the territorial structure of population growth in the study area (Table 2). The empirical results at multiple bandwidths outline spatial interactions ranging from the local scale (10 km) to the regional scale (150 km) and indicate how Moran's coefficients are particularly high and statistically significant for population density (Figure 4). This indicates the persistence of a spatial structure with intense (local and regional) interactions that reflect the urban–rural gradient in Greece, with polarization in high-density areas (Athens and Thessaloniki) and low-density rural districts. The global autocorrelation coefficients reach the highest value for intermediate bandwidths (50 km). At a local scale (10 km bandwidth), the global spatial autocorrelation coefficients were found to be particularly high in 1961 and 2011, while a completely different pattern was observed at broader geographical scales.

Table 2. Global Moran's spatial autocorrelation coefficients for demographic density (1961 and 2011) and population growth rates in Greece (1961–2011); all coefficients are significant at $p < 0.001$.

Bandwidth (km)	Population Density		Annual Population Growth Rate (%)				
	1961	2011	1961–1971	1971–1981	1981–1991	1991–2001	2001–2011
10	185.1	174.6	120.3	68.1	39.7	25.1	18.4
25	214.6	229.2	166.0	103.4	55.2	32.4	31.5
50	205.7	232.9	172.0	119.2	62.3	35.8	36.1
100	201.2	230.0	170.9	120.6	62.3	35.2	39.4
150	198.7	227.3	170.0	119.6	61.7	34.0	40.3

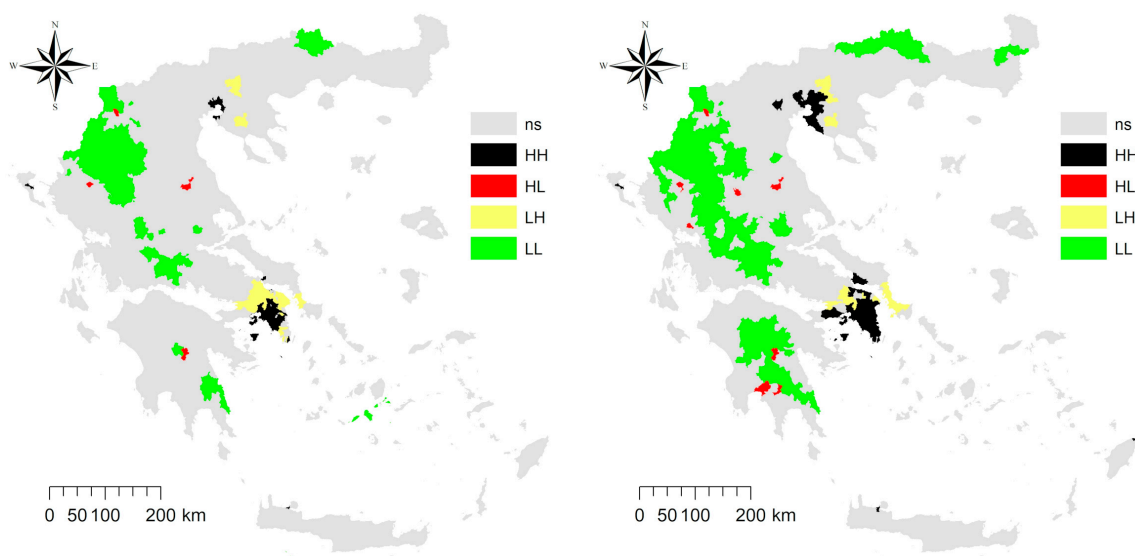


Figure 4. Maps illustrating spatial clustering of population density in Greece (left: 1961; right 2011; HH: High–High hotspots, HL: High–Low coldspots, LH: Low–High coldspots, LL: Low–Low hotspots, ns: non-significant).

Population growth rates were also asymmetrically distributed over the country. The highest global Moran's coefficients were observed in the initial decade (1961–1971), decreasing progressively over time, and reaching the minimum values in the last two decades (1991–2001 and 2001–2011). These results indicate that the spatial structure of the investigated variable was more clustered in a context of accelerated population growth (1961–1971) and more fragmented and heterogeneous—without significant spatial patterns—when the population was stable or declining slightly (2001–2011). Except for the last investigated decade, the highest global Moran's coefficients were observed at an intermediate geographical scale (50 km bandwidth).

The spatial distribution of the local Moran's coefficients of spatial autocorrelation in population growth rates (Figure 5) confirms the importance of the urban–rural gradient in Greece, with modest changes in both intensity and spatial direction between 1961 and 2011. The demographic consolidation of the two HH clusters (Athens and Thessaloniki) and the population expansion of some intermediate areas characteristic of peri-urban belts (LH cluster) surrounding both cities were observed during the same time interval. A low-density rural area classified as an LL cluster expanded during the study period to include the internal districts of Northern Greece (on the border with Bulgaria), Central Greece and Peloponnese. Intermediate areas (HL clusters) also expanded in Central Greece and Peloponnese, encompassing fast-growing, small-sized cities in the last decades. Our analysis highlights a highly polarized and dynamic demographic context in Greece. In general, urban–rural disparities were evident in all decades, with the inherent divide in large cities and marginal rural regions. The HH cluster (high population density in urban areas) encompassed a greater number of peri-urban municipalities in the last decades, involving economically dynamic rural districts outside Attica and Central Macedonia, which include coastal areas and (big and small) islands, such as Crete, Cyclades and Dodecanese. This implies that the spatial patterns of demographic densification became progressively more complex, becoming less dependent on population density and increasingly influenced by other socioeconomic forces characteristic of diversified local contexts. Conversely, the LL cluster (low population density in rural areas)—initially associated with the internal areas of central Greece and Peloponnese—decreased in size, moving towards mountainous areas characterized by intense emigration and violent depopulation.

3.2. Local Regression Analysis

The results of both the correlation analysis and regression models (Table 3) are supportive of density-dependent population growth in Greece, especially in the earlier and later decades of the investigation. The model's goodness of fit reflects the consolidation of non-linear and more complex spatial relationships over time. The Pearson linear correlation coefficients were higher in the initial decades of the study and decreased in the following time period. The Spearman correlation coefficients followed the reverse pattern, with the highest values observed in the most recent decade. This suggests the importance of non-linear relationships in the study area and outlines how settlement concentration below (or above) specific density thresholds impacts the spatial distribution of population growth rates in a highly variable fashion. The results of the aspatial regression models seem to confirm this assumption. The highest adjusted R^2 coefficients were observed for cubic models in the initial and final decades of the investigation (1961–1971 and 2001–2011). GWR models displayed adjusted R^2 coefficients systematically higher than all the other analyses run in this study, confirming the appropriateness of a spatially explicit analysis considering the geographical structure of the dependent variable and the predictor together. These results justify the use of local regression techniques in the analysis of demographic processes at disaggregated spatial scales.

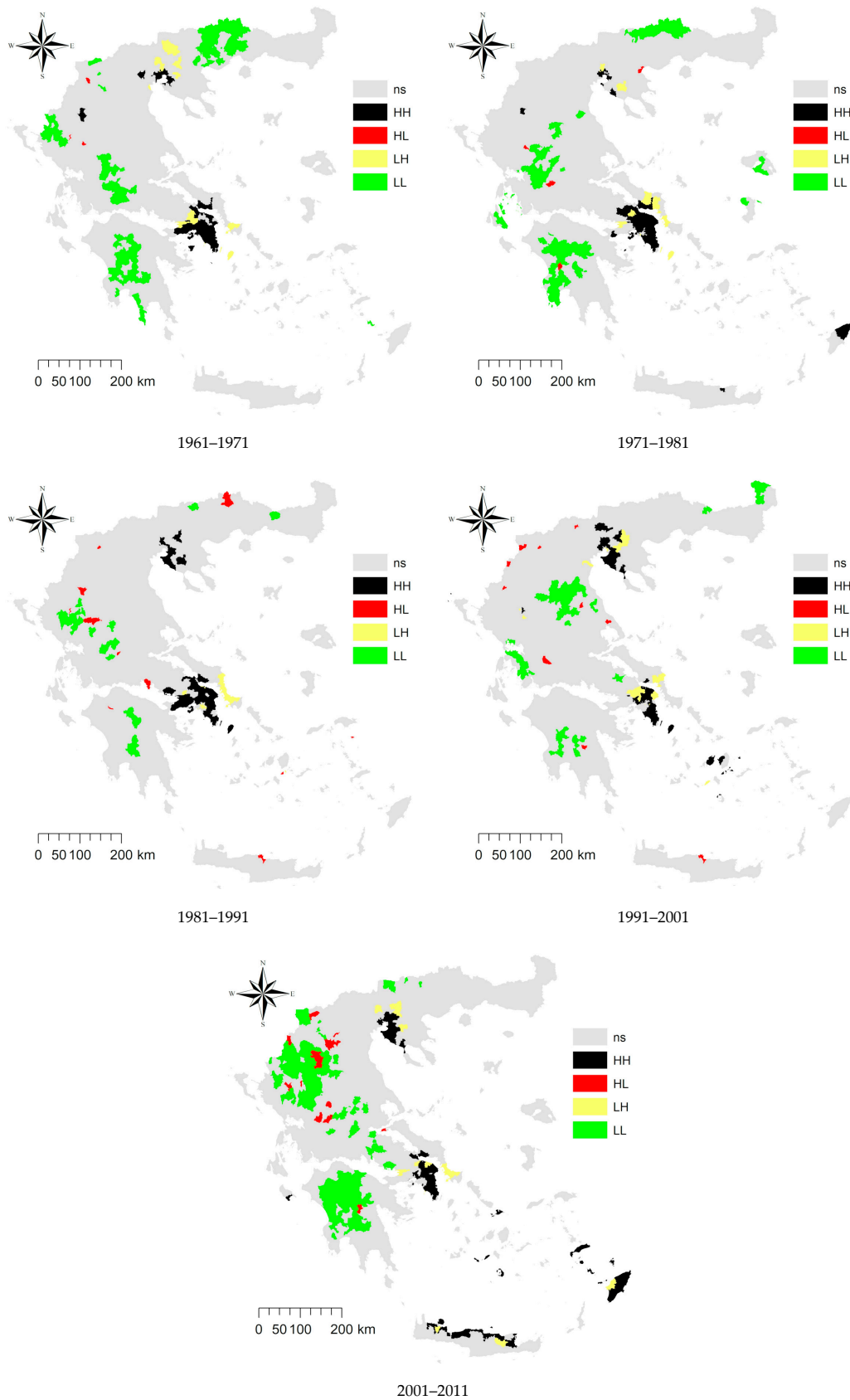


Figure 5. Maps illustrating spatial clustering of population growth in Greece by decade (HH: High–High hotspots, HL: High–Low coldspots, LH: Low–High coldspots, LL: Low–Low hotspots, ns: non-significant).

The results of the GWR models diverged over time (Figure 6). For the first decade of the study (1961–1971), the best performances of the local regression model were observed along the Aegean side of Greece; the reverse pattern was found along the Ionian side. The east–west gradient also impacted the regression coefficient of the density variable, being systematically higher on the Aegean side (this includes the Thessaloniki–Athens axis and many other medium-sized cities, e.g., Iraklio, Volos, Larissa, Kavala). The intercept of the model was negative almost everywhere in Greece. The standardized residuals of the local regression model were quite heterogeneous over space, with values higher than the average in municipalities surrounding the Greater Athens area.

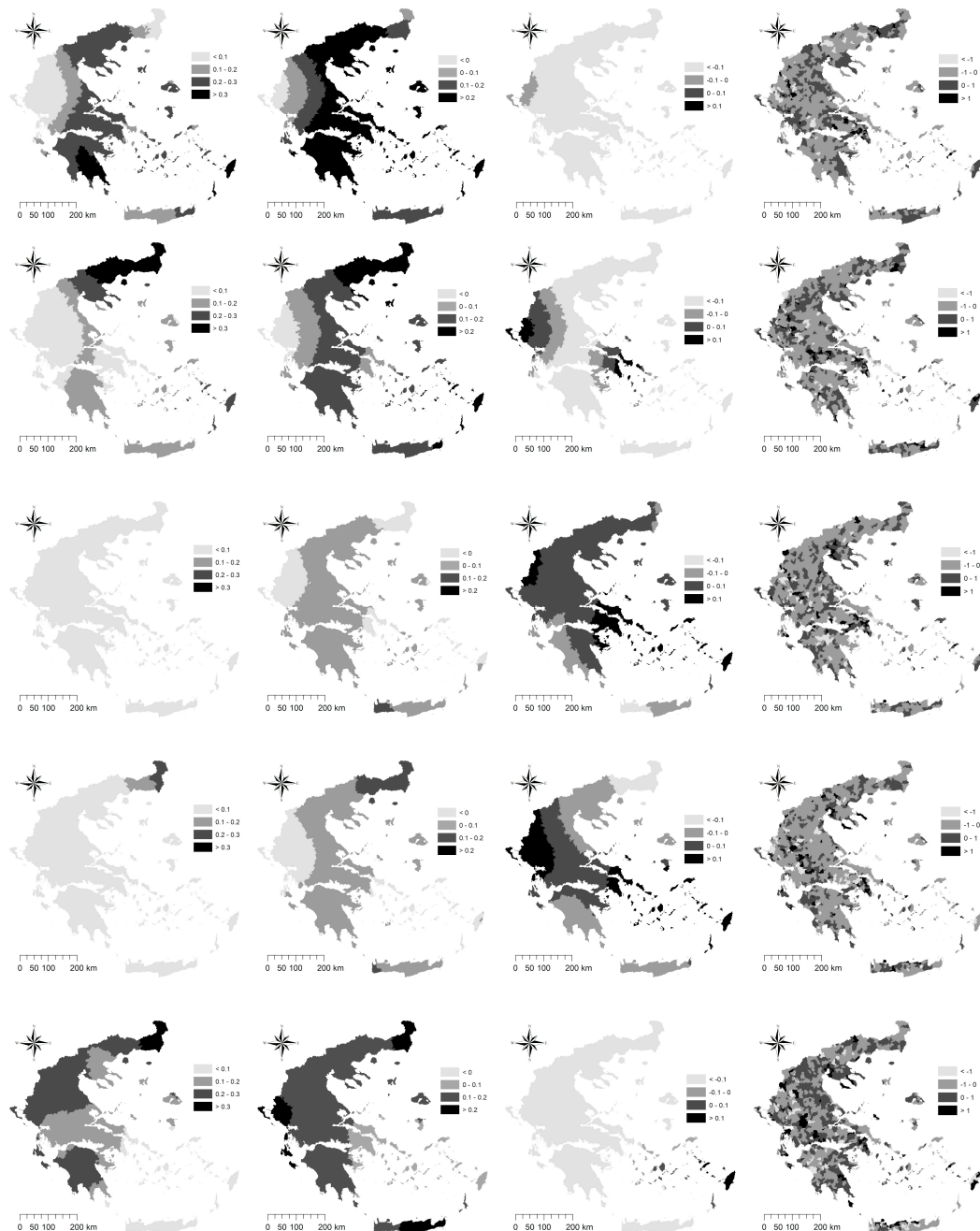


Figure 6. Results of geographically weighted regression (GWR) models with population growth rate (%) as the dependent variable and population density as a predictor (from left to right: local R^2 , slope coefficient, model intercept and standardized residuals; from top to bottom: 1961–1971, 1971–1981, 1981–1991, 1991–2001, 2001–2011).

Table 3. Analysis of the linkage between population increase (%) and density using different correlation coefficients, linear and non-linear (square, cubic) aspatial regressions (adjusted R^2) and a Geographically weighted regression (global adjusted R^2) for municipalities in Greece (* significance tested at $p < 0.001$, $n = 1033$).

Decade	Correlation Coefficients			Ordinary Least Square Regression			Geographically Weighted Regression
	Pearson	Spearman	Kendall	Linear	Square	Cubic	
1961–1971	0.47 *	0.44 *	0.31 *	0.15 *	0.18 *	0.25 *	0.36 *
1971–1981	0.34 *	0.36 *	0.25 *	0.04	0.05	0.10	0.28 *
1981–1991	0.11	0.20	0.14	0.01	0.01	0.08	0.11 *
1991–2001	0.12	0.24	0.17	0.02	0.02	0.11	0.09 *
2001–2011	0.36 *	0.52 *	0.37 *	0.12 *	0.17 *	0.21 *	0.28 *

For the second decade of the study (1971–1981), GWR estimated a more intense density–growth relationship in Northern Greece and the Aegean coastal region, from Macedonia to Peloponnese, with the exclusion of Attica, the administrative region of Athens. Local regression coefficients were found to be high and positive in the most marginal regions of Northeastern Greece, but also in the Dodecanese archipelago and in the eastern part of Crete. The values of the intercept coefficient were found to be almost negative. Moderately positive values were observed in Northwestern Greece and in a small part of Attica. Standardized residuals were distributed heterogeneously across the country area, with systematically positive values in the peri-urban area of Athens, in Western Greece and Thrace.

The GWR model for the decade 1981–1991 provided very low local R^2 coefficients across the whole of Greece. Consequently, local regression coefficients showed values close to 0 (both for the model’s slope and intercept); standardized residuals were distributed almost randomly. The GWR model for the 1991–2001 decade displayed moderately low local R^2 coefficients across the whole country, except for Northeastern Greece. Consequently, local regression coefficients showed values systematically close to 0 for both coefficients. Slopes >0.1 were observed in Attica and Northwestern Greece. In the last decade of the study (2001–2011), the GWR model showed a greater goodness of fit (local adjusted R^2) in Northern Greece and the Peloponnese region and a lesser fit in Attica, Thessaloniki, the islands of Cyclades and Dodecanese and Central Greece. The highest slope coefficients were observed in Northern Greece. Intercept coefficients were negative all over the country. As expected, the model’s residuals were distributed heterogeneously over space.

By comparing the value of the slope coefficient in each municipality of Greece over sequential decades throughout the study period (Figure 7), a generalized increase in local regression slopes—which reflects a greater impact of density on population growth—was observed between 1961 and 1981 in Northeastern Greece (Thrace) and the Aegean islands (mainly Dodecanese and Eastern Crete).

Considering the subsequent time interval, increasing local regression slopes were observed exclusively in the Ionian side of Central–Western Greece, in both coastal and internal contexts characterized by low population density and modest accessibility to Athens (Figure 8).

The highest growth in local regression slopes was observed in Northeastern Greece (Thrace and Eastern Macedonia) in the time interval between 1981 and 2001, the lowest being along the Ionian side of Western Greece (Figure 9).

Finally, in the last two decades, the largest slope increase at the local scale was observed in Central and Western Greece, as well as the eastern area of Crete and the Dodecanese archipelago (Figure 10). For each decade of study, correlations between population density in the first year of each decade and the respective local GWR slope coefficient for each municipality of Greece were investigated pairwise using Pearson moment-product coefficients. The analysis indicates that local slope coefficients of the respective regression models increased with population density in 1961–1971 ($r = 0.162$, $p < 0.05$) and decreased in 2001–2011 ($r = -0.295$, $p < 0.05$), but were statistically uncorrelated in the case of the three intermediate decades.

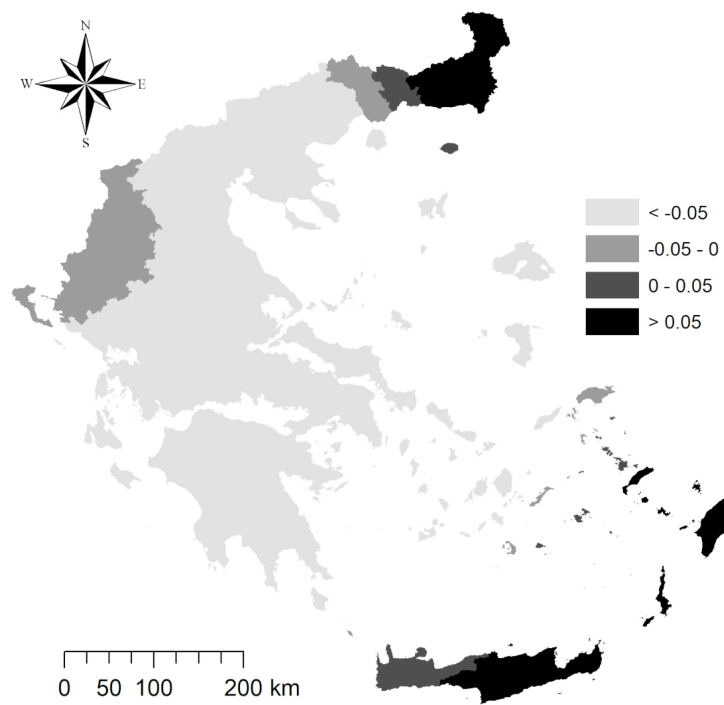


Figure 7. Absolute change in the GWR regression coefficient (local slope) during two consecutive decades in Greece, 1961–1981.

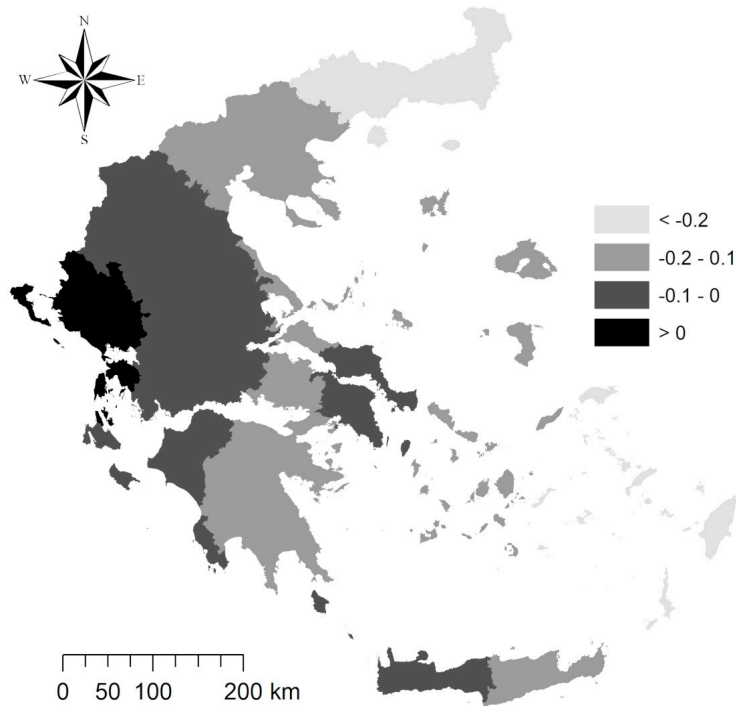


Figure 8. Absolute change in the GWR regression coefficient (local slope) during two consecutive decades in Greece, 1971–1991.

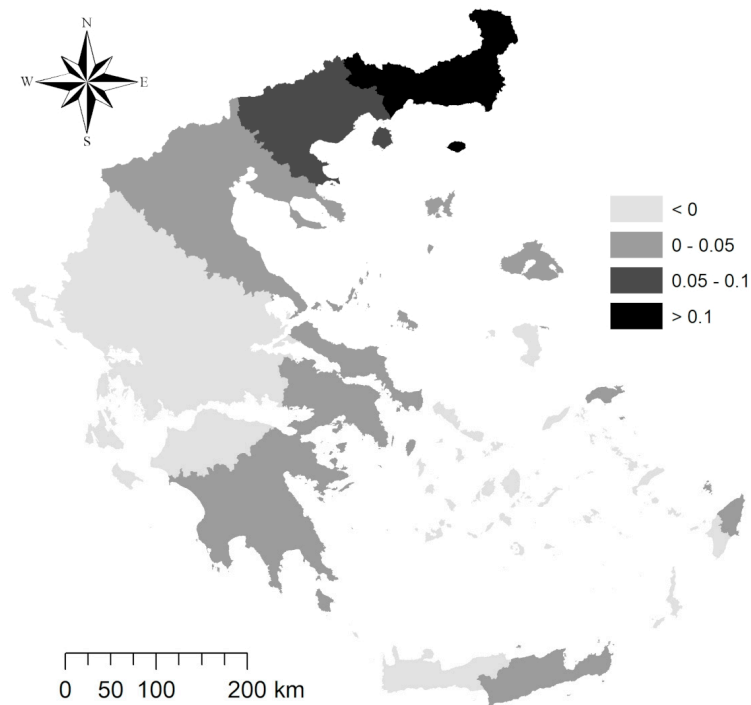


Figure 9. Absolute change in the GWR regression coefficient (local slope) during two consecutive decades in Greece, 1981–2001.

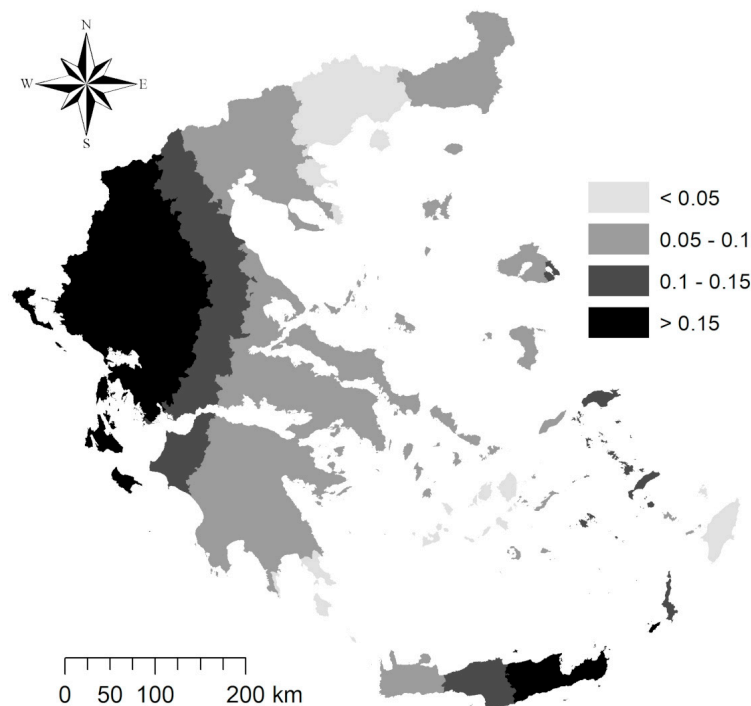


Figure 10. Absolute change in the GWR regression coefficient (local slope) during two consecutive decades in Greece, 1991–2011.

4. Discussion

Demographic dynamics were hypothesized to leverage spatial divides in socioeconomic local systems with distinctive patterns of change over time [53,91,99,100]. By considering mechanisms underlying population concentration and shrinkage together, our study gives new insights that may

clarify the role demographic trends play in both urban and rural contexts. Confirming empirical evidence from earlier studies [24], the empirical results of this study illustrate local mechanisms of population increase based on density [24]. In this way, our study illustrates the importance of a comprehensive investigation of sequential urban phases integrated with a refined analysis of population dynamics in rural districts. Results of this analysis suggest how convergence in population growth and urban density may lead to more cohesive settlements. At the same time, divergences in population growth and density are demonstrated to consolidate economic polarization and territorial divides between (morphologically dense) dynamic areas and (peripheral) depopulated districts.

Considering data at the municipal scale, a local regression analysis of long-term demographic trends was appropriate to delineate density-dependent and density-independent mechanisms of population growth [37,38,87]. In earlier studies [3,40,99,100], urban concentration was taken as the main factor lowering population increase [1,7,101–103]. However, a lack of information on the positive (or negative) regulation of population growth persists at low densities [41]. In this regard, very low densities and continuous population decline at the local scale are symptoms of land abandonment, depopulation and the demographic shrinkage of rural districts [42,43,85]. In Europe, demographic changes in recent decades have consolidated socio-spatial disparities and demographic divides [11,72,97,98,102]. Taken as a paradigmatic region with mixed population dynamics at larger scales and peculiar metropolitan systems at local scales, heterogeneous geographies of population growth in Southern Europe may reveal characteristic demographic patterns. These patterns basically reflect radio-centric settlement expansion and population concentration in economically dynamic and more accessible locations. As a result, metropolitan regions in Mediterranean Europe have experienced sequential cycles of urbanization–suburbanization, enhanced by a transition toward low fertility, aging, migratory movements and the accelerated (mostly negative) impacts of economic downturns [49,60,77].

By introducing a spatially explicit assessment of population dynamics over a sufficiently long time period, our study implements a geographically weighted regression to investigate (and model) population distribution and demographic dynamics in Greece. The methodology provides a local estimation of the importance of density-dependent processes of population increase for each municipality along a gradient spanning from compact–dense cities to low-density rural districts. By investigating local-scale settlement patterns in Greek municipalities, the spatial autocorrelation analysis delineated the progressive consolidation of a metropolitan hierarchy grounded in large cities such as Athens and Thessaloniki. Something similar was noted in other Mediterranean countries such as Spain or Italy [84]. Although covering a shorter time interval (1991–2011), a previous study in Spain [104] successfully adopted a GWR to identify spatially differentiated population growth factors in a context of increasing spatial heterogeneity. In this regard, Gutiérrez-Posada et al. [104] stated that (p. 211) “essential factors in urban and regional economics such as size (initial population) or distance (either to the big cities or to the coast) can have different effects on population growth across both space and time, corresponding to the global estimated effects for some areas but diverging from these in others. Using GWR estimation procedures, we can identify changes in the sign or the intensity of a factor’s effect across space, such that some factors could enhance population growth in one place but reduce it in another”.

Based on these premises, GWR models seem to be particularly appropriate to test for density-dependent or density-independent processes of population growth. To our knowledge, the present study adopts GWR for the first time in the literature to ascertain density-dependent mechanisms of population growth (and discriminate them from density-independent processes). For Greece, the results of the local regression models run in the present study indicate that density-dependent mechanisms of population growth were most frequently observed in the 1960s and 2000s; density-independent processes regulated population dynamics in the intermediate decades (1971–2001). Density-dependent processes of population growth in those decades have been associated with high (or increasing) fertility levels, as observed in 1961–1971 and 2001–2011, respectively. The reverse pattern was observed in the three intermediate decades, with density-independent

processes of population growth associated with declining fertility rates, reaching the lowest low (total fertility rate = 1.2) at the beginning of the 1990s. Positive local density–growth relationships have been observed in urban locations between 1961 and 1971, and rural locations between 2001 and 2011. The processes of growth observed in hyper-compact and dense cities were recorded in the last decades of the study (2001–2011), especially in Greater Athens and Thessaloniki.

Our results finally document spatial and temporal peculiarities in density-dependent mechanisms of population increase in some Greek regions and local districts. The results of the GWR distinguished consolidated urban contexts (Athens, Piraeus or Thessaloniki) from dynamic, rural municipalities growing under the deep pressure of suburbanization, and characterized by a residual potential for building. Stability over time was verified using a locally adjusted R^2 , an index of the model's fit to empirical data. Analysis of this metric outlined (i) a phase of intense population concentration in central locations driven by internal migration from rural areas, high fertility and relatively low mortality (1961–1971) and (ii) the demographic recovery of medium-sized cities and more accessible, dynamic rural areas (2001–2011). The latter process was recorded in a context of the slow decline of central cities because of decreasing international migration and negative vital balances [105,106]. Based on these premises, we conclude that the positive relationship between population growth rates and density at intermediate concentration levels confirms the positive contribution of agglomeration forces to metropolitan trends [98,107–109]. Agglomeration effects on population increase were rather weak in rural districts, with zero (1971–2001) or even negative (1961–1971; 2001–2011) rates. This suggests how rural shrinkage frequently underlies more volatile demographic dynamics and indicates the urgent need for more effective developmental policies against depopulation in hyper-rural districts.

5. Conclusions

While delineating peculiar spatial regimes at the local scale, our study focuses on similarities in long-term spatio-temporal interactions between population concentration and demographic growth. Being observed primarily in metropolitan contexts, social transformations are a key driver of demographic change and economic restructuring. More specifically, we found that (i) consecutive waves of growth and shrinkage of central cities, (ii) suburban expansion and (iii) the progressive depopulation of marginal rural areas have characterized long-term local development in Greece. These sequential phases consolidated non-linear density-dependent mechanisms of population growth. Future research should integrate the results of global and local statistical approaches to delineate more sophisticated approaches to spatial demography. High-resolution, geo-referenced databases collecting up-to-date information over long time windows represent a prerequisite of this kind of analysis. The methodology illustrated in our study provides an improved knowledge of density-dependent structures of population increase (or decrease), committed to rethinking territorial strategies and social policies adapting to increasingly heterogeneous local dynamics.

Author Contributions: Conceptualization, Jesús Rodrigo-Comino and Federico Benassi; methodology, Rosario Turco and Gloria Polinesi; software, Gloria Polinesi and Maria Cristina Recchioni; validation, Maria Cristina Recchioni and Kostas Rontos; formal analysis, Gloria Polinesi and Maria Cristina Recchioni; investigation, Maria Cristina Recchioni and Kostas Rontos; resources, Jesús Rodrigo-Comino and Federico Benassi; data curation, Gloria Polinesi and Federico Benassi; writing—original draft preparation, Luca Salvati and Federico Benassi; writing—review and editing, Maria Cristina Recchioni and Kostas Rontos; visualization, Rosario Turco and Jesús Rodrigo-Comino; supervision, Kostas Rontos and Jesús Rodrigo-Comino; project administration, Federico Benassi; funding acquisition, Maria Cristina Recchioni and Rosario Turco. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Combes, P.P.; Duranton, G.; Overman, H.G. Agglomeration and the adjustment of the spatial economy. *Pap. Reg. Sci.* **2005**, *84*, 311–349. [[CrossRef](#)]

2. Gardiner, B.; Martin, R.; Tyler, P. Does spatial agglomeration increase national growth? Some evidence from Europe. *J. Econ. Geogr.* **2011**, *11*, 979–1006. [\[CrossRef\]](#)
3. Haase, A.; Bernt, M.; Großmann, K.; Mykhnenko, V.; Rink, D. Varieties of shrinkage in European cities. *Eur. Urban Reg. Stud.* **2016**, *23*, 86–102. [\[CrossRef\]](#)
4. Tóth, G.; Nagy, Z. The world's economic centre of gravity. *Reg. Stat.* **2016**, *6*, 177–180.
5. Petrakos, G.C. Urban Concentration and Agglomeration Economies: Re-examining the Relationship. *Urban Stud.* **1992**. [\[CrossRef\]](#)
6. Turok, I. Cities, Regions and Competitiveness. *Reg. Stud.* **2004**, *38*, 1069–1083. [\[CrossRef\]](#)
7. Combes, P.-P.; Duranton, G.; Gobillon, L. The identification of agglomeration economies. *J. Econ. Geogr.* **2011**, *11*, 253–266. [\[CrossRef\]](#)
8. Munafò, M.; Salvati, L.; Zitti, M. Estimating soil sealing rate at national level—Italy as a case study. *Ecol. Indic.* **2013**, *26*, 137–140. [\[CrossRef\]](#)
9. Gavalas, V.S.; Rontos, K.; Salvati, L. Who Becomes an Unwed Mother in Greece? Sociodemographic and Geographical Aspects of an Emerging Phenomenon. *Popul. Space Place* **2014**, *20*, 250–263. [\[CrossRef\]](#)
10. Morelli, V.G.; Rontos, K.; Salvati, L. Between suburbanisation and re-urbanisation: Revisiting the urban life cycle in a Mediterranean compact city. *Urban Res. Pract.* **2014**, *7*, 74–88. [\[CrossRef\]](#)
11. Russo, A.P.; Giné, D.S.; Albert, M.Y.P.; Brandajs, F. Identifying and Classifying Small and Medium Sized Towns in Europe. *Tijdschr. Econ. Soc. Geogr.* **2017**, *108*, 380–402. [\[CrossRef\]](#)
12. Melo, P.C.; Graham, D.J.; Noland, R.B. A meta-analysis of estimates of urban agglomeration economies. *Reg. Sci. Urban Econ.* **2009**, *39*, 332–342. [\[CrossRef\]](#)
13. Solon, J. Spatial context of urbanization: Landscape pattern and changes between 1950 and 1990 in the Warsaw metropolitan area, Poland. *Landsc. Urban Plan.* **2009**, *93*, 250–261. [\[CrossRef\]](#)
14. Salvati, L. Agro-forest landscape and the 'fringe' city: A multivariate assessment of land-use changes in a sprawling region and implications for planning. *Sci. Total Environ.* **2014**, *490*, 715–723. [\[CrossRef\]](#)
15. Serra, P.; Vera, A.; Tulla, A.F.; Salvati, L. Beyond urban–rural dichotomy: Exploring socioeconomic and land-use processes of change in Spain (1991–2011). *Appl. Geogr.* **2014**, *55*, 71–81. [\[CrossRef\]](#)
16. Weilenmann, B.; Seidl, I.; Schulz, T. The socio-economic determinants of urban sprawl between 1980 and 2010 in Switzerland. *Landsc. Urban Plan.* **2017**, *157*, 468–482. [\[CrossRef\]](#)
17. Relethford, J.H. Density-dependent migration and human population structure in historical Massachusetts. *Am. J. Phys. Anthropol.* **1986**, *69*, 377–388. [\[CrossRef\]](#)
18. Delacroix, J.; Swaminathan, A.; Solt, M.E. Density Dependence Versus Population Dynamics: An Ecological Study of Failings in the California Wine Industry. *Am. Sociol. Rev.* **1989**, *54*, 245. [\[CrossRef\]](#)
19. Bauch, C.T. Wealth as a source of density dependence in human population growth. *Oikos* **2008**, *117*, 1824–1832. [\[CrossRef\]](#)
20. Lee, R.D. Population dynamics of humans and other animals. *Demography* **1987**, *24*, 443–465. [\[CrossRef\]](#)
21. Fowler, C.W. Density Dependence as Related to Life History Strategy. *Ecology* **1981**, *62*, 602–610. [\[CrossRef\]](#)
22. Turchin, P. Rarity of density dependence or population regulation with lags? *Nature* **1990**, *344*, 660–663. [\[CrossRef\]](#)
23. Hopfenberg, R. Human Carrying Capacity Is Determined by Food Availability. *Popul. Environ.* **2003**, *25*, 109–117. [\[CrossRef\]](#)
24. Berryman, A.A. *Principles of Population Dynamics and Their Application*; Stanley Thornes: Cheltenham, UK, 1999; ISBN 978-0-7487-4015-4.
25. Cohen, J.E. Human population: The next half century. *Science* **2003**, *302*, 1172–1175. [\[CrossRef\]](#)
26. Lima, M.; Berryman, A.A. Positive and negative feedbacks in human population dynamics: Future equilibrium or collapse? *Oikos* **2011**, *120*, 1301–1310. [\[CrossRef\]](#)
27. Ostfeld, R.S.; Canham, C.D.; Pugh, S.R. Intrinsic density-dependent regulation of vole populations. *Nature* **1993**, *366*, 259–261. [\[CrossRef\]](#) [\[PubMed\]](#)
28. Mueller, L.D.; Guo, P.Z.; Ayala, F.J. Density-dependent natural selection and trade-offs in life history traits. *Science* **1991**, *253*, 433–435. [\[CrossRef\]](#) [\[PubMed\]](#)
29. Åström, M.; Lundberg, P.; Lundberg, S. Population Dynamics with Sequential Density-Dependencies. *Oikos* **1996**, *75*, 174–181. [\[CrossRef\]](#)
30. Waters, J.M.; Fraser, C.I.; Hewitt, G.M. Founder takes all: Density-dependent processes structure biodiversity. *Trends Ecol. Evol.* **2013**, *28*, 78–85. [\[CrossRef\]](#)

31. Berry, B.J.L. City Size Distributions and Economic Development. *Econ. Dev. Cult. Chang.* **1961**, *9*, 573–588.
32. Sibly, R.M.; Hone, J.; Clutton-Brock, T.H. Population growth rate: Determining factors and role in population regulation. Introduction. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2002**, *357*, 1149–1151. [[CrossRef](#)]
33. Metcalf, C.J.E.; Pavard, S. Why evolutionary biologists should be demographers. *Trends Ecol. Evol.* **2007**, *22*, 205–212. [[CrossRef](#)] [[PubMed](#)]
34. Baker, J.; Ruan, X.; Alcantara, A.; Jones, T.; Watkins, K.; McDaniel, M.; Frey, M.; Crouse, N.; Rajbhandari, R.; Morehouse, J.; et al. Density-dependence in urban housing unit growth: An evaluation of the Pearl-Reed model for predicting housing unit stock at the census tract level. *J. Econ. Soc. Meas.* **2008**, *33*, 155–163. [[CrossRef](#)]
35. Sibly, R.M.; Hone, J. Population growth rate and its determinants: An overview. *Philos. Trans. R. Soc. Lond. B* **2002**, *357*, 1153–1170. [[CrossRef](#)]
36. Herrando-Pérez, S.; Delean, S.; Brook, B.W.; Bradshaw, C.J.A. Density dependence: An ecological Tower of Babel. *Oecologia* **2012**, *170*, 585–603. [[CrossRef](#)] [[PubMed](#)]
37. Beeson, P.E.; DeJong, D.N.; Troesken, W. Population growth in U.S. counties, 1840–1990. *Reg. Sci. Urban Econ.* **2001**, *31*, 669–699. [[CrossRef](#)]
38. Berliant, M.; Wang, P. Dynamic Urban Models: Agglomeration and Growth. In *Contributions to Economic Analysis*; Elsevier: Amsterdam, The Netherlands, 2004; Volume 266, pp. 531–581. ISBN 978-0-444-51481-3.
39. Parvinen, K.; Dieckmann, U.; Gyllenberg, M.; Metz, J.A.J. Evolution of dispersal in metapopulations with local density dependence and demographic stochasticity. *J. Evol. Biol.* **2003**, *16*, 143–153. [[CrossRef](#)]
40. Kincses, Á.; Nagy, Z.; Tóth, G. Modelling the spatial structure of Europe. *Reg. Stat.* **2014**, *4*, 40–54. [[CrossRef](#)]
41. Beale, C.L. Rural depopulation in the united states: Some demographic consequences of agricultural adjustments. *Demography* **1964**, *1*, 264–272. [[CrossRef](#)]
42. André, M.F. Depopulation, Land-use Change and Landscape Transformation in the French Massif Central. *AMBIO* **1998**, *27*, 351–353.
43. Hoggart, K.; Paniagua, A. The restructuring of rural Spain? *J. Rural Stud.* **2001**, *17*, 63–80. [[CrossRef](#)]
44. van Wissen, L. A Spatial Interpretation of the Density Dependence Model in Industrial Demography. *Small Bus. Econ.* **2004**, *22*, 253–264. [[CrossRef](#)]
45. Alados, C.L.; Errea, P.; Gartzia, M.; Saiz, H.; Escós, J. Positive and Negative Feedbacks and Free-Scale Pattern Distribution in Rural-Population Dynamics. *PLoS ONE* **2014**, *9*, e114561. [[CrossRef](#)] [[PubMed](#)]
46. Sale, P.F.; Tolimieri, N. Density dependence at some time and place? *Oecologia* **2000**, *124*, 166–171. [[CrossRef](#)]
47. Hamilton, M.J.; Burger, O.; DeLong, J.P.; Walker, R.S.; Moses, M.E.; Brown, J.H. Population stability, cooperation, and the invasibility of the human species. *Proc. Natl. Acad. Sci. USA* **2009**, *106*, 12255–12260. [[CrossRef](#)]
48. Caswell, H. Perturbation analysis of nonlinear matrix population models. *Demogr. Res.* **2008**, *18*, 59–116. [[CrossRef](#)]
49. Salvati, L.; Serra, P. Estimating Rapidity of Change in Complex Urban Systems: A Multidimensional, Local-Scale Approach. *Geogr. Anal.* **2016**, *48*, 132–156. [[CrossRef](#)]
50. Galor, O.; Weil, D.N. From Malthusian Stagnation to Modern Growth. *Am. Econ. Rev.* **1999**, *89*, 150–154. [[CrossRef](#)]
51. Bosker, M. Growth, Agglomeration and Convergence: A Space-time Analysis for European Regions. *Spat. Econ. Anal.* **2007**, *2*, 91–100. [[CrossRef](#)]
52. Baldini, R. The Importance of Population Growth and Regulation in Human Life History Evolution. *PLoS ONE* **2015**, *10*, e0119789. [[CrossRef](#)]
53. Lemelin, A.; Rubiera-Morollón, F.; Gómez-Loscos, A. Measuring Urban Agglomeration: A Refoundation of the Mean City-Population Size Index. *Soc. Indic. Res.* **2016**, *125*, 589–612. [[CrossRef](#)]
54. Cohen, J.E. Population growth and earth's human carrying capacity. *Science* **1995**, *269*, 341–346. [[CrossRef](#)] [[PubMed](#)]
55. Strulik, H. Learning-by-doing, population pressure, and the theory of demographic transition. *J. Popul. Econ.* **1997**, *10*, 285–298. [[CrossRef](#)]
56. Rodríguez-Pose, A.; Fratesi, U. Between Development and Social Policies: The Impact of European Structural Funds in Objective 1 Regions. *Reg. Stud.* **2004**, *38*, 97–113. [[CrossRef](#)]
57. Salvati, L.; Carlucci, M. The economic and environmental performances of rural districts in Italy: Are competitiveness and sustainability compatible targets? *Ecol. Econ.* **2011**, *70*, 2446–2453. [[CrossRef](#)]

58. Zitti, M.; Ferrara, C.; Perini, L.; Carlucci, M.; Salvati, L. Long-Term Urban Growth and Land Use Efficiency in Southern Europe: Implications for Sustainable Land Management. *Sustainability* **2015**, *7*, 3359–3385. [[CrossRef](#)]
59. Varga, L.; Tóth, G.; Néda, Z. An improved radiation model and its applicability for understanding commuting patterns in Hungary. *Reg. Stat.* **2016**, *6*, 27–38. [[CrossRef](#)]
60. Zambon, I.; Serra, P.; Sauri, D.; Carlucci, M.; Salvati, L. Beyond the ‘Mediterranean city’: Socioeconomic disparities and urban sprawl in three Southern European cities. *Geogr. Ann. Ser. B Hum. Geogr.* **2017**, *99*, 319–337. [[CrossRef](#)]
61. Oueslati, W.; Alvanides, S.; Garrod, G. Determinants of urban sprawl in European cities. *Urban Stud.* **2015**. [[CrossRef](#)]
62. Partridge, M.D.; Rickman, D.S.; Ali, K.; Olfert, M.R. Do New Economic Geography agglomeration shadows underlie current population dynamics across the urban hierarchy? *Pap. Reg. Sci.* **2009**, *88*, 445–466. [[CrossRef](#)]
63. Portnov, B.A.; Schwartz, M. Urban Clusters as Growth Foci. *J. Reg. Sci.* **2009**, *49*, 287–310. [[CrossRef](#)]
64. Salvati, L.; Gemmiti, R.; Perini, L. Land degradation in Mediterranean urban areas: An unexplored link with planning? *Area* **2012**, *44*, 317–325. [[CrossRef](#)]
65. Kabisch, N.; Haase, D. Diversifying European agglomerations: Evidence of urban population trends for the 21st century. *Popul. Space Place* **2011**, *17*, 236–253. [[CrossRef](#)]
66. Crescenzi, R.; Luca, D.; Milio, S. The geography of the economic crisis in Europe: National macroeconomic conditions, regional structural factors and short-term economic performance. *Camb. J. Reg. Econ. Soc.* **2016**, *9*, 13–32. [[CrossRef](#)]
67. Lauf, S.; Haase, D.; Kleinschmit, B. The effects of growth, shrinkage, population aging and preference shifts on urban development—A spatial scenario analysis of Berlin, Germany. *Land Use Policy* **2016**, *52*, 240–254. [[CrossRef](#)]
68. Duvernoy, I.; Zambon, I.; Sateriano, A.; Salvati, L. Pictures from the other side of the fringe: Urban growth and peri-urban agriculture in a post-industrial city (Toulouse, France). *J. Rural Stud.* **2018**, *57*, 25–35. [[CrossRef](#)]
69. Tapia, F.J.B.; Díez-Minguela, A.; Martínez-Galarraga, J. Tracing the Evolution of Agglomeration Economies: Spain, 1860–1991. *J. Econ. Hist.* **2018**, *78*, 81–117. [[CrossRef](#)]
70. Kiochos, P.; Rontos, K. Urbanization and Large Cities in the Mediterranean Countries. *Arch. Econ. Hist.* **1999**, *10*, 1–2.
71. Mykhnenko, V.; Turok, I. East European Cities—Patterns of Growth and Decline, 1960–2005. *Int. Plan. Stud.* **2008**, *13*, 311–342. [[CrossRef](#)]
72. Paulsen, K. Geography, policy or market? New evidence on the measurement and causes of sprawl (and infill) in US metropolitan regions. *Urban Stud.* **2014**, *51*, 2629–2645. [[CrossRef](#)]
73. Rickman, D.S.; Wang, H. US regional population growth 2000–2010: Natural amenities or urban agglomeration? *Pap. Reg. Sci.* **2017**, *96*, S69–S90. [[CrossRef](#)]
74. Petrakos, G.; Rodríguez-Pose, A.; Rovolis, A. Growth, Integration, and Regional Disparities in the European Union. *Environ. Plan. A* **2016**. [[CrossRef](#)]
75. Di Felicianantonio, C.; Salvati, L. ‘Southern’ Alternatives of Urban Diffusion: Investigating Settlement Characteristics and Socio-Economic Patterns in Three Mediterranean Regions. *Tijdschr. Econ. Soc. Geogr.* **2015**, *106*, 453–470. [[CrossRef](#)]
76. De Rosa, S.; Salvati, L. Beyond a ‘side street story’? Naples from spontaneous centrality to entropic polycentricism, towards a ‘crisis city’. *Cities* **2016**, *51*, 74–83. [[CrossRef](#)]
77. Cuadrado-Ciuraneta, S.; Durà-Guimerà, A.; Salvati, L. Not only tourism: Unravelling suburbanization, second-home expansion and “rural” sprawl in Catalonia, Spain. *Urban Geogr.* **2017**, *38*, 66–89. [[CrossRef](#)]
78. Kasanko, M.; Barredo, J.I.; Lavalle, C.; McCormick, N.; Demicheli, L.; Sagris, V.; Brezger, A. Are European cities becoming dispersed? A comparative analysis of 15 European urban areas. *Landsc. Urban Plan.* **2006**, *77*, 111–130. [[CrossRef](#)]
79. Grekousis, G.; Manetos, P.; Photis, Y.N. Modeling urban evolution using neural networks, fuzzy logic and GIS: The case of the Athens metropolitan area. *Cities* **2013**, *30*, 193–203. [[CrossRef](#)]
80. Colantoni, A.; Grigoriadis, E.; Sateriano, A.; Venanzoni, G.; Salvati, L. Cities as selective land predators? A lesson on urban growth, deregulated planning and sprawl containment. *Sci. Total Environ.* **2016**, *545–546*, 329–339. [[CrossRef](#)]

81. Cecchini, M.; Zambon, I.; Pontrandolfi, A.; Turco, R.; Colantoni, A.; Mavrakakis, A.; Salvati, L. Urban sprawl and the 'olive' landscape: Sustainable land management for 'crisis' cities. *GeoJournal* **2019**, *84*, 237–255. [[CrossRef](#)]
82. Pili, S.; Grigoriadis, E.; Carlucci, M.; Clemente, M.; Salvati, L. Towards sustainable growth? A multi-criteria assessment of (changing) urban forms. *Ecol. Indic.* **2017**, *76*, 71–80. [[CrossRef](#)]
83. Schneider, A.; Woodcock, C.E. Compact, Dispersed, Fragmented, Extensive? A Comparison of Urban Growth in Twenty-five Global Cities using Remotely Sensed Data, Pattern Metrics and Census Information. *Urban Stud.* **2008**. [[CrossRef](#)]
84. Carlucci, M.; Grigoriadis, E.; Rontos, K.; Salvati, L. Revisiting a Hegemonic Concept: Long-term 'Mediterranean Urbanization' in Between City Re-polarization and Metropolitan Decline. *Appl. Spat. Anal.* **2017**, *10*, 347–362. [[CrossRef](#)]
85. Price, D. Carrying Capacity Reconsidered. *Popul. Environ.* **1999**, *21*, 5–26. [[CrossRef](#)]
86. Lutz, W.; Sanderson, W.; Scherbov, S. The end of world population growth. *Nature* **2001**, *412*, 543–545. [[CrossRef](#)]
87. Lutz, W.; Qiang, R. Determinants of human population growth. *Philos. Trans. R. Soc. Lond. B Biol. Sci.* **2002**, *357*, 1197–1210. [[CrossRef](#)] [[PubMed](#)]
88. Sato, Y.; Yamamoto, K. Population concentration, urbanization, and demographic transition. *J. Urban Econ.* **2005**, *58*, 45–61. [[CrossRef](#)]
89. Klasen, S.; Nestmann, T. Population, population density and technological change. *J. Popul. Econ.* **2006**, *19*, 611–626. [[CrossRef](#)]
90. Frick, S.A.; Rodríguez-Pose, A. Change in urban concentration and economic growth. *World Dev.* **2018**, *105*, 156–170. [[CrossRef](#)]
91. Ceccarelli, T.; Bajocco, S.; Luigi Perini, L.; Luca Salvati, L. Urbanisation and Land Take of High Quality Agricultural Soils—Exploring Long-term Land Use Changes and Land Capability in Northern Italy. *Int. J. Environ. Res.* **2014**, *8*, 181–192. [[CrossRef](#)]
92. Giannakourou, G. Transforming spatial planning policy in Mediterranean countries: Europeanization and domestic change. *Eur. Plan. Stud.* **2005**, *13*, 319–331. [[CrossRef](#)]
93. Halbac-Cotoara-Zamfir, R.; Egidi, G.; Mosconi, E.M.; Poponi, S.; Alhuseen, A.; Salvati, L. Uncovering Demographic Trends and Recent Urban Expansion in Metropolitan Regions: A Paradigmatic Case Study. *Sustainability* **2020**, *12*, 3937. [[CrossRef](#)]
94. Ciommi, M.; Egidi, G.; Salvia, R.; Cividino, S.; Rontos, K.; Salvati, L. Population Dynamics and Agglomeration Factors: A Non-Linear Threshold Estimation of Density Effects. *Sustainability* **2020**, *12*, 2257. [[CrossRef](#)]
95. Zambon, I.; Rontos, K.; Serra, P.; Colantoni, A.; Salvati, L. Population Dynamics in Southern Europe: A Local-Scale Analysis, 1961–2011. *Sustainability* **2019**, *11*, 109. [[CrossRef](#)]
96. Salvati, L.; Sateriano, A.; Grigoriadis, E. Crisis and the city: Profiling urban growth under economic expansion and stagnation. *Let. Spat. Resour. Sci.* **2016**, *9*, 329–342. [[CrossRef](#)]
97. Ali, K.; Partridge, M.D.; Olfert, M.R. Can Geographically Weighted Regressions Improve Regional Analysis and Policy Making? *Int. Reg. Sci. Rev.* **2016**. [[CrossRef](#)]
98. Rontos, K.; Grigoriadis, E.; Sateriano, A.; Syrmali, M.; Vavouras, I.; Salvati, L. Lost in protest, found in segregation: Divided cities in the light of the 2015 "Oxi" referendum in Greece. *City Cult. Soc.* **2016**, *7*, 139–148. [[CrossRef](#)]
99. Biasi, R.; Colantoni, A.; Ferrara, C.; Ranalli, F.; Salvati, L. In-between sprawl and fires: Long-term forest expansion and settlement dynamics at the wildland–urban interface in Rome, Italy. *Int. J. Sustain. Dev. World Ecol.* **2015**, *22*, 467–475. [[CrossRef](#)]
100. Kazemzadeh-Zow, A.; Shahraki, S.Z.; Salvati, L.; Samani, N.N. A spatial zoning approach to calibrate and validate urban growth models. *Int. J. Geogr. Inf. Sci.* **2017**, *31*, 763–782. [[CrossRef](#)]
101. Grafeneder-Weissteiner, T.; Prettnner, K. Agglomeration and demographic change. *J. Urban Econ.* **2013**, *74*, 1–11. [[CrossRef](#)]
102. Beenstock, M.; Felsenstein, D. Marshallian theory of regional agglomeration. *Pap. Reg. Sci.* **2010**, *89*, 155–172. [[CrossRef](#)]
103. Boserup, E. *Population and Technological Change: A Study of Long-Term Trends*; University of Chicago Press: Chicago, IL, USA, 1981; Volume 3.

104. Gutiérrez-Posada, D.; Rubiera-Morollon, F.; Viñuela, A. Heterogeneity in the determinants of population growth at the local level: Analysis of the Spanish case with a GWR approach. *Int. Reg. Sci. Rev.* **2017**, *40*, 211–240. [[CrossRef](#)]
105. Di Feliciano, C.; Salvati, L.; Sarantakou, E.; Rontos, K. Class diversification, economic growth and urban sprawl: Evidences from a pre-crisis European city. *Qual. Quant.* **2018**, *52*, 1501–1522. [[CrossRef](#)]
106. Salvati, L.; Ciommi, M.T.; Serra, P.; Chelli, F.M. Exploring the spatial structure of housing prices under economic expansion and stagnation: The role of socio-demographic factors in metropolitan Rome, Italy. *Land Use Policy* **2019**, *81*, 143–152. [[CrossRef](#)]
107. Lamonica, G.R.; Chelli, F.M. The performance of non-survey techniques for constructing sub-territorial input-output tables. *Pap. Reg. Sci.* **2018**, *97*, 1169–1202. [[CrossRef](#)]
108. Rosti, L.; Chelli, F. Self-employment among Italian female graduates. *Educ. Train.* **2009**, *51*, 526–540. [[CrossRef](#)]
109. Chelli, F.; Rosti, L. Age and gender differences in Italian workers' mobility. *Int. J. Manpow.* **2002**, *23*, 313–325. [[CrossRef](#)]



© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<http://creativecommons.org/licenses/by/4.0/>).