Agglomeration *vs* Amenities? Unraveling The Latent Engine of Growth in Metropolitan Greece

Abstract

Economic downturns, social change, and migrations shape population expansion and shrinkage, making city life cycles particularly complex over time and intrinsically diversified over space. Identifying local drivers of population change plays a major role when addressing metropolitan cycles of growth and decline, and provides insights to any policy and planning strategy aimed at promoting together local development, economic competitiveness and socio-environmental sustainability at large. Timing of metropolitan cycles is, however, heterogeneous, and reflects the individual development path of any city. Assuming economic downturns and the associated social processes at the base of spatially heterogeneous patterns of population growth and decline in Mediterranean Europe, we adopted a spatial econometric approach investigating short-term and long-term demographic dynamics (1960-2010) in metropolitan Athens (Greece), with the aim at identifying contextual drivers of population change. Spatial regressions evaluated the role of economic and non-economic dimensions of metropolitan growth, quantifying the impact of agglomeration, scale, accessibility, and amenities at different phases of the city life cycle. Settlement models grounded on scale and agglomeration processes – with growing population in high and medium-density municipalities – were observed under economic expansion. Recession consolidated a settlement model with population growth in socially dynamic and accessible (low-density) districts with natural/cultural amenities, reflecting the inherent decline of agglomeration economies. Based on such dynamics, the polarized hierarchy of central and peripheral locations resulting from radio-centric population expansion was replaced with a settlement model grounded on population increase in 'intermediate-density', attractive locations.

Keywords: City Life cycle; Scale; Accessibility; Spatial panel; Mediterranean basin.

1. Introduction

Understanding local drivers of population gain and loss – and their intimate relationship with economic downturns – plays a major role informing policies of sustainable urban development (Combes et al., 2011; Chien and Woodworth, 2018; Ciommi et al., 2018). Economic cycles were (and still are) a powerful driver of population growth (Chen, 2009; Carson et al., 2016; Carlucci et al., 2018). The intrinsic timing of economic downturns reflects accelerated (or slowed) demographic dynamics depending on the local background (Connaughton, 2010; Dyson et al., 2013; Zambon et al., 2017). Economic booms and busts, with the ensuing changes in local job markets and the enhanced volatility in land and housing prices (Camagni et al., 2017), move internal and international migrations (Stockdale, 2011), reinforce suburbanization (or counter-urbanization) impulses (Czamanski and Broitman, 2018), and fuel gentrification of inner cities as well as re-urbanization processes (Arapoglou and Sayas, 2009).

A particularly complex evolution of local contexts, typical of contemporary cities, is at the base of less predictable patterns of population redistribution over larger regions – beyond the metropolitan hierarchy consolidated over a long time (Serra et al., 2014; Carlucci et al., 2017; Cuadrado-Ciuraneta et al., 2017). Diverging production structures at the regional scale, the unequal development of central and peripheral locations altering metropolitan hierarchies, asymmetric market-state interactions, demographic transitions and political instability, all contribute to consolidate regional disparities in population density (Berliant and Wang, 2004). These divides were demonstrated to be particularly intense in areas with limited access to infrastructure and reduced accessibility, prevalence of traditional activities, aging, unemployment, as well as low-quality human capital (Dijkstra et al., 2015).

In this context, external shocks shape socioeconomic dynamics at regional scales, exerting a distinctive impact on local systems that feature a variable ability to resist short-term disturbances when confronted with long-term demographic shrinkage and economic stagnation (Storper, 2011; Colantoni et al., 2016; Frick and Rodriguez-Pose, 2018). Earlier studies have started analyzing the relationship between economic downturns, metropolitan cycles, and population dynamics with the aim at identifying demographically resilient regions and the related socioeconomic profile (Maloutas, 2007; Kulu et al., 2009; Lopez-Gay, 2014). The increased variability in population growth rates along time and between different regions calls for the adoption of multi-dimensional approaches and spatially explicit analyses that are able to delineate the rising complexity of background contexts (Haase et al., 2010; Kabisch et al., 2011; Kroll and Kabisch, 2012).

The objective of this work can be traced back to the analysis of metropolitan growth drivers in a context of sustainability and resilience science (Hortas-Rico, 2014). More precisely, we investigate the (apparent and latent) mechanisms of urban growth - evaluated through a spatially explicit analysis of population dynamics - considering push and pull factors (Firmino Costa da Silva et al., 2017). As Glaeser and coworkers (2014) showed in their long term analysis of United States cities, drivers of urban population growth “waxed and waned in importance” over space and time, thus causing demographic dynamics following “different patterns in different times”. Thus, spatial and temporal heterogeneity of local responses to centripetal (agglomerative) and, respectively, centrifugal (de-concentrative) forces lead to mixed evidence about direction and significance of their effects (Gutiérrez-Posada et al., 2017).

A particularly intriguing aspect of the interplay between population growth drivers and local contexts transforming rapidly over time depends on spatially differentiated impacts of economic downturns on demographic dynamics. Earlier studies on this challenging issue (Ciommi et al., 2019; Salvati, 2019; Salvia et al., 2020) have provided interesting hints on the nature of linkages between the economic cycle and urban diffusion at different metropolitan locations; however, due to the descriptive character of many empirical studies, no causal relationship has been inferred. Therefore, these processes are worth to additional investigation, looking deeply into the mechanisms behind population dynamics with use of spatial econometric tools modeling population growth drivers and settlements' choices. For this reason, we have adopted a spatially explicit analysis of population dynamics in 115 municipalities of metropolitan Athens (Greece) covering a long time period between the early 1960s and the early 2010s. We have defined a ‘City Life Cycle’ (CLC) following the notion of Cuberes (2011) as a sequential set of population growth and decline waves displaying heterogeneous economic characteristics and diversified social and territorial profiles.

In so doing, we have adopted a holistic approach, choosing a large set of indicators covering social, economic, demographic, territorial, environmental, and planning factors that contribute to regulate (positively or negatively) CLC progress through a sequence of distinctive development waves (Garcia, 2010; Gil-Alonso et al., 2013; Goldstein et al., 2013). Spatial econometric modelling allows an accurate representation of the determinants at the base of metropolitan cycles – from urbanization to re-urbanization (Klasen and Nestmann, 2006). More precisely, we performed two analyses mixing (i) a short-term approach based on repeated cross-section spatial regressions (1960, 1970, 1980, 1990, 2000, 2010), identifying distinctive socioeconomic profiles at the base of sequential stages of the metropolitan cycle; (ii) a long-term approach based on spatial panel models that take account of the regulatory effect of socioeconomic drivers of metropolitan growth representative of the whole cycle.

2. Methodology

2.1. Study area

We investigated population dynamics at the municipal scale in the Athens' metropolitan region extending 3025 km^2 in Central Greece (SM.Figure 1). Boundaries of the study area were defined in accordance with the Urban Atlas (UA) Global Monitoring and Environmental Surveillance (GMES) Copernicus Land initiative (European Environment Agency, 2006). The Athens' metropolitan region is administered by 115 municipalities and local communities, half of which form the Athens-Piraeus' conurbation (430 km^2) known as the 'Greater Athens' area' (Pili et al., 2017). More than 3.7 million inhabitants (> 1250 inhabitants/km^2) settled in the study area at the last census (2011). A complete description of the study area was provided in Morelli et al. (2014), Rontos et al. (2016), and Salvati and Serra (2016). A shapefile of municipal boundaries produced and disseminated by the Greek Statistical Authority (ELSTAT) was used to prepare thematic maps and to built-up spatial models as detailed in the following sub-sections.

Municipalities have been adopted as representative spatial units in earlier studies investigating urban growth and demographic dynamics in Mediterranean Europe (Cecchini et al., 2019). While spatial planning is a centralized issue in Greece (Giannakourou, 2005), municipalities remain the local authority taking decisions about land destination, building volume, settlement size, land taxation, and other prescriptions influencing population distribution and urban development across metropolitan regions (Chorianopoulos et al., 2014). Moreover, municipalities are the most disaggregated spatial unit allowing combination, integration, and comparison of indicators from official statistics (national censuses, public registers, and other selected surveys) with information derived from external sources (Ciommi et al., 2018). Spatial coordinates (Latitude and Longitude) of each elementary unit considered in this study were measured referring to the 'centroid' of each municipality determined through computation in ArcGIS (ESRI Inc., Redwoods, USA).

2.2. Logical framework and model specification

We assume long-term population dynamics as a proxy of metropolitan growth at the local scale (e.g. Manrubia et al., 1999; Montgomery, 2008; Montalvo et al., 2019). Being easily derivable from demographic censuses (Morelli et al., 2014), population growth rates allow testing the role of socioeconomic profiles characteristic of each municipality (Pili et al., 2017). We also assume metropolitan development as governed by factors exerting multiple feedbacks and interacting with the local context in a complex way (Nechyba and Walsh, 2004; Porter and Howell, 2009; Perez, 2010; Peck, 2012). A statistical analysis run on disaggregated spatial domains may control both aspects, delineating direct (on-site) and indirect (off-site) mechanisms of urban growth (Rodriguez-Pose and

Fratesi, 2007). Identification of (positive and negative) on-site and off-site drivers of metropolitan development benefits from the decomposition of total impacts into direct and indirect (spillover) effects associated with each predictor, a typical result of spatial econometric models (Schneider and Mertes, 2014). Population Growth (G) was thus modeled as a function of 6 dimensions regulating metropolitan development (e.g. Seto et al., 2011): (i) Territory and topography (T), (ii) Environmental attributes (E), (iii) Planning constraints (P), (iv) socio-Demographic dynamics (D), (v) economic Specialization (S), (vi) Land-use and urban functions (L) as

$$G = f\,(T, E, P, D, S, L) \qquad \text{(Equation 1)}$$

Following earlier literature (Siedentop and Fina, 2012; Li and Gong, 2016; Salem et al., 2021), each dimension was characterized using appropriate predictors that estimate the net impact on the dependent variable (see below), assumed to be positive, negative, or mixed (Salvati et al., 2019). Model estimation based on spatial econometrics reveals the aggregate (direct and indirect) effect of each predictor controlling for spatial location (Yaping and Min, 2009), making direction and intensity of the net predictor's impact completely explicit, and thus refining the interpretation of characteristic (short-term and long-term) development paths (Ruiz et al., 2018). For each stage of the CLC, drivers of population growth were identified using cross-sectional spatial regressions (e.g. Zambon et al., 2018). The most significant forces shaping the whole cycle (1960-2010) were identified analyzing all years together through a spatial panel with homogeneous observations at 6 time points.

2.3. Elementary data sources and relevant variables

Per cent (annual) population growth rate by municipality was taken as the dependent variable in this study. Population growth rates were calculated using total population derived from general censuses of Greece carried out by the National Statistical Authority (ELSTAT) every ten years since 1951. The main reason at the base of selecting population growth rates instead of other predictors of metropolitan expansion (e.g. settlement density, urban footprints, building activity) as the dependent variable in our study lies in the substantial stability of the (census) official methodology at the base of field data collection over a long time interval (e.g. Carlucci et al., 2018). In this perspective, total population was likely the most reliable (statistical) aggregate collected over demographic censuses in the last decades and especially after World War II, when census techniques stabilized and consolidated in Europe and, more generally, in advanced economies throughout the world (Ciommi et al., 2018). This is a reason that justifies the extensive use of total population in empirical works addressing local/regional demographic trends and estimating urban expansion (and metropolitan growth and change) in both advanced economies and emerging countries (Haase et al., 2010; Dyson, 2011; Cuadrado-Ciuraneta et al., 2017). Overall, census data are regarded as having a better quality than administrative sources (e.g. national/regional population registers) – that resulted to be more sensitive to technological development or changes in administrative regulations – and sampling surveys – whose precision is intrinsically associated with sample size, relevant units' selection criteria, and issues of representativeness and scale coverage (e.g. Stockdale, 2016; Reynaud et al., 2020; Benassi et al., 2020). Census data in European statistical systems were released and certified, since a long time, as affected by minor systematic errors – mostly stable over decades (Kroll and Kabisch, 2012; Gil-Alonso et al., 2013; Morelli et al., 2014). On the contrary, official statistics from (continuous) administrative data sources and socioeconomic sampling surveys were affected by two types of interacting errors (namely the systematic component (basically associated with recording mistakes) and the random component, associated with sampling errors, poor comparability of recording systems and registration rules over long times, and technological change). Based on these considerations, population census data were considered an appropriate source of information for studies addressing long-term metropolitan growth (Siedentop and Fina, 2012; Zambon et al., 2018; Benassi et al., 2022).

Subsequent to the selection of the dependent variable, the candidate predictors of metropolitan growth were chosen with the aim of guaranteeing full comparability both in time and space (e.g. Lerch, 2014), providing detailed information in the analysis' dimensions mentioned above (territorial context, environmental characteristics, planning constraints, socio-demographic dynamics, economic specialization, urban functions and land-use). The analysis of such a detailed space-time horizon, together with a refined identification of impacts referring to each growth stage and to the cycle as a whole, are original and novel aspects of our study in regional science. According with earlier studies (e.g. Di Feliciantonio and Salvati, 2015), predictors were selected to provide a comprehensive assessment of multiple (economic and non-economic) aspects that characterize the evolving structure and functions of a given city (Le Gallo and Chasco, 2008; Kroll and Kabisch, 2012; Parr, 2012). All these variables were made available from official statistics (ELSTAT, Eurostat, European Environment Agency) or derived from digital maps of public use (www.geodata.gov.gr) elaborated with operational tools available in a Geographic Information System.

2.3.1. Analytical dimensions of metropolitan growth

In line with the approach delineated above (Section 2.2), identification of population growth drivers took account of three operational perspectives (e.g. Chi and Ventura, 2011): (i) factors influential on population growth, (ii) spatial dynamics of population expansion (or decline), and (iii) temporal dimension of change. Accordingly, the choice of the regulatory dimensions of metropolitan growth and the related explanatory variables reflect a necessary compromise between (i) the conceptual relevance of the predictors with respect to the study objective, (ii) the statistical reliability of predictors - such as to ensure full comparability over time and space, and (iii) the availability of basic information necessary for the construction of the individual variables. Being comparable over time, 18 indicators (three for each dimension mentioned in Section 2.2) were considered as representative predictors of urban growth at each survey year (SM.Table 1). Assumed to be a proxy of metropolitan concentration, demographic density is likely the most used indicator quantifying the degree of urbanity (Batty, 2008; Garcia-López and Muñiz, 2013; Qiang et al., 2020). The choice of proximity to the sea cost as another predictor of metropolitan growth is consistent with empirical findings on the attractiveness of coastal areas for amenity-driven residential development (Carlino and Sainz, 2019). Taken together, closeness to the sea coastline, average elevation, and environmental attributes – including land cover, soil quality, and climate – delineate the natural landscape of each municipality (Clark et al., 2002).

The locally varying interactions between landscape, settlement network, and economic activity may represent one of the most relevant sources of spatial heterogeneity (Yiannakou et al., 2017). In this context, planning constraints play a role in shaping settlement networks (Yaping and Min, 2009); even more in Greece, where the balance between the facilitation of developmental projects/investments – recovering from the late 2000s crisis – and the protection of ecologically fragile ecosystems, has given rise to a variety of local regulatory patterns (Papageorgiou, 2017). Socio-demographic aspects complete the regulatory dimensions (Salvati and Carlucci, 2017), providing the necessary information on social dynamics (at local scale) and demographic processes (at regional scale). A direct relationship between marriage/birth rates and the economic cycle resulted from different spatial dynamics reflecting the sub-regional heterogeneity of income distribution in Greece (Salvati, 2016).

Economic specialization was regarded as a factor shaping attractiveness of local contexts and thus catalyzing metropolitan development (Wolff and Wiechmann, 2018). Agglomerations and scale factors at the base of city growth are generally included in such an interpretative dimension (Wu, 2019). However, industrial specialization was also seen, in some cases, as a negative externality of metropolitan expansion determining congestion and dis-amenities that fueled short-haul population mobility and suburbanization impulses (Cuadrado-Ciuraneta et al., 2017). The shares of industrial, tourism, and other services in total businesses allow tracking the effect of economic specialization (Rontos et al., 2016). In fact, empirical evidence has suggested that place-specific performance of Greek economic sectors designed spatially heterogeneous patterns of regional resilience (Giannakis and Bruggeman, 2015). Reflected in multiple land-use, urban functions are finally considered the result of past dynamics and an important factor regulating metropolitan expansion (Pili et al., 2017). Their net effect varies largely over time and space, depending on the background context (Dembski et al., 2021). In particular, the three indicators considered in this dimension have been extensively used to delineate urban morphology in terms of land-use patterns, such as compactness, fragmentation, and diversification (Di Feliciantonio et al., 2015).

In this perspective, and based on earlier considerations in Section 2.3, amenities were intended here as desirable (or useful) features or facilities of a place (Berliant and Wang, 2004), e.g. contributing to the pleasantness or attractiveness of a given territory (Carlino and Saiz, 2019) – whose investigation is made difficult by the intrinsic complexity of the definition (Clark et al., 2002). Moreover, the inherent lack in direct information sources and relevant indicators may prevent the comprehensive estimation of an ‘all-inclusive’ local capital acting as amenities in the study area (e.g. Gkartzios, 2013). However, the selection of indicators detailed above allowed a focus on specific examples (based on proxies) of well-defined place-based capitals (namely, access to nature (protected land), landscape beauty, mild climate, and cultural/tourism attractiveness), that were recognized as relevant amenities in the study area (Cuadrado-Ciuraneta et al., 2017; Salvati, 2020; Salvia et al., 2020).

2.4. Spatial econometric analysis

Assuming local-scale population dynamics in metropolitan regions and the underlying socioeconomic context as spatially heterogeneous (Gutiérrez-Posada et al., 2017), a mixed approach was introduced here considering together statistical techniques that use different functional forms modeling spatial heterogeneity in population growth and, for generalization, identifying the main predictors of metropolitan expansion over different time scales. A comparison of the final output of each approach estimating the multivariate relationship between territorial and socioeconomic attributes of local communities, contributes to identify the most relevant variables influencing local-scale population dynamics (Salvati, 2020). Since multi-collinearity may occur in a multiple predictors’ dataset, we initially checked for statistical robustness of the model specification based on 6 dimensions influencing population growth and decline and the related 18 predictors of metropolitan development. More specifically, we calculated a Variance Inflation Factor (VIF) for each investigation year in order to identify collinearity among predictors. Results presented in SM.Table 2 document a substantially low collinearity rate among predictors, with average VIFs ranging between 1.91 and 2.55 across the time series and no variables overpassing an individual VIF of 7, with a value of 10 considered a diagnostic threshold for a critical level of collinearity among variables. To run model estimation, both the dependent variable and the predictors were standardized by mean subtraction and division by standard deviation of the spatial series.

We additionally provided some overall measures of multicollinearity going beyond the univariate evaluation provided by VIF for each individual predictor. SM.Table 3 shows different overall measures of multicollinearity diagnostics for the whole ensemble of regressors. Overall measures of collinearity detection include (i) the Red normalized indicator (Kovacs et al., 2015) which uses eigenvalues or quantifies the average correlation of the regressors, (ii) the sum of reciprocal eigenvalues of the sample correlation matrix according to the work of Chatterjee and Price (1977) and (c) Theil's indicator (Theil, 1971), a measure of collinearity based on the incremental contribution (R^2-R^2_j) to the squared multiple correlation, where R^2_j represents the R^2 from an auxiliary regression of predictor variables. Red indicator ranges between 0, which indicates absence of redundancy, thus all regressors are mutually uncorrelated and 1, which denotes maximum redundancy. Furthermore, values of the Theil's indicator near to 1 and the sum of reciprocal eigenvalues five times larger than the number of regressors detect collinearity among predictors. Measures reported in SM.Table 3 reject the hypothesis of multicollinearity among regressors for all the time intervals investigated here.

The relationship between annual population growth rate (dependent variable) and territorial/socioeconomic predictors was analyzed using cross-sectional regressions and spatial panel techniques. More specifically, we run spatially implicit models including a linear Ordinary Least Square (OLS) panel regression taken as a reference estimate, pooled regressions creating dummies for all the cross-sectional units, Generalized Least Squares (GLS) random-effects and between-effects panel regressions, as well spatially explicit panel regressions. The reduced form of a linear model for a given municipality $i = 1 \ldots N$ at time $t = 1 \ldots T$ is:

$$\underbrace{y_i}_{T\times 1} = \underbrace{x_i}_{T\times k} \underbrace{\beta}_{k\times 1} + \underbrace{\epsilon_i}_{T\times 1} \quad \text{(Equation 2)}$$

The random-effects model deals individual effects as part of the error term, allowing the inclusion of within-municipalities, time-invariant predictors without running into multicollinearity problems associated with the fixed-effects model (Baltagi, 2008). Considering the $i - th$ municipality, the form of a random-effects model is

$$y_i = \alpha + x'_i\beta + \mu_i + \epsilon_i \quad \text{(Equation 3)}$$

where $\alpha_i = \alpha + \mu_i$ is a $T \times 1$ vector, μ_i is the individual-specific random effect measuring the difference between the mean of the dependent variable at municipality i and the mean of the dependent variable in the entire area. The between transformation of the random-effects model was obtained expressing all variables as individual time averages.

Analysis of the spatial structure of population growth rates according to the local Moran's test highlighted a highly interconnected context meaning that values of a single variable are strictly attributable to their closer neighbors. Spatial autocorrelation is a special case of cross-sectional dependence and refers to the coincidence of value similarity with locational similarity. Specifically, outcome in one area can be affected by outcomes, covariates or errors in nearby areas meaning that models contain spatial lags of the outcome variable, spatial lags of covariates, and autoregressive errors, respectively. We denoted, for each period $t = 1...T$, y_t as the $N \times 1$ column vector of the dependent variable, and X_t as the $N \times k$ matrix of predictors. For each cross-section, the lag operator became a $N \times N$ matrix W describing the spatial arrangement of the N units computed using planar coordinates of municipal centroids. Generally, the coefficient $w_{ij} \in W$ denotes the spatial weight associated with units i and j, with the diagonal elements w_{ii} conventionally set equal to zero to exclude self-neighbors effects. Based on these premises, we considered the following approaches:

(i) a Spatial Autoregressive Model (SAR) specified with the form

$$y_t = \lambda W y_t + X_t \beta + \mu + \epsilon_t \qquad \text{(Equation 4)}$$

where $\mu \sim N(0, \sigma_\mu^2)$ in the random-effects case.

(ii) a Spatial Autocorrelation Model (SAC) combining SAR with a spatial autoregressive error specified with the form

$$y_t = \lambda W y_t + X_t \beta + \mu + \nu_t \qquad \text{(Equation 5)}$$

$$\nu_t = \rho M \nu_t + \epsilon_t \qquad \text{(Equation 6)}$$

where M is a matrix of spatial weights which may (or may not) be equal to W.

(iii) a Spatial Durbin Model (SDM) including spatially weighted independent variables as predictors, specified with the form

$$y_t = y_t + X_t \beta + W Z_t \theta + \mu + \epsilon_t \qquad \text{(Equation 7)}$$

Spatial terms λ, ρ and θ measure indirect (spillover) effects between municipalities which decline as the distance between units increases. In what follows we set $M = W$ and $Z_t = X_t$. A best-fit estimation of the considered models using empirical data was evaluated using R^2 and pseudo R^2. Best fit model's outcomes are shown in the following sections for both cross-section and panel analysis.

3. Results

The empirical analysis evaluated the importance of predictors representative of 6 dimensions of metropolitan growth (territory/topography, environmental attributes, planning constraints, socio-demographic context, economic specialization, urban functions/land-use) at 6 time points in Athens. The following sections illustrate the empirical results of (i) cross-section spatial regressions reflecting short-term population dynamics and (ii) a comprehensive spatial panel delineating long-term mechanisms of metropolitan development in the study area.

3.1. Short-term population dynamics

A generalized significance of Moran's index of spatial autocorrelation justified the extensive use of spatial models instead of traditional (spatially implicit) econometric approaches (results available on request from the authors). A Spatial Durbin Model (SDM) provided the best-fit estimation of population dynamics for all years considered, with pseudo R^2 increasing over time and overpassing 0.8 in the last observation year. Regression coefficients of SDM were reported in Table 1 (direct impacts) and Table 2 (spillovers). Other spatially explicit models (such as SAR and SAC) provided similar results (sign, intensity and significance of regression coefficients) although with a smaller goodness-of-fit, i.e. low adjusted R^2 or pseudo R^2 (results available on request from the authors).
Population dynamics and metropolitan development primarily responded to agglomeration factors during economic expansions and to non-economic factors – such as amenities – during recession. Moving from the first to the last decades under investigation, traditional forces and contexts underlying population dynamics (e.g. tourism specialization, demographic density, and compact settlements) lost importance and were progressively replaced with territorial and environmental factors, taking relevance in the last two-three decades. For instance, proximity to the sea coast exerted a significant and positive impact on population growth rates only in the most recent times. Regression coefficients suggested how accessibility drove population dynamics under recession, leveraging a process of population redistribution towards 'intermediate-density' locations. This spatial shift was particularly evident when looking at spillovers of environmental and territorial predictors. For instance, the across-county spillover effect of a 1 percent increase in the Climate Quality Index (CQI) resulted into an increment of population growth rate by 2.29 percent, on average. With a sparse population increase of 1 percent, population growth rate increased by 5.82 percent on average, highlighting the role of 'intermediate' locations (e.g. reflecting peri-urban settlements) and the attractiveness of peripheral districts rather than urbanities during the most recent recession stage.

3.2. Long-term population dynamics

Table 3 compared the results of spatially implicit panel regressions and direct effects of spatially explicit models, spillovers being reported in Table 4. As in the case of cross-section regressions, spatial panels provided the best-fit models. Direct impacts reflect how predictors affect the dependent variable within a given municipality at time *t*, whereas spillovers capture the variation in the dependent variable due to the behavior of predictors in neighboring units. The total effect is the sum of direct and indirect effects. Inhabitants per building and self-contained settlements exerted a negative impact on annual population growth rates. Self-contained settlements reflect a process of urban densification (e.g. brownfield development) instead of the (partial) conversion of non-urban areas into impervious surfaces (e.g. greenfield development), playing a fundamental role contrasting urban sprawl. Population density and crude fertility index positively affected population growth rates. Conversely, marriage rate seems to negatively influence population growth, and this evidence can be explained with the rise in the mean age of marriage – which led to a decline in total fertility rate. In fact, late marriage was associated with issues of unrealized fertility, i.e. desires of fertility at the end of the reproductive career, or the underachievement of fertility aspirations that can have meaningful implications for individuals' well-being as well as for population growth rates. Significance and sign of the coefficients seem to converge for all regressions except for the between-effects model. As in the case of cross-sectional regressions, SDM provided the best-fit estimation of spatial panels (pseudo R^2 = 0.50). With spillover effects being often significant, the across-county spillover effect of a 1 percent increase in population density and crude fertility rate incremented population growth rate by 1.42 and 1.53 percent on average, respectively. When marriage rate increased by 1 percent, population growth rate reduced by 0.98 percent, on average.

4. Discussion

Intensity and spatial direction of urban growth in Europe result from varying impacts of social change, heterogeneous territorial contexts, economic expansion and shrinkage (Siedentop and Fina, 2012). Diverging historical settings, migration flows, and households' choices, as far as fertility postponement and pre-marital cohabitation are concerned, influenced local population trends (Lesthaeghe, 2020). Long-term analysis of population distribution over space allowed a deeper insight in the interplay between demographic and socioeconomic dynamics (Camagni et al., 2017). Our study showed a sharp differentiation in population dynamics between urban and suburban districts based on location factors, income, economic specialization, and social functions (Storper, 2011). Differential population growth rates were also demonstrated to reduce the socioeconomic divide in central and peripheral locations along the metropolitan gradient (Carson et al., 2016).

In the timespan explored in our study, changes related to the first and second demographic transition, intertwined with economic downturns, reflected in alternate swings of Greek development, with sequential waves of urbanization and suburbanization (Petrakos, 1992; Gavalas et al., 2014; Remoundou et al., 2016). At the onset of the study period, Greece shared the characteristic profile of a Mediterranean country, with population and economic activities polarized along urban-rural gradients (e.g. Serra et al., 2014). Pull factors (agglomeration and scale) defined a typical pattern of compact urbanization (Tapia et al. 2018). Afterwards, spatial heterogeneity exerted a more intense role in population dynamics, progressively re-shaping the divide in low-density and high-density settlements and fostering counter-urbanization towards peripheral areas (Gkartzios, 2013; Gkartzios and Scott, 2015; Zambon et al., 2017).

Even preserving the role of urban nodes within a broader network (Chen, 2009), central locations progressively loose importance and coastal districts started attracting new population and economic activities since the 1970s (Salvati et al., 2016). Urban sprawl and suburbanization in the 1980s, linked to new marriage and fertility behaviors, coexisted with more traditional models reflecting socially polarized and dense settlements – resulting in a complex pattern of spatially heterogeneous population growth increasingly decoupled from traditional density gradients (Nechyba and Walsh, 2004). Following a continuous increase of resident population, a less intense gap between central and peripheral areas was observed since the early 1990s, as a result of economic processes and a more mixed social context (Remoundou et al., 2016). A mix of economic factors that includes industrial decline, informal activities in tertiary sectors and strong dependence on subsidies for urban poor (Monastiriotis, 2011), determined population shrinkage in central locations (Koutsampelas and Tsakloglou, 2013), outlining the inherent complexification in the spatial regime of population growth and decline characteristic of metropolitan Athens (Di Feliciantonio et al., 2018) and, likely, of many other Mediterranean cities (Carlucci et al., 2018).

Economic recession favored population redistribution towards suburban districts and low-density, tourism-specialized areas, reflecting place-specific growth paths less and less associated with agglomeration and scale factors (e.g. Stockdale, 2016). Even if urban-to-rural movements did not substantially alter the metropolitan hierarchy at the regional scale (Salvati, 2016), central locations were less resistant to recessionary shocks than more peripheral places with dynamic economic sectors, highlighting the contribution of amenities and place-specific attractiveness in metropolitan expansion (Clark et al., 2002). These findings suggest that any strategy of sustainable development in urban contexts should incorporate measures improving local competitiveness and regional attractiveness, avoiding economic shrinkage and population decline (Dyson, 2011; Lerch, 2014; Stockdale, 2016).

With spatial re-distribution of population being closely linked with economic downturns, our results definitely suggest new developmental paths beyond the traditional dichotomy in compact and dispersed settlements, assigning a key role to 'intermediate' areas in-between central locations and peripheral districts (Pérez, 2010). While economic expansions were still associated with radio-centric and semi-dense metropolitan development (with population increase in large and medium-size cities), recessions were associated to a different growth model, reflecting suburbanization (or even counter-urbanization) processes (Tapia et al., 2018). In this perspective, population dynamics and metropolitan development responded to agglomeration forces especially during economic expansions, being more sensitive to amenities during recessions (Zambon et al., 2017). Regression analysis confirmed a complex regional framework – with diversified socioeconomic dimensions going beyond traditional theories linking urbanization with scale and agglomeration economies (Schneider and Mertes, 2014). The empirical findings of spatially explicit econometric models suggest the importance of a comparative analysis of local systems and bring insights on the debate over future population trends along the metropolitan density gradient in economically developed (and socially divided) contexts (Salem et al., 2021). The empirical evidence of our study finally confirm the informative power of a multi-scale investigation of the differential impact of metropolitan cycles and economic downturns in past, present, and future population growth.

5. Conclusions

By focusing on the holistic regulation (namely, positive or negative, direct or indirect) of population dynamics on a local scale, our empirical work proposes an innovative framework to urban studies and regional science, mixing a classical econometric approach with an interpretative analysis that goes beyond the economic determinants of metropolitan growth, including relevant (non-economic) factors of change. Regulatory (feedback) mechanisms – partially investigated so far at smaller (i.e. low-resolution) spatial scales – outline the inherent complexity of both economic and urban cycles. In line with recent studies documenting the existence of non-linear stages of urban growth, our results contribute to a novel interpretation of population dynamics in metropolitan areas as an adaptive response to regulatory forces that interact on a local scale. The outcome of these forces is a sequence of economic impulses that are heterogeneous in space and diversified over time, which result in largely promiscuous developmental stages characteristic of the individual development of each city. In this perspective, a comparative understanding of the individual paths of urban expansion contributes to an integrated reading of the regulatory factors of metropolitan growth from both historical and spatial perspectives.

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