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Suburban fertility and the role of local contexts in a Mediterranean country: A spatial exercise

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ABSTRACT

Assuming spatial fertility as contextual to the development stage of a given region, this study formulates an interpretative framework integrating small-scale fertility variations with metropolitan cycles and economic downturns. Using spatial econometrics, spatial trends in a gross fertility rate were investigated along a sequence of economic expansions and recessions, distinguishing urban, suburban, and rural settlements in 51 Greek prefectures. Suburban fertility overpassed urban fertility, being in turn higher than rural fertility in several prefectures. Urban fertility was higher with economic expansion and declined with recession. The reverse pattern was observed for suburban fertility – increasing with crisis and assuming a greater spatial heterogeneity. By documenting a differential response of fertility to economic downturns and metropolitan cycles, our work suggests that spatial fertility divides are temporary outcomes of a specific ensemble of socioeconomic forces underlying regional growth.

1. Introduction

A complex interplay between socioeconomic change and population trends has characterized the long-term development path of European countries – especially in recent decades [1–3]. Demographic transitions have took place since the 19th century, with countries moving from high fertility and low mortality of relatively young populations to aging and a generalized reduction in birth rates [4–6]. Moderately declining fertility levels were characteristic of the 'First Demographic Transition', hereafter FDT [7]. With the FDT, life expectancy turned out to be longer [8], with joint reductions in mortality and fertility [9–11]. In advanced countries, the FDT encompassed a rather long time interval in parallel with urban concentration [12]. Regional fertility divides basically reflected urban-rural gradients [13], since urban fertility was demonstrated to be lower than rural fertility at the beginning of the transition, reverting such a trend at the end of this phase [14] (see Fig. 1).

The Second Demographic Transition (SDT) has occurred with intense socioeconomic transformations and huge population redistribution at regional scale [15], contributing to aliment exurban development in some cases. More intensively than the FDT, the SDT enlightened changes in individual and household characteristics – shaping fertility directly, or indirectly through changes in sexual and childbearing behaviors [16]. At the same time, the SDT consolidated widespread aging and a greater heterogeneity in population dynamics, households' size, as well as individual choices concerning marriage or cohabitation [2,17,18]. Demographic factors, e.g. the changing rates of marriage, cohabitation, and separation [19], have been studied extensively during the SDT. For instance, changing gender roles emerged as women's socioeconomic characteristics [6], including job market engagement (e.g. Ref. [20]) and educational achievement [21].

By defining new fertility purposes and behaviors [22], the SDT accompanied the emergence of regional structures oriented toward polycentric development and spatially balanced urban settlements [1]. These structures consolidated in advanced economies (e.g. Ref. [23]), leading to different spatial configurations from the original, compact one, and new relationships between cities and suburbs [24–26]. As a consequence, suburbs were frequently found to have higher fertility than central districts and neighboring rural areas (in line with the so-called 'suburban fertility hypothesis'), although in a context of rising spatial heterogeneity in birth rates [21].

The intrinsic linkage between economic transformations and fertility trends along metropolitan gradients was a unifying trait of the

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development history of several European countries [7]. Fertility shaped urbanization and suburbanization processes, contributing differently to socioeconomic dynamics associated with both (demographic) transitions [27]. On the one hand, the FDT alimented socioeconomic changes along metropolitan gradients, consolidating the uneven divide in urban and rural areas (e.g. Ref. [28]). On the other hand, empirical studies have indicated suburbanization as one of the basic outcomes of the SDT [29], being associated with younger and larger families whose child-bearing behaviors determine positive feedbacks in terms of local fertility and demographic dynamics – with increasing spatial heterogeneity across regions and countries [5]. Anyway, with both transitions, fertility proved to be sensitive to economic downturns [18,30,31], evidencing latent relationships with social dynamics [10].

The complex interplay of economic downturns, social change, and settlement patterns [32], justifies a comprehensive analysis of the relationship between fertility levels, urban cycles, and regional development. This investigation should be aimed at verifying if different types of metropolitan growth (reflecting e.g. compact urbanization or dispersed suburbanization) are associated with specific fertility levels [33]. While being extensively documented in Northern and Central Europe – mostly based on micro-level analysis [34], studies focusing on the suburban fertility hypothesis were rather scarce in Mediterranean countries, despite a relatively broad regional demography literature (e.g. Ref. [35]). A delayed timing of metropolitan cycles compared with Western and Northern Europe (being e.g. at the base of the 'differential urbanization theory' [36]), could be a reason of the scarce interest toward the issue in Southern Europe [37]. However, intense suburbanization since the 1980s, and a diffused process of local development – extending rapidly from urban to rural districts – reinforce the idea that a renewed, comparative investigation of economic downturns and local fertility trends – in light of the suburban fertility hypothesis – is particularly timely also in Northern Mediterranean societies [38].

Based on these premises, the present study assumes that suburban fertility rose over time more rapidly than urban and rural fertility depending on the short-term evolution of local contexts [39]. Making use of macro-level indicators, the suburban fertility hypothesis was tested explicitly in a low-fertility Mediterranean country experiencing sequential economic expansions (2000s) and recessions (2010s). Using a spatial analysis [40], local trends in a gross birth rate were investigated in Greece distinguishing long-term from short-term fertility dynamics in urban, suburban, and rural settlements of 51 Greek prefectures. By documenting a differential response of fertility to economic downturns and urban cycles, our work re-frames the relationship between birth rates and metropolitan change, demonstrating that spatial fertility divides are temporary outcomes of a specific ensemble of socioeconomic forces underlying regional growth.

1.1. The spatial dimension of fertility

Birth rates were documented to vary along the urban-rural gradient in advanced economies, suggesting that fertility patterns intimately reflect the sequential stages of demographic transitions [28]. Urban

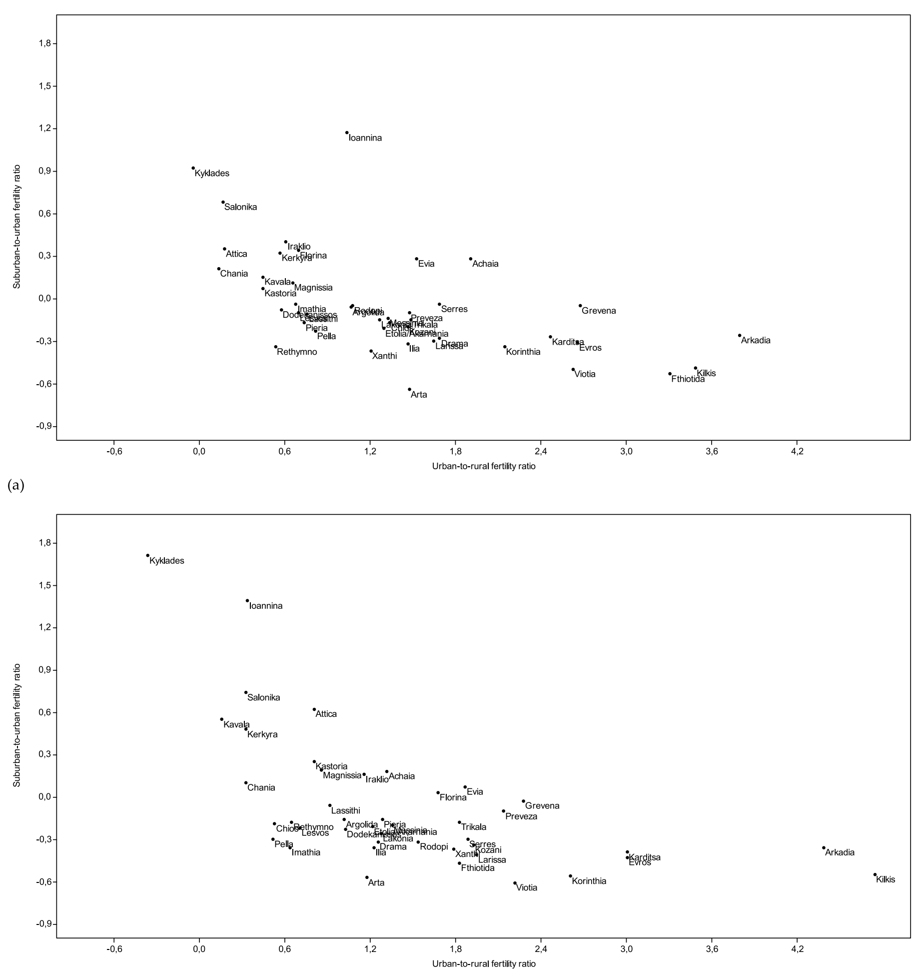

Fig. 1. The relationship between urban-to-rural and suburban-to-urban fertility ratios in Greek prefectures between 2000 and 2009 (a) and between 2010 and 2019 (b).

fertility was hypothesized to be lower than rural fertility during the last part of the FDT, decreasing more rapidly with the SDT [41]. Empirical studies document higher and lower fertility levels respectively in rural areas and large cities of many countries and regions around the world, such as the United States [42], Eastern Europe [43], Northern Europe [44], England and Wales [45], the Netherlands [46], Italy [47], as well as Germany and Austria [48].

Sharlin [49] summarized the dominant fertility trends along urban-rural gradients in the old continent as follows: (i) high fertility in rural contexts before the overall decline in fertility; (ii) increasing fertility in urban areas; (iii) a fast decline in urban fertility followed by increasing rural-urban divides, and (iv) rural fertility slightly higher than urban fertility in the post-transition period [44]. Fertility differences across regions were, however, connected intimately with the local context (e.g. Ref. [50]). Different desirable family sizes were at the base of fertility differences among rural areas and urban settlements [51]. In this perspective, the costs of children fluctuated among urban and rural locations [52], as well as the impact of religious and social standards on individual behavior mixed with settlement size [53].

Another factor shaping urban-rural fertility variations was educational composition – revealing spatial differences in childlessness [54]. Fertility variation by residence may also derive from the larger portion of students in urban areas than in rural contexts [34]. Spatial differences in urban and rural fertility have risen over time [21,55,56], whereas temporal differences in fertility were evident only more recently. These differences were particularly intense when controlling for the socioeconomic configuration of each study area [1], suggesting that contextual effects outline fertility choices.

In addition to differences among urban and rural fertility during demographic transitions [44], fertility divides across settlements reveal constraints on family size and work-related configurations [49]. Suburbs were found to record higher fertility [21], with single-family households at the base of the higher birth rates observed in metropolitan areas [57]. Inspiring couples to have more children (Vobecka and Piguet 2012), residential mobility toward suburban locations fueled population growth in fringe districts [15]. Differences in fertility within different residential contexts consolidated when controlling for population composition [41] and specific migration patterns [58].

1.2. *Differential fertility levels in urban and suburban settlements: the European context*

An increasing attention to spatial regimes of fertility emerged from recent literature [46]. Urban-rural fertility variations may have decreased over time, but significant differences among settlement types still persist nowadays [44]. Suburban fertility in contemporary Europe started increasing since the 1960s, following the post-war baby boom [21]. During the 1970s, a number of people in Europe moved to suburbs living in large apartments or semi-detached houses, thanks to the appropriateness of these areas for larger families with children [57]. Fertility rates became higher in such suburbs than in central cities [48].

The residential background demonstrated to have an independent impact over fertility decision-making, where internal migration towards suburban areas in Europe revealed a higher fertility rate [1]. Individual socioeconomic characteristics have determined significant urban-rural differences in fertility behaviors [34]. In these regards, compositional effects indicate that fertility rates differ among places since different people live in different settlements, while the 'contextual' hypothesis assumes that factors connected to immediate living areas are of critical importance [41]. For instance, couples with childbearing purposes may choose suburbs as more suitable residential contexts for families [51], while those with no childbirth plans may prefer larger settlements [28]. Housing conditions and the larger suburban setting may concurrently account for high levels of suburban fertility [21]. Housing is a proxy for household-specific features affecting childbearing behavior, e.g. household economic resources or financial support from parents [59], while assuming the role of background variables that reflect the living situation and direct setting of a family in some specific contexts [44].

1.3. *The logical framework of this study*

Although fertility divides have been studied at various geographical scales and with reference both to individual behaviors and to aggregated demographic outcomes (e.g. Ref. [60]), they have rarely been re-contextualized in a spatial perspective, considering the influence of exogenous factors that change over time along economic downturns and sequential stages of the metropolitan cycle [61]. In this regard, the present work re-frames the analysis of regional fertility gaps in Mediterranean Europe going beyond the classic 'urban-rural' polarization, and providing a long-term vision that integrates small-scale fertility variations and the evolution of the background context [62], as suggested in earlier studies for both Italy [63] and Spain [64] Assuming that spatial fertility variations are contextual to the development stage of a given metropolitan region [65], regional divides in birth rates are intended as temporary outcomes of a specific ensemble of socioeconomic forces underlying a given growth model [66]. Accordingly, the present study proposes a comparative, macro-scale analysis of fertility levels in urban, suburban, and rural settlements of 51 Greek prefectures during economic expansion (2000s) and recession (2010s). A spatial econometric analysis of the influence of the local context on fertility levels in different settlement types was also run in both periods, with the aim at verifying the role of local contexts in suburban fertility. In other words, this analysis was aimed at testing the 'contextual' hypothesis of differential fertility along metropolitan gradients [67].

More specifically, the analysis identifies relevant factors associated to fertility dynamics across spatial scales (from regional to local), estimating the joint impact of (i) economic downturns at national scale, (ii) metropolitan cycles (resulting in sequential urbanization and suburbanization stages at regional scale), and (iii) the background (socioeconomic) context at local scale. Assuming social forces as characteristic elements of urban growth, the intrinsic role of local contexts was evaluated using a vast set of indicators derived from official statistics. By linking agglomeration factors and scale economies with biophysical limits to settlement expansion and the emerging cultural and institutional aspects [68], these indicators delineate the intrinsic evolution of urban-rural gradients in Greece, as representative of long-term regional development processes in Mediterranean Europe.

2. Methodology

2.1. *Study area*

The investigated area encompasses Greece (131,982 km^2), a Mediterranean country divided in 51 prefectures ('nomoi') corresponding to the third level of the European Nomenclature of Territorial Statistical Units (NUTS-3). Prefectures are considered an appropriate spatial domain allowing a comprehensive analysis of population growth as a function of economic downturns and the background (social) context. More than half of Greek population (11 million inhabitants) settled in the Greater Athens and Thessaloniki regions [68]. These two cities expanded largely in the 1950s and the 1960s accommodating increased flows of population from the surrounding rural areas [69], as already observed in other Mediterranean countries such as Spain [70], Italy [50], and Portugal [49]. Regional capital cities (Iraklio, Patras, Larisa) and prefectural head towns (e.g. Volos, Kalamata, Chania, Kavala, Ioannina, Kozani) grew more intensively in the 1970s and the 1980s [71]. Internal districts were frequently exposed to depopulation and economic shrinkage in the 1990s, as the aggregate result of Athens' expansion first [68] and, later on, the rest of urban agglomerations [68]. Dynamic, tourism-specialized districts, especially in the Aegean region (Crete, Cyclades, Dodecanese), started growing in the 2000s after a relatively long stagnation [66]. Fertility in Greece showed evident fluctuations since World War II with spatial heterogeneity in birth rates rising since the 1960s [22]. Fertility decline was more intense in the early 1990s, in line with a general trend observed in Mediterranean Europe [72]. Birth rates recovered slightly in the early 2000s, especially in suburban locations [38]. In the last decade, economic recession has negatively affected fertility levels in both urban and rural locations [73].

2.2. Data and variables

The present study analyses the evolution over time in the spatial distribution of a Gross Fertility Rate (GFR) calculated from official statistics as the number of children in the total number of women in fertile age (15–49 years). Assumed as a basic, crude indicator of fertility in a context where more precise, specific rates are not available – or affected by non-negligible errors – GFRs were derived from vital statistics (number of births) and census data (population structure by sex and age) collected annually (births) or once per decade (population) on behalf of the Hellenic Statistical Authority (ELSTAT). More precisely, GFRs were calculated as 10-years averages (i.e. cumulating the total number of births between 2000 and 2009 and between 2010 and 2019, in turn divided by the number of women in fertile age derived from census data respectively for 2001 and 2011) at NUTS-3 spatial level. For each prefecture, birth rates were computed separately for three settlement types (urban, suburban and rural) as defined by Greek censuses on the base of key attributes such as population density and the dominant socioeconomic profile [72]. Being representative of dominant socioeconomic conditions over a sufficiently long time interval [38], average birth rates provided reliable fertility estimates at disaggregated spatial scales, avoiding the confounding effect of single-year outliers [22].

To investigate the positive (or negative) impact of the underlying (socioeconomic) context on birth rates, a dataset with 26 independent variables (i.e. candidate fertility predictors) at prefectural scale was prepared elaborating official statistics derived from national (and European) data sources (Table 1) referring to the early 2000s and the early 2010s. These variables quantify (i) specific drivers of (and constraints to) metropolitan growth (e.g. elevation, proximity to the sea coast, and linear distance from central locations such as Athens and Thessaloniki), (ii) settlement morphology (iii) spatial planning aspects (e.g. land-use, protected areas, soil and climate quality), and (iv) selected socioeconomic characteristics [61]. Most of these variables have proven effective in profiling the most representative (territorial and socioeconomic) characteristics of Mediterranean contexts, both urban and rural (see Ref. [62] and references therein). A shapefile of Greek prefectures provided by ELSTAT and other public sources (www.geodata.gov.gr) was used for spatial analysis using tools available in a Geographic Information Systems package.

Table 1
List of territorial and socioeconomic variables profiling Greek prefectures with some technical details (ELSTAT means the statistical office of Greece).

Variable	Data source	Reference year
Distance from Athens	ELSTAT shapefile	–
Distance from Thessaloniki	ELSTAT shapefile	–
Regional head town	ELSTAT, population census	–
Highway	ELSTAT/EEA shapefiles	–
Distance from sea coastline	ELSTAT/EEA shapefiles	–
International Airport	ELSTAT/EEA shapefiles	–
Public University	ELSTAT	–
Tourism specialization	ELSTAT, business statistics	2001, 2011
Total income growth, mean rate	ELSTAT, national accounts	2000–2009, 2010–2019
Per-capita value added, average	ELSTAT, national accounts	2000, 2010
Population density	ELSTAT, population census	2001, 2011
Share of agriculture in total value added	ELSTAT, national accounts	2000, 2010
Share of public administration in total value added	ELSTAT, national accounts	2000, 2010
Industry-to-service value added ratio	ELSTAT, national accounts	2000, 2010
Share of construction in total value added	ELSTAT, national accounts	2000, 2010
Share of finance/high-tech in total value added	ELSTAT, national accounts	2000, 2010
Share of real estate in total value added	ELSTAT, national accounts	2000, 2010
Natural population growth	ELSTAT, vital statistics	2000–2009, 2010–2019
Housing costs, dummy	ELSTAT, business statistics	2000, 2010
Climate quality	European Environment Agency (EEA)	30-years avg. (1961–1990)
Share of forests in total landscape	Corine Land Cover map (code 3.1)	2000, 2012
Sprawled settlement models	Corine Land Cover map (Code 1.1.2)	2000, 2012
Districts with >5 museums/ archeological sites, dummy	ELSTAT, cultural statistics	2000, 2010
Elderly index	ELSTAT, vital statistics	2001, 2011
Total unemployment rate	OECD/ELSTAT, population census	2001, 2011
Female unemployment rate	OECD/ELSTAT, population census	2001, 2011

2.3. Data analysis

Summary statistics of GFRs were tabulated by settlement type (urban, suburban, rural) and time interval (2000–2009 and 2010–2019). For each time interval, the relationship between 'urban-to-rural' and 'suburban-to-urban' fertility ratios across prefectures was illustrated using scatterplots. A two-step statistical strategy was adopted with the aim at identifying the most significant variables explaining local-scale variability in birth rates within Greek prefectures. The first step includes the definition of a socioeconomic profile for each prefecture based on a Principal Component Analysis (PCA) of the 26 contextual variables illustrated above (Table 1). The analysis produced few composite predictors of local birth rates tested for significance using spatial regression models in the second step.

2.3.1. Decomposing complexity of local contexts in few relevant predictors of fertility levels

To summarize the socioeconomic profile of prefectures, a Principal Component Analysis (PCA) was run on the matrix composed of 26 contextual variables (by column) and 51 prefectures (by row) separately for two time intervals (2000–2009 and 2010–2019). PCA is a multivariate exploratory technique aimed at evaluating the latent correlation structure of variables in a complex dataset, after reducing redundancy and multi-collinearity [74]. PCA performs a spectral decomposition of a correlation matrix aimed at extracting meaningful components that form an optimal combination of the input variables [40]. Components were extracted that explain the highest proportion of the total matrix variance [68]. Components with eigenvalues >1 were retained and analyzed as candidate predictors of local fertility (see below). Component loadings > |0.5| were considered significant when profiling the multivariate relationship among contextual variables [65]. A biplot was finally drawn to illustrate the correspondence between variables and cases (prefectures) in the multivariate space [35].

2.3.2. Spatial regression models

The relationship between GFRs and the predictors of fertility levels described above was analyzed over 51 Greek prefectures during two time intervals of equal duration (10-years) reflective of economic expansion (2000–2009) and recession (2010–2019). The dependent variable y_{it} measures, alternatively, GFRs in (i) urban, (ii) suburban, and (iii) rural settlements, as well as the absolute difference in GFR between (iv) urban and rural settlements and (v) suburban and urban settlements. In other words, five linear models were specified for each dependent variable (i-v) using different spatial econometric approaches (see below). All the principal components selected in the previous analysis' step (PCA) in accordance with the technical criteria made explicit in Section 2.3.1 entered each regression model as independent predictors of fertility. By construction, principal components are selected as orthogonal, linear combination of the input variables, thus reflecting the most relevant (socioeconomic) dimensions of the background context [35]. Use of orthogonal components in both standard and spatial regressions eliminates the risk of redundancy among predictors, allowing coherent and precise estimates. The relationship between components and variables was made explicit considering the individual (component-variable) loading, as delineated above in Section 2.3.1.

We assumed an Ordinary Least Square (OLS) regression as the baseline model (Equation (1)), that was extended further by incorporating several sources of spatial interaction effects with the aim at exploring spatial variability of the dependent variables [75]. This approach aims at capturing spatial autocorrelations that occur when the outcome of the *i*-th prefecture is influenced by features of the neighboring *j*-th prefecture. Adopting a linear specification, the OLS model was estimated as follows:

$$Y = \alpha i_N + X\beta + \epsilon \qquad \text{(Equation 1)}$$

where Y denotes a N × 1 vector consisting of one observation on the dependent variable for every spatial unit in the sample (i = 1, …, 51). X indicates a N × K matrix of predictive variables derived from PCA and associated with the K × 1 parameter vector β. Finally, i_N is a N × 1 vector of ones associated with the constant term parameter α and ϵ is a Nx1 vector of independently and identically distributed disturbance terms with zero mean and variance σ^2. Cross-sectional models were estimated separately for each of the two time spans (2000–2009 and 2010–2019).

Spatial models were then derived by augmenting any OLS to allow for three different types of spatial autocorrelations among the observation units, basically (i) the endogenous interaction of the dependent variable; (ii) the exogenous interaction among the explanatory variables; and (iii) the interaction among the error terms. Following Elhorst [75], the full set of interaction effects were specified in the General Nesting Spatial (GNS) model:

$$Y = \rho WY + \alpha i_N + X\beta + WX\theta + u, u = \lambda Wu + \epsilon \qquad \text{(Equation 2)}$$

where W is a positive N × N spatial weights matrix that describes the structure of dependence between observation units and reflects the spatial influence of location j on location i or conversely. In this paper, we adopted an inverse-distance spatial-weighting matrix with zero diagonal elements and off-diagonal elements ω_{ij} that are the reciprocal of distance between the units i and j. We assume linear distance as the best predictor of spatial interactions within fertility levels at the (aggregated) spatial scale adopted in this study, namely NUTS-3 provinces, and in a relatively small country (as far as surface area is concerned) like Greece, in line with earlier studies [35]. The matrix has been row normalized so that each row will sum to 1 [76]. The variable WY denotes the endogenous interaction effects among the dependent variables, WX denotes the exogenous interaction effects among the explanatory variables, and Wu denotes the interaction effects among the disturbance terms of the different prefectures. The scalar parameters ρ and λ measure the strength of dependence between units, while θ is a K × 1 vector of response parameters; they all show the underlying mechanism of spatial effects conditional on W. The remaining variables and parameters are the same as in Equation (1).

The most commonly applied spatial models that account for at least one of the spatial autocorrelations above can be obtained by imposing restrictions on one (or more) parameter(s) in Equation (2). Accordingly, three variants of spatial models were examined in this paper. When $\theta = \lambda = 0$, we assume the Spatial Autoregressive Model (SAR) wherein the spatial spillovers arise from the dependent variable:

$$Y = \rho WY + \alpha i_N + X\beta + u \qquad \text{(Equation 3)}$$

When interdependence among prefectures takes place through the error term, so that $\rho = \theta = 0$, we end up with the Spatial Error Model (SEM):

$$Y = \rho WY + \alpha i_N + X\beta + WX\theta + u, u = \lambda Wu + \epsilon \qquad \text{(Equation 4)}$$

Finally, we examined spatial spillovers in observables with the Spatial Durbin Model (SDM), assuming $\lambda = 0$:

$$Y = \rho WY + \alpha i_N + X\beta + WX\theta + u \qquad \text{(Equation5)}$$

These specifications were implemented to select the one that best fits the data. Models were estimated with the generalized method-of-moments [76] and best-fit estimation of the above-mentioned models was evaluated using adjusted-R^2 or pseudo-R^2. For the empirical analysis, all variables were standardized by mean subtraction and division by standard deviation of the spatial series [77].

3. Results

3.1. Descriptive analysis

During both economic expansion (2000–2009) and recession (2010–2019), gross birth rates diverged in urban, suburban, and rural districts of Greece, and regional divides in fertility levels increased over time. Table 2 shows, on the left, a ranking of the Greek prefectures that assumed the largest difference between urban and rural fertility rates. A considerable difference was observed, in both decades, in internal and peripheral prefectures, both in Northern and Southern Greece. These are generally low-density areas – with the only exceptions of Viotia, Korinthia, Achaia, and Larissa. These results highlight how, on the one hand, urban fertility was higher than rural fertility in peripheral and sparsely populated prefectures. On the other hand, the difference between suburban and urban gross fertility rates was more marked in metropolitan areas or in prefectures with compact and medium-high density towns. The ranking on the right in Table 2 includes all the prefectures with regional capitals or economically dynamic urban centers, with the only exception of Kerkyra, Evia, Florina and Kastoria. The first two prefectures, however, represent dynamic, tourism-specialized, economic districts. This means that suburban fertility was systematically higher than urban fertility in accessible, dense and economically dynamic areas. In both cases, the two rankings remain fairly stable over time.

3.2. Contextual analysis

Table 3 reports the results of a PCA aimed at decomposing the main dimensions of territorial and socioeconomic complexity of Greek prefectures into homogeneous (and independent) latent variables affecting the spatial variability of gross fertility rates. Seven components were

Table 2
Ranking of the 10 Greek prefectures with the highest figure in the specified birth rate.

Urban-to-rural		Suburban-to-urban	
2000–2009	2010–2019	2000–2009	2010–2019
Arkadia	Evritania	Ioannina	Kyklades
Kilkis	Kilkis	Kyklades	Ioannina
Fthiotida	Arkadia	Salonika	Salonika
Evritania	Karditsa	Iraklio	Attica
Grevena	Evros	Attica	Kavala
Evros	Korinthia	Florina	Kerkyra
Viotia	Grevena	Kerkyra	Kastoria
Karditsa	Viotia	Evia	Magnissia
Korinthia	Preveza	Achaia	Achaia
Achaia	Larissa	Chania	Iraklio

Table 3
Component loadings identifying the dominant socioeconomic profile of Greek prefectures under expansion (2000s) and recession (2010s) waves of the recent economic cycle in the country (bold, italics and standard characters respectively indicate significance at $p < 0.001$, $0.001 < p < 0.01$, $0.01 < p < 0.05$).

Variable	2000–2009							2010–2019						
	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Distance from Athens	−0.42			**−0.77**						*0.51*	*−0.56*			
Distance from Thessaloniki	0.41		*−0.54*					0.47	*−0.55*					
Regional head town	**0.65**		*0.50*					**0.62**	*0.55*					
Highway	0.40		0.45					0.41	0.45					
Distance from sea coastline	*0.54*							*0.55*						
International Airport	**0.71**							**0.69**						
Public University	**0.69**							**0.67**	*0.51*					
Tourism specialization	0.48		*−0.52*	−0.46				*0.52*	*−0.54*					
Total income growth, mean rate	0.43	*0.56*	−0.43							−0.44		−0.40		
Per-capita value added, average	*0.56*	**−0.70**						**0.64**		*−0.53*				
Population density	**0.69**							**0.68**				0.40		
Share of agriculture in total value added	**−0.61**					−0.45		*−0.53*					**−0.67**	
Share of public administration in total value added		**0.77**							*0.51*	*0.50*				
Industry-to-service value added ratio		**−0.65**		0.41						**−0.86**				
Share of construction in total value added		−0.47				**0.62**			*−0.53*					−0.46
Share of finance/high-tech in total value added	*0.52*	**0.63**						*0.52*	0.49		0.40			
Share of real estate in total value added		*0.52*									*0.58*	−0.48		
Natural population growth	0.49		0.46	−0.45				**0.72**			−0.48			
Housing costs, dummy	0.46		−0.43						−0.42					
Climate quality	*0.56*							*0.56*						
Share of forests in total landscape	*−0.58*							**−0.60**	0.47					
Sprawled settlement models	**0.68**							**0.70**						
Districts with >5 museums/ archeological sites, dummy	0.46			0.45				0.46						
Elderly index	*−0.56*		*−0.51*					*−0.59*			0.42			
Total unemployment rate				0.42			*0.57*						0.49	
Female unemployment rate					**0.74**							*0.56*		
Explained variance (%)	24.2	13.4	11.4	8.1	6.1	5.1	4.4	25.3	12.8	9.3	8.0	5.6	5.0	4.5

extracted for both the first (2000–2009) and the second decade (2010–2019), explaining respectively 73 % and 70 % of the total variance. All input variables were associated with at least one component; few variable were associated with more than one component. For both decades, Component 1 explained a dominant part of the total variance, being associated with the largest number of input variables – although component loadings demonstrated to be rather different between decades.

In the first decade (2000–2009), corresponding with accelerated economic growth, Component 1 (24 %) delineated a traditional urban-rural gradient in Greece. Positive coefficients were observed for variables characteristic of urban contexts (population density, regional capital city, international airport, public university, sprawled residential settlements, per-capita income). On the contrary, negative coefficients were observed in contexts with a preponderance of rural land-use (cropland, forests) and population aging leading to a moderate demographic decline. Component 2 (13 %) reflected a gradient of industrial-service specialization moving from economically dynamic areas specialized in advanced services (finance/high-tech) and public administration (receiving positive coefficients), to areas specialized in industrial activities – traditionally wealthier but possibly less dynamic under economic expansion (receiving negative coefficients).

Component 3 (11 %) highlighted a socio-demographic gradient distinguishing dynamic areas with high accessibility and intense population growth (positive loadings) from marginal districts with population aging (negative loadings), tourism specialization and higher dwelling costs. Component 4 (8 %) distinguished industrial areas with above-average unemployment rate (positive loadings) from tourism-specialized districts far away from Athens. Component 5 (6 %) outlined prefectures with the highest female unemployment rate (positive loadings). Component 6 (5 %) separated intermediate-density, dynamic prefectures specialized in the construction industry, from rural prefectures specialized in crop productions. Finally, Component 7 (4 %) identified prefectures with the highest unemployment rate (positive loadings).

In the 'recession' decade (2010–2019), Component 1 (25 %) represented the urban-rural gradient in Greece, similarly to what observed during economic expansion. Positive coefficients were observed for variables describing urban contexts (population density, regional capital city, international airport, public university, presence of sprawled residential settlements, per-capita income). Negative coefficients delineated local contexts with dominant rural land-use (e.g. cropland, forests) and population aging. In contrast with the intrinsic decline of the latter regions, the former regions were demographically dynamic. Component 2 (13 %) reflected the uneven polarization in (dominant) industrial and service activities, delineating a geographical gradient from dynamic areas specialized in advanced services (finance/high-tech) and public administration (positive coefficients), to areas specialized in traditional industries, mainly constructions.

Component 3 (11 %) highlighted the divide in industrial prefectures (negative loadings) and wealthier, service-specialized areas with above-average per-capita value added. Component 4 (8 %) delineated a center-periphery gradient with dynamic (mostly suburban) areas specialized in real estate and finance activities close to Athens (positive loadings), and demographically declining districts concentrated in peripheral areas far from the capital city. Component 5 (6 %) distinguished prefectures with the highest female unemployment rate, in turn associated with population density (positive loadings). Component 6 (5 %) discriminated intermediate-density and dynamic prefectures with above-average unemployment rates, from hyper-rural prefectures specialized in the primary sector. Finally, Component 7 (4 %) represented a more marginal dimension identifying prefectures with an above-average specialization in constructions (negative loadings).

3.3. Spatial regression models

Results of the econometric models identifying the most relevant predictors of differential fertility levels in urban, suburban, and rural areas were illustrated in Tables 4–8. Ordinary Least Square (OLS) regressions were used as a baseline. Spatial models, from the simplest SAR to the most complex GNS specification, have been introduced in order to check for the violation of the main assumptions underlying the OLS model. Regression models provided a variable goodness-of-fit depending on the input variables. The Wald test of spatial terms was significant in almost all regressions, pointing to an overall meaningfulness and reliability of the predictors. In general, there was a notable improvement in the goodness-of-fit when moving from the baseline (OLS) to a refined spatial model (GNS) interpreting the geographical and temporal variability of local contexts. Differences in the models' goodness-of-fit document how local contexts moderately affected urban fertility rates. Conversely, local contexts impacted suburban and rural fertility more significantly. Furthermore, the local context influenced the differential urban-to-rural fertility rate during economic expansion, while the differential fertility between suburban and urban settlements was demonstrated to depend less explicitly on the local context, especially with recession, being better represented by a simple spatial model like SEM, unlike the other predictors.

3.3.1. Urban fertility

Results of the econometric models identifying predictors of the spatial variability of GFRs in urban settlements demonstrate the significant role of specific dimensions of the local context – slightly more intense in conditions of economic expansion than recession. In both cases, the best performing models were SDM and GNS (with significant slopes systematically higher than 0.35). In the case of economic expansion (2000–2009), models documented a negative (direct) influence of Components 1 and 4 on fertility levels and a negative (indirect) influence of Components 3, 6, and 7. With recession (2010–2019), Components 1 and 4 negatively influenced the dependent variable (direct effects), while a spillover (negative) impact was observed for

Table 4

Results of Ordinary Least Square (OLS) and spatial regression models[a] (showing coefficients – both direct and indirect – and standard errors) with gross fertility rate in urban settlements (n = 51 prefectures) as the dependent variable and the selected principal components (see Table 1) as predictors of the background socioeconomic context by time interval (significance at * $p < 0.05$; ** $0.001 < p < 0.05$; ***$p < 0.001$).

Predictor	OLS	SAR		SEM		SDM		GNS	
	Coefficient	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
2000-2009									
Component 1	−0.0231	−0.0385		−0.0240		−0.121*	−0.321	−0.183***	−0.229
	(0.0518)	(0.0488)		(0.0496)		(0.073)	(0.576)	(0.049)	(0.440)
Component 2	−0.140*	−0.148**		−0.142**		−0.062	1.405	−0.033	0.901
	(0.0696)	(0.0651)		(0.0634)		(0.083)	(0.914)	(0.059)	(0.741)
Component 3	−0.0132	0.00813		−0.0027		0.028	−2.087***	0.108	−2.350***
	(0.0755)	(0.0712)		(0.0720)		(0.109)	(0.797)	(0.081)	(0.553)
Component 4	−0.151	−0.144*		−0.164*		−0.249**	0.044	−0.327***	0.294
	(0.0896)	(0.0838)		(0.0870)		(0.115)	(0.643)	(0.098)	(0.502)
Component 5	0.111	0.0991		0.111		−0.001	−0.367	−0.042	−0.651
	(0.103)	(0.0962)		(0.0952)		(0.103)	(0.952)	(0.084)	(0.718)
Component 6	0.0285	0.0309		0.0371		−0.115	−2.374**	−0.129	−1.996***
	(0.113)	(0.105)		(0.103)		(0.109)	(1.038)	(0.084)	(0.764)
Component 7	−0.144	−0.114		−0.134		−0.143	−1.949*	−0.104	−1.829**
	(0.122)	(0.114)		(0.112)		(0.111)	(1.124)	(0.091)	(0.723)
W spatial matrix			1.203**				0.866		1.096***
			(0.524)				(0.693)		(0.384)
Spatial error(**W**)					0.464				−6.297***
					(0.313)				(2.337)
Adjusted-R^2	0.181	0.170		0.192		0.391		0.379	
Moran's index	2.07								
Wald test spatial terms avalue		5.28*		2.20		19.34*		369.09***	
2010-2019									
Component 1	0.0422	0.0191		0.0333		−0.152**	−0.105	−0.164**	0.098
	(0.0577)	(0.0549)		(0.0554)		(0.075)	(0.449)	(0.067)	(0.331)
Component 2	−0.128	−0.0991		−0.114		−0.022	−2.294***	0.018	−1.948***
	(0.0811)	(0.0768)		(0.0768)		(0.096)	(0.884)	(0.081)	(0.754)
Component 3	0.0436	0.0297		0.0405		0.035	0.873	0.063	0.712
	(0.0954)	(0.0890)		(0.0892)		(0.091)	(0.777)	(0.085)	(0.623)
Component 4	−0.195*	−0.215**		−0.208**		−0.241**	0.300	−0.265***	0.488
	(0.102)	(0.0958)		(0.0962)		(0.102)	(0.958)	(0.095)	(0.762)
Component 5	−0.0020	−0.0139		−0.0114		0.105	3.059***	0.112	2.596***
	(0.123)	(0.114)		(0.113)		(0.101)	(1.046)	(0.094)	(0.857)
Component 6	−0.0054	0.0005		−0.0049		−0.080	−0.777	−0.078	−0.252
	(0.130)	(0.121)		(0.120)		(0.106)	(1.223)	(0.097)	(0.968)
Component 7	0.0196	0.0104		0.0125		−0.049	0.768	−0.052	0.018
	(0.136)	(0.127)		(0.126)		(0.111)	(1.599)	(0.102)	(1.417)
W spatial matrix			0.949**				−0.257		0.040
			(0.482)				(0.701)		(0.488)
Spatial error(**W**)					0.382				−5.495
					(0.364)				(3.381)
Adjusted-R^2	0.135	0.130		0.141		0.364		0.356	
Moran's index	0.66								
Wald test spatial terms avalue		3.87*		1.10		22.60**		148.47***	

[a] Model's abbreviations. OLS: Ordinary Least Square regression; SAR: Spatial Autoregressive model; SEM: Spatial Error Model; SDM: Spatial Durbin Model; GNS: General Nesting Spatial model.

Table 5
Results of Ordinary Least Square (OLS) and spatial regression models[a] (showing coefficients – both direct and indirect – and standard errors) with gross fertility rate in suburban settlements (n = 43 prefectures) as the dependent variable and the selected principal components (see Table 1) as predictors of the background socio-economic context by time interval (significance at * $p < 0.05$; ** $0.001 < p < 0.05$; ***$p < 0.001$).

Predictor	OLS	SAR		SEM		SDM		GNS	
	Coefficient	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
2000-2009									
Component 1	0.192***	0.189***		0.192***		0.149**	0.178	0.132**	−0.082
	(0.0488)	(0.0450)		(0.0458)		(0.062)	(0.552)	(0.062)	(0.555)
Component 2	0.00104	0.0116		0.00184		−0.009	−0.694	−0.020	−0.990
	(0.0705)	(0.0657)		(0.0640)		(0.082)	(0.627)	(0.084)	(0.604)
Component 3	0.156*	0.161**		0.142**		0.128	0.660	0.098	0.345
	(0.0768)	(0.0708)		(0.0712)		(0.101)	(0.864)	(0.102)	(0.861)
Component 4	−0.193**	−0.192**		−0.225***		−0.365***	0.720	−0.370***	0.594
	(0.0891)	(0.0819)		(0.0849)		(0.098)	(0.466)	(0.100)	(0.440)
Component 5	0.126	0.114		0.117		0.157	0.225	0.146	0.230
	(0.107)	(0.0993)		(0.0978)		(0.107)	(0.902)	(0.109)	(0.887)
Component 6	0.0502	0.0672		0.0944		0.185*	−1.325	0.204*	−1.444
	(0.125)	(0.116)		(0.116)		(0.108)	(0.901)	(0.106)	(0.893)
Component 7	0.0887	0.110		0.107		0.082	−0.861	0.098	−0.794
	(0.120)	(0.113)		(0.110)		(0.102)	(0.693)	(0.105)	(0.624)
W spatial matrix			0.474				−2.165**		−1.654
			(0.490)				(1.050)		(1.091)
Spatial error(**W**)					0.532*				−1.392
					(0.306)				(2.119)
Adjusted-R^2	0.442	0.448		0.469		0.537		0.527	
Moran's index	1.59								
Wald test spatial terms avalue		0.93		3.02*		22.70**		42.19***	
2010-2019									
Component 1	0.225***	0.217***		0.228***		0.185***	−0.249	0.186***	−0.349
	(0.0374)	(0.0341)		(0.0358)		(0.057)	(0.341)	(0.056)	(0.330)
Component 2	0.0262	0.0627		0.0395		−0.108	−1.372*	−0.114	−1.477*
	(0.0571)	(0.0564)		(0.0536)		(0.104)	(0.775)	(0.104)	(0.767)
Component 3	0.104	0.0858		0.0946*		0.111*	0.686	0.103	0.587
	(0.0622)	(0.0573)		(0.0573)		(0.065)	(0.540)	(0.066)	(0.527)
Component 4	−0.215***	−0.202***		−0.211***		−0.217***	−0.797	−0.220***	−0.815
	(0.0688)	(0.0626)		(0.0635)		(0.068)	(0.774)	(0.069)	(0.747)
Component 5	−0.160*	−0.146*		−0.150*		−0.131*	0.229	−0.133*	0.459
	(0.0889)	(0.0807)		(0.0811)		(0.074)	(0.679)	(0.074)	(0.670)
Component 6	0.205**	0.181**		0.181**		0.217***	0.635	0.208**	0.378
	(0.0991)	(0.0906)		(0.0902)		(0.083)	(0.733)	(0.084)	(0.725)
Component 7	−0.124	−0.101		−0.108		−0.210**	−0.742	−0.202**	−0.425
	(0.0974)	(0.0890)		(0.0880)		(0.095)	(1.018)	(0.095)	(1.016)
W spatial matrix			0.459				−2.132		−1.833
			(0.287)				(1.367)		(1.336)
Spatial error(**W**)					0.438				−0.107
					(0.297)				(1.754)
Adjusted-R^2	0.621	0.622		0.634		0.628		0.621	
Moran's index	1.54								
Wald test spatial terms avalue		2.56		2.17		11.68		17.72*	

[a] Model's abbreviations. OLS: Ordinary Least Square regression; SAR: Spatial Autoregressive model; SEM: Spatial Error Model; SDM: Spatial Durbin Model; GNS: General Nesting Spatial model.

Components 2 and 5. The remaining components produced insignificant impacts, either direct or indirect.

3.3.2. Suburban fertility

The adopted regression framework outlines that local contexts play a key role shaping the spatial variability of birth rates in suburban areas – especially with recession. All spatial models referring to the 2010s had similar goodness-of-fit, with a slightly higher value associated to SEM ($R^2 = 0.63$). With economic expansion, SDM produced a better fit, detecting negative spillovers of the fertility rate of neighbors. In both periods, Components 1 and 6 exerted a (direct) positive impact on suburban fertility while Component 4 contributed negatively. With recession, a negative impact of Components 7 and 5 (direct) and Component 2 (indirect) was detected.

3.3.3. Rural fertility

In both decades, local contexts affected the spatial variation of gross fertility rates in rural areas; SDM provided the best goodness-of-fit. With economic upturns, SDM and GNS documented how Component 1 produced a positive (direct) effect (with regression coefficient around 0.15 in the case of SDM model) on the dependent variable. Components 4 and 5 produced a negative (direct) effect (with coefficients, respectively, of −0.35 and −0.16), in turn highlighting that additional dimensions of local contexts (e.g. Component 6) indirectly contributed to reduce rural fertility. A direct and positive impact of Component 1, and a negative impact of Components 2 and 4, were characteristic of recession. Other components were statistically significant when examining indirect effects on rural fertility arising from SDM and/or GNS, such as Component 6 (positive impact) or Components 1 and 2 (negative impact). The latter, however, resulted to be significant solely for the GNS model.

3.3.4. Rural-to-Urban fertility divide

Modeling rural-to-urban fertility differentials performed better when including a spatial pattern of dependence; in this perspective, SDM gave the best results in both periods, delineating a direct effect of Component 1 in the first decade. With recession, a more abundant set of components affected the spatial variability of the examined fertility ratio. As to direct

Table 6
Results of Ordinary Least Square (OLS) and spatial regression models[a] (showing coefficients – both direct and indirect – and standard errors) with gross fertility rate in rural settlements (n = 51 prefectures) as the dependent variable and the selected principal components (see Table 1) as predictors of the background socioeconomic context by time interval (significance at * $p < 0.05$; ** $0.001 < p < 0.05$; ***$p < 0.001$).

Predictor	OLS	SAR		SEM		SDM		GNS	
	Coefficient	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
2000-2009									
Component 1	0.213***	0.180***		0.207***		0.152***	−0.600	0.118***	−1.193***
	(0.0387)	(0.0360)		(0.0372)		(0.055)	(0.412)	(0.046)	(0.372)
Component 2	−0.104*	−0.0749		−0.0968**		−0.102	−0.145	−0.126**	−1.020
	(0.0520)	(0.0471)		(0.0461)		(0.063)	(0.694)	(0.053)	(0.675)
Component 3	−0.0326	0.00171		−0.0297		−0.051	−0.757	−0.069	−1.324**
	(0.0564)	(0.0513)		(0.0537)		(0.080)	(0.606)	(0.075)	(0.523)
Component 4	−0.393***	−0.307***		−0.384***		−0.335***	−0.150	−0.335***	−0.392
	(0.0669)	(0.0658)		(0.0653)		(0.088)	(0.439)	(0.083)	(0.358)
Component 5	−0.122	−0.172**		−0.134*		−0.159**	0.836	−0.160**	0.597
	(0.0768)	(0.0701)		(0.0697)		(0.080)	(0.707)	(0.078)	(0.628)
Component 6	0.00994	0.00869		0.0251		−0.045	−1.648**	−0.063	−1.537**
	(0.0841)	(0.0746)		(0.0753)		(0.082)	(0.786)	(0.076)	(0.685)
Component 7	0.0874	0.139*		0.0976		0.120	−0.580	0.173**	−1.407**
	(0.0908)	(0.0823)		(0.0823)		(0.082)	(0.770)	(0.080)	(0.571)
W spatial matrix			1.611***				1.470**		1.491***
			(0.535)				(0.599)		(0.399)
Spatial error(**W**)					0.611				−3.589*
					(0.378)				(2.154)
Adjusted-R^2	0.622	0.640		0.644		0.715		0.705	
Moran's index	6.24*								
Wald test spatial terms avalue		9.07**		2.60		17.50*		298.27***	
2010-2019									
Component 1	0.200***	0.180***		0.201***		0.193***	−0.494	0.196***	−0.707***
	(0.0364)	(0.0332)		(0.0352)		(0.052)	(0.319)	(0.046)	(0.233)
Component 2	−0.150***	−0.127***		−0.151***		−0.216***	−0.813	−0.226***	−1.138**
	(0.0512)	(0.0462)		(0.0483)		(0.066)	(0.640)	(0.058)	(0.546)
Component 3	0.121*	0.102*		0.111**		0.053	0.159	0.098	−0.258
	(0.0602)	(0.0540)		(0.0551)		(0.064)	(0.536)	(0.067)	(0.456)
Component 4	−0.277***	−0.270***		−0.267***		−0.221***	−0.580	−0.278***	−0.546
	(0.0647)	(0.0574)		(0.0597)		(0.070)	(0.739)	(0.070)	(0.632)
Component 5	0.0719	0.0711		0.0614		0.083	1.257*	0.030	2.073***
	(0.0774)	(0.0687)		(0.0690)		(0.068)	(0.759)	(0.070)	(0.630)
Component 6	0.00974	0.0158		0.0158		0.004	−0.860	0.007	−1.038
	(0.0821)	(0.0729)		(0.0727)		(0.073)	(0.840)	(0.073)	(0.698)
Component 7	−0.0010	−0.0121		−0.0087		−0.005	0.873	0.018	0.925
	(0.0860)	(0.0764)		(0.0767)		(0.076)	(1.151)	(0.075)	(1.136)
W spatial matrix			0.683***				0.526		0.752*
			(0.264)				(0.568)		(0.402)
Spatial error(**W**)					0.573**				−3.421
					(0.265)				(2.174)
Adjusted-R^2	0.585	0.608		0.610		0.661		0.645	
Moran's index	7.80**								
Wald test spatial terms avalue		6.68***		4.67*		13.45*		271.36***	

[a] Model's abbreviations. OLS: Ordinary Least Square regression; SAR: Spatial Autoregressive model; SEM: Spatial Error Model; SDM: Spatial Durbin Model; GNS: General Nesting Spatial model.

effects, results of SDM highlighted the negative impact of Components 1 and 5 and the positive contribution of Component 2. Spillovers of Component 4 and 7 (respectively positive and negative) characterized the relationship between rural-to-urban fertility differentials and the local context. Outcomes of GNS delineated a similar picture, further evidencing an indirect (positive) influence of Component 1 on fertility divides.

3.3.5. Suburban-to-Urban fertility divide

The contribution of local contexts to the spatial variability of suburban-to-urban fertility divides was less evident than in previous cases. With expansion, spatial models did not produced a truly satisfactory goodness-of-fit (adjusted-R^2 ranging between 0.01 and 0.45). With recession, SEM achieved the best performance while GNS produced the worst one, with SAR and SDM giving similar outcomes. In the first decade, only Component 1 contributed - directly and positively - to shape the spatial pattern of the dependent variable. With recession, SEM indicated a (direct) positive impact of Components 1 and 6; a negative impact emerged for Components 5 and 6, although with a relatively low coefficient (above 0.20).

4. Discussion

Understanding regional fertility dynamics requires a more effective identification of drivers and consequences of demographic transitions oriented along both economic (e.g. wealth) and urban (e.g. density) gradients [2,28,67]. Although urban–suburban–rural divides in fertility may have decreased over time, significant differences among various types of settlement persist [44], in agreement with the negative relationship between human fertility and population density observed at continental and global scales [78]. In Southern Europe, internal migration flows were directed first to inner cities (between the late-1940s and the late-1960s) and second to suburban locations - underlining different settlement models and fertility transitions at local and regional scales [58,59,79].

As a result of socioeconomic transformations [80], spatial fertility regimes had changed substantially in Mediterranean Europe [67,81,82], with peculiar patterns across countries. In Spain, for instance, many

Table 7
Results of Ordinary Least Square (OLS) and spatial regression models[a] (showing coefficients – both direct and indirect – and standard errors) with the absolute difference in gross fertility rate between urban and rural settlements (n = 51 prefectures) as the dependent variable and the selected principal components (see Table 1) as predictors of the background socioeconomic context by time interval (significance at * $p < 0.05$; ** $0.001 < p < 0.05$; *** $p < 0.001$).

Predictor	OLS	SAR		SEM		SDM		GNS	
	Coefficient	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
2000-2009									
Component 1	−0.181***	−0.176***		−0.180***		−0.231***	0.345	−0.191***	1.101**
	(0.0391)	(0.0378)		(0.0351)		(0.062)	(0.483)	(0.052)	(0.401)
Component 2	−0.0115	−0.0326		−0.00940		0.038	0.707	0.056	1.019
	(0.0526)	(0.0525)		(0.0490)		(0.074)	(0.792)	(0.063)	(0.733)
Component 3	0.0107	0.0109		0.00355		0.082	−0.822	0.088	0.220
	(0.057)	(0.055)		(0.051)		(0.089)	(0.681)	(0.087)	(0.579)
Component 4	0.266***	0.201***		0.275***		0.149	−0.079	0.075	1.130
	(0.068)	(0.078)		(0.059)		(0.097)	(0.628)	(0.084)	(0.485)
Component 5	0.173**	0.192**		0.171**		0.114	−0.843	0.160*	−0.721
	(0.078)	(0.076)		(0.071)		(0.090)	(0.813)	(0.087)	(0.657)
Component 6	0.065	0.073		0.069		0.017	−0.443	0.083	−0.551
	(0.085)	(0.082)		(0.079)		(0.093)	(0.898)	(0.084)	(0.748)
Component 7	−0.089	−0.097		−0.090		−0.081	−0.744	−0.098	0.085
	(0.092)	(0.089)		(0.084)		(0.092)	(0.850)	(0.086)	(0.582)
W spatial matrix			1.423				1.732		3.078***
			(0.945)				(1.452)		(1.052)
Spatial error(**W**)					−0.125				−5.257***
					(0.879)				(2.002)
Adjusted-R^2	0.496	0.498		0.498		0.554		0.473	
Moran's index	0.10								
Wald test spatial terms avalue		2.27		0.01		13.68*		22.16**	
2010-2019									
Component 1	−0.182***	−0.178***		−0.175***		−0.299***	0.695	−0.335***	1.132***
	(0.052)	(0.050)		(0.046)		(0.072)	(0.463)	(0.059)	(0.328)
Component 2	0.046	0.041		0.034		0.217**	0.149	0.274***	0.452
	(0.073)	(0.070)		(0.066)		(0.093)	(0.840)	(0.080)	(0.657)
Component 3	−0.106	−0.098		−0.113		0.037	0.645	0.052	0.665
	(0.087)	(0.083)		(0.078)		(0.091)	(0.755)	(0.094)	(0.634)
Component 4	0.125	0.112		0.149*		0.065	1.972*	0.046	1.900*
	(0.093)	(0.091)		(0.084)		(0.103)	(1.128)	(0.095)	(0.978)
Component 5	−0.241**	−0.246**		−0.235**		−0.200**	0.882	−0.180**	0.501
	(0.112)	(0.106)		(0.103)		(0.094)	(1.187)	(0.090)	(0.894)
Component 6	0.078	0.079		0.073		0.048	−0.267	0.042	0.607
	(0.118)	(0.112)		(0.110)		(0.103)	(1.193)	(0.095)	(0.983)
Component 7	0.039	0.046		0.028		−0.008	−2.986*	−0.014	−3.781**
	(0.124)	(0.117)		(0.114)		(0.109)	(1.58)	(0.095)	(1.531)
W spatial matrix			0.430				−0.410		−0.039
			(0.781)				(1.565)		(1.187)
Spatial error(**W**)					−0.638				−4.487
					(0.881)				(2.763)
Adjusted-R^2	0.322	0.314		0.321		0.450		0.435	
Moran's index	0.25								
Wald test spatial terms avalue		0.30		0.33		27.95***		48.66***	

[a] Model's abbreviations. OLS: Ordinary Least Square regression; SAR: Spatial Autoregressive model; SEM: Spatial Error Model; SDM: Spatial Durbin Model; GNS: General Nesting Spatial model.

young families decided to move to suburbs since the 1960s, and highly suburbanized areas (e.g. in Madrid, Barcelona, Valencia, and Seville) experienced moderately high fertility [70]. Conversely, central cities displayed lower fertility rates, although this trend was rather heterogeneous both over time and space [83]. In Italy, internal migrations were directed toward the largest urban areas – especially in Northern regions – since the 1950s. Conversely, internal migrations toward suburbs and rural contexts took place in recent decades (e.g. Ref. [84]), approximately since the 1980s, in correspondence with a stationary population growth in central cities [38,65,77].

With this complex background in mind, the present contribution delineates the intimate relationship between suburbanization and local fertility in Greece as mediated by economic downturns. Recent literature indicated that young population segments - with a greater propensity to childbearing - were key agents of settlement sprawl [66,83,85]. Earlier studies also clarified the intrinsic connection between population structure and issues such as residential migration, social vulnerability, and demographic changes – identifying distinctive dynamics for urban and suburban districts (e.g. Ref. [59,69,86]).

Assuming a differential response of fertility to metropolitan cycles and economic downturns [87], our study documents how the socioeconomic profile of Greek prefectures accounted for highly differentiated fertility patterns [21], providing insights in favor of the suburban fertility hypothesis [34]. Regression outcomes indicate how metropolitan hierarchies – basically scale and agglomeration factors – have relied heavily on supporting high fertility on a local scale especially with the first stage of the city life cycle ('urbanization'). Conversely, the role of local contexts should be better investigated when explaining spatial variations in fertility rates over the most recent period, characterized by intense social change typical of the second demographic transition [88]. As a matter of fact, the influence of socioeconomic variables on birth rates was demonstrated to decrease with economic crisis [89]. These results suggest that, in a context of late suburbanization, recession has led to a greater spatial heterogeneity in birth rates [90], with a possible decoupling of fertility levels from both economic and urban gradients [38].

Based on these premises, our study demonstrates that recent fertility dynamics in Greek prefectures are in line with predictions of both (i) the

Table 8
Results of Ordinary Least Square (OLS) and spatial regression models[a] (showing coefficients – both direct and indirect – and standard errors) with the absolute difference in gross fertility rate between suburban and urban settlements (n = 43 prefectures) as the dependent variable and the selected principal components (see Table 1) as predictors of the background socioeconomic context by time interval (significance at * $p < 0.05$; ** $0.001 < p < 0.05$; ***$p < 0.001$).

Predictor	OLS	SAR		SEM		SDM		GNS	
	Coefficient	Direct	Indirect	Direct	Indirect	Direct	Indirect	Indirect	Indirect
2000-2009									
Component 1	0.161***	0.152***		0.157***		0.192***	0.069	0.191**	−0.117
	(0.043)	(0.037)		(0.035)		(0.061)	(0.574)	(0.061)	(0.579)
Component 2	0.074	0.055		0.077		0.030	−0.328	0.011	−0.528
	(0.062)	(0.055)		(0.054)		(0.083)	(0.644)	(0.088)	(0.618)
Component 3	0.074	0.051		0.088		0.044	0.638	0.014	0.517
	(0.067)	(0.061)		(0.055)		(0.103)	(0.700)	(0.108)	(0.690)
Component 4	−0.110	−0.128*		−0.079		−0.165	0.529	−0.144	0.325
	(0.078)	(0.068)		(0.055)		(0.100)	(0.556)	(0.105)	(0.541)
Component 5	−0.020	−0.030		−0.026		0.055	−0.264	0.065	−0.067
	(0.094)	(0.081)		(0.079)		(0.104)	(0.825)	(0.107)	(0.798)
Component 6	0.034	0.042		0.011		0.147	0.552	0.149	0.322
	(0.109)	(0.094)		(0.083)		(0.110)	(0.898)	(0.108)	(1.888)
Component 7	0.204*	0.209**		0.207**		0.163	0.903	0.150	0.936
	(0.105)	(0.090)		(0.085)		(0.103)	(0.813)	(0.107)	(0.777)
W spatial matrix			−1.677				−1.384		−1.247
			(1.386)				(2.047)		(2.130)
Spatial error(**W**)					−1.509				−0.146
					(1.731)				(2.851)
Ajusted-R^2	0.394	0.404		0.390		0.454		0.439	
Moran's index	0.70								
Wald test spatial terms avalue		1.46		0.57		13.10*		102.16***	
2010-2019									
Component 1	0.185***	0.180***		0.155***		0.330***	−0.451	0.349***	−0.710**
	(0.057)	(0.048)		(0.044)		(0.055)	(0.380)	(0.054)	(0.356)
Component 2	0.074	0.014		0.110		−0.306***	0.424	−0.391***	0.053
	(0.087)	(0.082)		(0.070)		(0.118)	(0.600)	(0.116)	(0.540)
Component 3	0.056	0.089		0.050		0.026	0.613	0.003	0.647
	(0.094)	(0.082)		(0.077)		(0.076)	(0.572)	(0.077)	(0.541)
Component 4	−0.094	−0.139		−0.102		−0.038	−1.422***	−0.030	−1.784***
	(0.104)	(0.092)		(0.086)		(0.079)	(0.680)	(0.081)	(0.615)
Component 5	−0.163	−0.229*		−0.204*		−0.365***	−0.847	−0.389***	−0.344
	(0.135)	(0.121)		(0.114)		(0.094)	(0.780)	(0.095)	(0.742)
Component 6	0.222	0.254**		0.226*		0.287***	0.791	0.278***	0.504
	(0.150)	(0.127)		(0.124)		(0.094)	(0.743)	(0.096)	(0.701)
Component 7	−0.148	−0.197		−0.168		−0.327***	−0.773	−0.353***	−0.254
	(0.148)	(0.128)		(0.128)		(0.105)	(1.192)	(0.104)	(1.161)
W spatial matrix			−2.324				−7.095***		−7.448***
			(1.493)				(1.648)		(1.669)
Spatial error(**W**)					−1.552				−0.973
					(1.818)				(2.523)
Adjusted-R^2	0.338	0.311		0.328		0.031		0.014	
Moran's index	0.47								
Wald test spatial terms avalue		2.42		0.68		69.06***		72.45***	

[a] Model's abbreviations. OLS: Ordinary Least Square regression; SAR: Spatial Autoregressive model; SEM: Spatial Error Model; SDM: Spatial Durbin Model; GNS: General Nesting Spatial model.

first demographic transition (e.g. increasing rural-urban fertility divides), and (ii) the second demographic transition (e.g. direct and indirect outcomes of the 'suburban fertility hypothesis'). While inner cities were still losing population through out-migration and aging, a series of small-scale migration flows have increasingly concentrated 'non-traditional' households in suburban locations, pointing to the emergence of spatially fragile and socially fragmented landscapes [65,68,91]. These findings definitively show that fertility differentials are inherent in the specific stage of the metropolitan cycle [35], being influenced by socioeconomic forces that evolve rapidly over time, in line with the 'contextual' hypothesis at the base of higher suburban fertility levels [44].

Differential fertility between urban and rural areas – and the increase in birth rates typical of suburban locations – should be therefore regarded as short-term phenomena, with a variable impact on country's fertility ([38,77]; Panori et al., 2019). At the same time, local-scale fertility variations may illustrate – likely better than other variables – the intrinsic evolution of a given metropolitan system from urbanization to suburbanization [67,92,93]. By integrating macro and micro approaches, a comparative analysis of local fertility rates may confirm such assumptions for other European cities and regions.

Moving from the conceptual issue to more technical perspectives, future studies should refine the empirical results of regression models by enlarging the time interval under investigation with the aim at capturing additional stages of the city life cycle and, more in general, covering a complete economic cycle. According with the enhanced availability of official statistics, fertility dynamics at smaller scales (e.g. economic districts, municipalities) should be more deeply investigated. Moreover, the analysis' design should integrate spatial econometric global models (such as those adopted in the present study) with local models (including e.g. Geographically Weighted Regressions) providing a coherent description of the intimate (demographic) interactions between neighborhood areas, whose geography is emerging as a particularly complex issue in recent fertility dynamics. In this perspective, the spatial structure of fertility levels should be finally tested against more complex hypotheses than the assumption done in the present study (i.e. dynamics based on linear distances prevail on other types of spatial interactions). A comparison of spatial econometrics implementing different spatial matrices with both distance and contiguity metrics may help in clarifying this research aspect.

5. Conclusions

According to an extensive demographic analysis of recent dynamics in a Mediterranean country experiencing dispersed urban expansion and rural shrinkage, our study evaluates the contribution of suburban fertility to urban cycles in Greece, verifying the specific impact of recent economic expansions and recessions. The importance of the background socioeconomic context at the local scale was investigated using urban, suburban and rural districts as distinctive spatial analysis' units. Grounded on spatial econometrics, the specific information derived from this study can be useful when planning local-scale development actions containing metropolitan expansion, balancing urban-suburban divides, and mitigating the economic decline of rural areas. The selection of the study area is appropriate for this objective, since Greece underwent important changes in land-use, economic structure, and social dynamics due to the increasing pressure of global crisis.

While documenting the decline of the 'urban-rural' paradigm in favor of new 'metropolitan settings', evidence supporting the suburban fertility hypothesis in contemporary Greece outline the need to integrate knowledge of individual (demographic) behaviors with a more accurate interpretation of urban growth models, combining morphological and socioeconomic aspects. With this perspective in mind, urban studies may deeply benefit from demographic approaches, since an in-depth analysis of changes in local fertility seem to be an indispensable tool for a refined understanding of metropolitan cycles. Results of our study suggest that urban-to-rural and suburban-to-urban fertility divides are temporary and respond to a specific stage of metropolitan development, likely contributing to economic growth more heterogeneously than in the past. The most recent dynamics (e.g. Covid-19 pandemics) seem to delineate an even more complex territorial framework, with exogenous shocks acting more rapidly, and exerting spatially heterogeneous impacts on local populations. These aspects require a specific investigation, taking account of short-term population dynamics in a broader context of demographic and social change characteristic of the Mediterranean countries of Europe.

The intimate comprehension of the impact of economic downturns on local-scale demographic dynamics is of great relevance for regional studies and contributes to clarify the intrinsic relationship between population and economic processes at both neighborhood and urban levels. To provide policy-makers with useful scientific guidance in the upcoming urban era, demographers are required to refine their data sets to include spatially explicit (and temporally extensive) vital statistics (e.g. urban-, suburban-, and rural-specific birth rates). Since investigation of economic and population dynamics has traditionally followed parallel but distinct courses, regional studies have to better integrate these aspects, contributing to a multi-dimensional interpretation of metropolitan growth and change.

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Nothing to declare.

Consent for publication

All authors agree on submitting the present version.

Availability of data and material

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Barbara Ermini: Data curation, Software, Supervision, Validation. **Margherita Carlucci:** Conceptualization, Data curation, Funding acquisition, Investigation. **Marianna Cucci:** Supervision, Validation, Visualization. **Kostas Rontos:** Conceptualization, Formal analysis, Writing – review & editing. **Luca Salvati:** Formal analysis, Methodology, Resources, Writing – original draft.

Declaration of competing interest

Nothing to declare. No conflicts of interest to disclose.

Data availability

Data will be made available on request.

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