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March 2018

ASSESSING SPATIAL VARIATION AND HETEROGENEITY OF FERTILITY IN GREECE AT LOCAL AUTHORITY LEVEL

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March, 2018

Abstract

In the absence of spatial fertility analysis for Greece this paper aims at assessing spatial variations and underlying relationships between fertility and selected socio-demographic indicators at local authority level. The analysis is based on the 2001 census data for the 325 local authorities of the country. The results reveal the presence of significant spatial autocorrelation and the existence of spatial heterogeneity of structural interrelationship between fertility and predictors. The application of local models out-performs the standard OLS approach. However, the relationship between socioeconomic indicators and fertility is not always clear and further investigation is needed.

Keywords: Greece, Fertility, Spatial Heterogeneity, Spatial Dependence, Local Models, GWR

JEL Classification: J13, C21

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An earlier version of this paper was presented at the 2010 BSPS Annual Conference, 13-15 September, 2010, University of Exeter.

BACKGROUND
During the post War period Greece has experienced substantial fertility reductions reaching levels below replacement. In 2001, 36 out of the 51 prefectures exhibited lowest-low total fertility rates (less than 1.3 children). Fertility variations at small area units and their implications for policy purposes have not been studied thoroughly, yet.

OBJECTIVE
In the absence of spatial fertility analysis for Greece this paper aims at assessing spatial variations and underlying relationships between fertility and selected socio-demographic indicators at local authority level.

METHODS
The analysis is based on the 2001 census data for the 325 local authorities of the country. The response variable, fertility, is measured by the child woman ratio. We employ descriptive and mapping techniques, global spatial autocorrelation measures as well as Ordinary Least Square (OLS) and Geographically Weighted Regression (GWR) models.

RESULTS
The results reveal the presence of significant spatial autocorrelation and the existence of spatial heterogeneity of structural interrelationship between fertility and predictors. The use of diagnostic tests indicates that global regression is inappropriate to portray the underlying relationships of fertility across the regions. The performance of local models is best in Athens and the surrounding areas and relatively poor in most islands and in parts of Central Greece. Proportion married exerts the strongest effect on spatial fertility differentials. Socioeconomic conditions are significant only in half of the local authorities.

CONCLUSIONS
The application of local models out-performs the standard OLS approach. GWR methodology is an efficient and appropriate tool to elucidate fertility associations and responses over space helping policy makers in formulating measures at local rather than national level. The relationship between socioeconomic indicators and fertility is not always clear and further investigation is needed.

COMMENT
Percentage of extra marital births in Greece is low (4.2% in 2000-2002). Implementation of fiscal and social measures supporting marriage and young married couples is essential.

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1. Introduction

It is nowadays well recognised that space and population are closely related through an inherent multi-facet process of shared or diverse demographic, socioeconomic and cultural factors and values. Geographical studies concerning fertility are of great interest as they serve to describe local reproductive levels and practices, to detect the impact of community effects on childbearing and to raise policy-making issues at district level. However, it is rather recently that demographers have started to examine systematically the spatial patterns of fertility and to assess their underlying mechanisms that account for the prevailing regional childbearing differentials. The growing piece of research on this discipline has been facilitated by a number of reasons including, among others, the availability of detailed spatial data, the development of powerful computer hardware and software tools and the introduction of advanced statistical methodologies (de Castro 2007). In trying to establish associations in a spatial framework between a response variable of interest and a number of explanatory indicators, it is found that traditional multivariate techniques, such as the OLS regression models, are not always appropriate. Fotheringham, Charlton, and Brunsdon (1998) argue that the regression parameter estimates are likely to exhibit nonstationarity over space due to three main reasons: sampling variations in the data, intrinsically different relationships across space and misspecification of the calibrated models. When spatially dependence of the data is present the application of spatial econometric techniques or Geographically Weighted Regression models can be applied to illuminate the underlying spatial reality (Fotheringham, Brunsdon, and Charlton 2002; Lesage and Pace 2009). The application of such laborious methodologies requires a relatively large number of observations (regions located in space).

In the absence of spatial fertility analysis for Greece this paper contributes to the knowledge of demographic differentials and mechanisms with the aim to assess spatial variations and patterns of the relationships between fertility and selected socioeconomic indicators at local authority level and to examine the presence of homogeneity/heterogeneity of causal relationships over space applying global and local regression models to official census material. In addition, it is proposed that centering the values of the independent variables, a well-established technique in usual econometric analysis, eliminates local multicollinearity effects arisen during the estimation process of local models.

2. Background of fertility trends and differentials in Greece

During the post War period Greece has experienced substantial fertility reductions as a result of considerable socio-economic changes as well as modifications in norms, attitudes and behaviour concerning family formation and childbearing. Until 1970 the period total fertility rate (TFR) was fluctuating around the level of 2.3 children per woman but since 1970 it has followed a noticeable declining trend which has been accelerated in the 1980s and 1990s. In 2000 TFR reached the lowest-low level (Kohler, Billari, and Ortege 2002) of 1.22 children per woman (Figure 1). In the subsequent years a moderate increased has been observed, partly attributed to immigrants (Tsimbos 2008), but TFR has remained below the level of replacement. Considering the overall evaluation of the fertility patterns and trends pertaining in the EU region (Bijak, Kupiszewska, and Kupiszewski 2008; Coleman 2005) as well as the possible dynamic effects of the late economic crisis which is underway in Greece, the prospects for recovering to replacement level are rather poor. The persistent of low period fertility rates for a long period of time has resulted in declining cohort fertility rates, too (Figure

2). Although signs of the Second Demographic Transition (Lesthaeghe and Kaa 1986; Sobotka 2008) are not clearly visible in Greece, postponement of parenthood and childbearing is palpable. Marriage is not as stable as it used to be but the proportion of extra-marital births in Greece is still very low compared to other European countries (4% in 2000, 7% in 2010).

[FIGURE 1 about HERE]

[FIGURE 2 about HERE]

Looking at the data at regional level (NUTS 3) it can be seen that across country fertility changes have been occurred in the same directions with the national trends (Figure 3). In 1981, the TFR in 30 out of the 51 prefectures of Greece was above replacement level but in 1991 and 2001 all prefectures exhibited period fertility less than 2.0 children per woman; in particular in 2001, 36 of the 51 administrative regions experienced lowest-low fertility rates (TFR<1.3). Between 1981 and 2001 the drop in TFR ranged from 0.4 (in Kilkis, located in Northern Greece) to 1.54 (in Ahaia, located in Peloponnese) children (Figure 4). For all prefectures, the gap in TFR was more pronounced during 1981-1991. A convergence in regional fertility differentials has been observed over time as a result of more or less common movements of the demographic and ideational alteration of the country's geographical and administrative departments.

[FIGURE 3 about HERE]

[FIGURE 4 about HERE]

3. Methodology

The analysis is based on spatial samples that is, observations collected from different administrative regions (municipalities). The traditional econometric framework ignores the geographic aspect of the data as it does not take into account the spatial effects which arise through two attributes inherent in regional population studies, the spatial dependence and the spatial heterogeneity (Anselin 1988).

Spatial dependence means that the values of a variable are not independent in space but they are correlated according to their geographical positions. For this reason, spatial dependence is better known in the literature as spatial autocorrelation. Spatial autocorrelation appears as a tendency of the observations to cluster. In the case of positive spatial autocorrelation high values of the variable are clustered with other high values (or low values with other low values) while in the case of negative spatial autocorrelation high values are surrounded by low values of the variable and vice versa.

In this study spatial autocorrelation is measured using the Moran`s *I* index (Moran 1950)

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(z_i - \overline{z}\right)\left(z_j - \overline{z}\right)}{\sum_{i=}^{n}\left(z_i - \overline{z}\right)^2}$$

where z_i and z_j are the values of the variable of interest at locations *i* and *j*, $\overline{z}$ its mean, *n* the number of different regions and w_{ij} the spatial weight for the two regions, that is the *i, j* element of the row standardized spatial weight matrix (*W*) which captures the spatial structure. Two regions have a spatial weight different from zero when they are neighbors. Different approaches for the construction of spatial weights are suggested that they are based on contiguity, distance or K-nearest neighbors. As a large number of Greek municipalities lack physical borders (islands) the contiguity spatial weights are inappropriate so that the K-nearest neighbor's criterion is used in this paper. Like the familiar Pearson correlation coefficient, Moran's *I* statistic takes values in the range -1 to 1. Positive values of the index indicate the existence of positive spatial autocorrelation, negative values the existence of negative spatial autocorrelation while values close to zero the absence of spatial autocorrelation. Tests for the statistical significance of the index can be conducted estimating the distribution of the index using permutations or randomizations or assuming normality (Cliff and Ord 1981).

The term spatial heterogeneity (Anselin 1988) refers to the lack of stability in the relationship among the variables in the different geographical regions. This means that the parameters of a regression model are non-stationary but vary in space. The cause of this phenomenon, which is common in regional economic and demographic studies, is the existence of considerable population and income disparities between regions, the different sizes of the census tracts and in general the non-stationarity of the variables in space.

When spatial autocorrelation or spatial heterogeneity appear the conventional econometric methods lead to unreliable conclusions and advanced modelling techniques comprising spatial effects should be adopted. One category of techniques concerns local modelling that is, econometric models which allow for the existence of spatial non-stationarity in the parameter of the estimated equation. Local models consider that the relationships between variables change across regions. Essentially, this is an extension of a broader class of statistical measures, called local statistics (Anselin 1995) which estimate causal relationships existing in a given region of space taking into account the dependence with the neighbouring areas. Local models are useful tools in exploratory analysis of regional data and contribute to identify the spatial variations of the determinants under investigation.

Consider the multiple regression model:

$$y_i = \beta_0 + \beta_1 x_{1i} + \ldots + \beta_k x_{ki} + \varepsilon_i \quad (1)$$

where $\varepsilon_i \sim iid\, N(0, \sigma^2)$ and $i = 1, 2, \ldots, n$ refers to n different points in space. The above model is called global model and assumes that the relationship between dependent and independent variables remains stationary over the study region. The estimation of this model is achieved by the application of the usual Ordinary Least Square method (OLS). Fotheringham, Brunsdon, and Charlton (2002) based on the principles of locally weighted regression and kernel regression models (Cleveland 1979; Cleveland and Devlin 1988) developed the Geographically Weighted Regression (GWR), a non – parametric local regression methodology which allows for the existence of spatial non-stationarity in the parameters of a regression model providing local estimates for each geographic point.

Suppose the relationship described by the model (1) is non-stationary at any point in space. Then, the new model is written as:

$$y_i = \beta_0(u_i, v_i) + \beta_1(u_i, v_i) x_{1i} + \ldots + \beta_k(u_i, v_i) x_{ki} + \varepsilon_i \quad (2)$$

where (u_i, v_i) are the coordinates of i point in space. Model (2) is called local model and it is estimated separately for each point in space. Assuming that neighbouring areas have similar characteristics, model (2) for the region of i can be estimated using OLS with a subset of the sample consisting of points in the vicinity of point i.

To achieve the lowest possible bias, observations should be weighted so that these near to the point i have more influence in the model estimation than those located farther. In estimating the weights of the model, the First Law of Geography proposed by Tobler (1970) is taken into consideration. The weights are considered to be decreasing functions of the distance from point *i*. Using matrix notation, the GWR model can be written as $\mathbf{Y} = (\boldsymbol{\beta} \odot \mathbf{X})\mathbf{1} + \boldsymbol{\varepsilon}$ where $\mathbf{Y}$ is the $n \times 1$ vector of the values of the dependent variable, $\boldsymbol{\beta}$ and $\mathbf{X}$ are the $n \times (k+1)$ matrixes of the local parameters and of the independent variables, $\mathbf{1}$ is a $(k+1) \times 1$ vector of unities and $\boldsymbol{\varepsilon}$ is the $n \times 1$ vector of errors. The GWR estimator for point *i* (i.e. the *i*-row of matrix $\boldsymbol{\beta}$) is $\hat{\boldsymbol{\beta}}_i = \left(\mathbf{X}^{\mathrm{T}} \mathbf{W}_i \mathbf{X}\right)^{-1} \mathbf{X}^{\mathrm{T}} \mathbf{W}_i \mathbf{Y}$ where $\mathbf{W}_i = diag\left[w_{i1}, w_{i2}, \ldots, w_{in}\right]$ is a diagonal matrix which contains the weights for the observed data for point *i*. The estimation method is similar to the common method of Weighted Least Squares (WLS). What distinguishes GWR from WLS is that in WLS the weight matrix remains fixed for all observations while in GWR the weights have to be re-computed for each *i* during the estimation procedure.

The weights are computed using a weight function. In this paper, the adaptive b-square weight function is used which has the form:

$$w_{ij} = \begin{cases} \left[1 - \left(d_{ij}/h_i\right)^2\right]^2, & \text{if } d_{ij} \le h_i \\ 0 & \text{, otherwise} \end{cases}$$

where w_{ij} is the weight of the *j* observation at point *i*, d_{ij} is the distance between *i* and *j* points and h_i is the bandwidth that is the distance from point *i* to the point of the Nth nearest neighbor of *i*. In the above function, the ratio is called kernel and determines the number of data points included in each estimation step. The use of the adaptive kernel ensures that the estimation in each regression point will be made with the same number of observations with non-zero-weights. That is, the bandwidth is adjusted so that the same number of nearest neighbors for each regression is selected. The optimal bandwidth can be found by minimizing the corrected Akaike Information Criterion defined by Hurvich, Simonoff, and Tsai (1998) which for GWR model takes the form:

$$AIC_c = 2n\ln(\hat{\sigma}) + n\ln(2\pi) + n\left[\left(n + tr(\mathbf{S})\right)/\left(n - 2 - tr(\mathbf{S})\right)\right]$$

where $\hat{\sigma}$ is the estimated standard deviation of the residuals and $tr(\mathbf{S})$ the trace of the GWR hat matrix.

In practise in many situations, it is difficult to distinguish whether the source of the problem in a regression analysis is spatial autocorrelation of the data or spatial heterogeneity in the relationship because both result in a non-random patterning in the residuals. Brunsdon, Fotheringham, and Charlton (1999) support that if an analyst ignores the existence of spatial heterogeneity and estimates a regression model using the traditional methods, spatial autocorrelation will be presented in the residuals. GWR application seems to have remedy ramifications in the cases when regression residuals suffer from spatial autocorrelation.

The application of the GWR results in a set of local parameter estimates, standard errors and coefficients of determination at all points in space. By mapping the local estimates, the spatial variations in the direction and the magnitude of the relationship among independent and dependent variables can be explored. To assess the overall goodness of fit of the GWR model a pseudo coefficient of determination is constructed by comparing the predicted and observed values of the dependent variable at local level. If the GWR model explains better the data, the new coefficient of determination will take a greater value than the coefficient of determination of the global model obtained by OLS. The performance of the OLS and GWR models can be also achieved by means of a statistical test which is based on an ANOVA table. The null hypothesis is that the GWR model represents no improvement over the global model and the test statistic is:

$$F = \frac{\dfrac{SSE_{OLS} - SSE_{GWR}}{tr(\mathbf{S}) - (k+1)}}{\dfrac{SSE_{GWR}}{n - tr(\mathbf{S})}}$$

which has an approximate F-distribution. In the above statistic, SSE_{OLS} and SSE_{GWR} denote the residual sum of squares of the global and the GWR models respectively, $tr(\mathbf{S})$ is the trace of the GWR hat matrix and k the number of independent variables included in the model. Further methodological issues about GWR can be found in Brunsdon, Fotheringham, and Charlton (1996, 1998), Fotheringham, Charlton, and Brunsdon (1998) and Paez, Uchida, and Miyamoto (2002 a, 2002 b). Some applications of GWR can be found in Kalogirou and Hatzichristos (2007), Isik and Pinarcioglu (2006) and Muniz (2009).

A potential problem which arises during the estimation procedure of local models is the presence of possible local multicollinearity involving the intercept term. Local multicollinearity may arise from the existence of local invariance of one or more independent variables in some neighboring geographical areas. This is due to the space characteristic that socioeconomic conditions are similar in close regions. Thus, when GWR algorithm attempts to find the optimum bandwidth minimizing the *AICc* criterion selects samples in which the values of some independent variable are almost constant which leads to local multicollinearity with the intercept term of the local models. This type of local multicollinearity prevents the estimation algorithm to converge to an optimum number of nearest neighbors or in less severe situations selects local samples consisting of many observations for which the lowest possible *AICc* is not achieved. Although the problem of local multicollinearity in GWR models has been pointed out by Wheeler and Tiefelsdorf (2005) and Wheeler (2007), there has not been so far an established method to deal with it. The available suggestions are not easily applicable and the relevant tests are not incorporated into the existing spatial analysis software.

A practical way to deal with multicollinearity caused by invariant independent variables can be borrowed from the well-established remedy in the context of the OLS regression methodology by centering the independent variables that is subtracting their values from their means (Rawling, Pantula, and Dickey 1998). This transformation renders the independent variable vectors orthogonal to the intercept and eliminates the multicollinearity effects, while the estimated parameters and their standard errors obtained by the application of OLS remain unchanged. As GWR is considered as an extension of classical OLS regression, centering the independent variables can eliminate the multicollinearity influences in the case of local models, too. In this study centering of independent variables is adopted as a solution to the multicollinearity problems arisen during the estimation of local models.

4. Data and variables

4.1 Data

In this study we use data deriving from the 2001 census of Greece for the 325 Local Authority Districts (Municipalities) of Greece provided by the Hellenic Statistical Authority (ELSTAT 2011). The administrative divisions used in the analysis are in accordance with the new system of the Local Government Areas which has been adopted by the Greek Ministry of the Interior since 2010 and is known as the "Kallkrates Operational Programme".

4.2 Dependent variable

Fertility is measured by the Child–Woman Ratio (*CWR*):

$$CWR = \frac{P_{0-4}}{W_{15-49}} \times 1000$$

where P_{0-4} is the number of children under age 5 and W_{15-49} the number of women of reproductive age. The *CWR* is based entirely on census counts and represents a useful measure of fertility when vital statistics are not available at small-area level or the registered numbers of births are negligible. Because of this characteristic *CWR* has important applications in spatial population studies (Rowland 2006). One-fifth of the *CWR* is interpreted as an indirect estimate of the general fertility rate but with a downward bias due to mortality. Variations in *CWR*s correspond closely to variations in vital-statistics based childbearing rates indicating that high values of *CWR*s point towards high levels of fertility and vice versa (Siegel and Swanson 2004). Child-Woman Ratio tends to underestimate the true fertility levels because it relies only on the surviving children on census date. It is assumed that the relative downward bias of child-woman ratios due to mortality or enumeration errors is the same for all local areas.

4.3 Independent variables

A number of socio-demographic indicators are considered as potential explanatory variables of fertility.

(a) Married women aged 15-49 per 100 women of reproductive age; according to the official data (ELSTAT 2011) illegitimate livebirths represent a very small proportion of the total (3% in 2000-2002). As extramarital fertility is almost negligible it is expected that the proportion married will exert a positive impact on fertility.

(b) Number of immigrants per 100 population of the local area. Since 1990 immigration has been the main steering force of the population change in Greece affecting the growth and the age structure of the population and contributing to the number of livebirths realized (Tsimbos 2006, 2008). It is expected that the percentage of immigrants will exert a positive impact on the child-woman ratio.

(c) Number of nuclear families per 100 households. As there is no detailed information on three-generation households or household structures we introduce this contextual variable to express the type of family structure of the local populations. The nuclear families constitute the new family formation type, particularly in cities. It is expected that the proportion of nuclear families through the child-care constraints on employment of mother and via the general family economy (Burch and Gendell 1970; Presser and Baldwin 1980) will be negatively associated with fertility level.

(d) To express statistically the socio-economic environment of each area, we prepare a composite index of low socioeconomic conditions (LSE) based on indicators that are available at local authority level using the simple methodology of human poverty index proposed by the UNDP (1997, 2006). The proposed index is calculated as average of three basic indicators: the percentage of illiterate population, the probability at birth of not surviving to age 60 (per 100) and the unemployment rate (per 100). The construction of the socioeconomic index is based on census data on illiteracy and unemployment (Kalogirou, Tragaki and Tsimbos 2011) and survival estimates of the Greek local authorities (Tsimbos, Kalogirou, and Verropoulou 2011). Relying on previous survey research carried out in Greece (Symeonidou et al. 1997) it is expected that low socioeconomic conditions are associated with high fertility.

5. Results

5.1 Descriptive statistics

Table 1 presents the descriptive statistics of the variables used in the analysis and Figure 5 depicts their spatial distributions on quantile maps. All variables exhibit considerable regional differentials. Fertility (*CWR*) ranges from 60 to 583 children per 1000 women of reproductive age. High values of Child-Woman Ratios (210 or higher) are observed mainly in Northern Greece, parts of Central Greece, in Crete and in most islands of the country. Proportions married higher than national average (60% or more) can be found also in Northern Greece and in Crete, while percentage of nuclear families less than average (80%) are observed mainly in Aegean and Ionian islands, in Crete and parts of Peloponnese and Central Greece. Percentage married and percentage of nuclear families exhibit the lowest coefficients of variation (about 9%). Immigrants are concentrated mainly in cities and display the highest relative variance. The poorer socio-economic environment appears in north-eastern part of the country (Thrace), Epirus and in north-west part of Peloponnese.

[TABLE 1 about HERE]

5.2 Spatial autocorrelation

Moran's *I* statistic for the indicators used in the analysis were estimated considering alternative spatial weights constructed with different number of nearest neighbors (Table 2). Regardless of the neighbor numbers considered, Moran's *I* values for each variable are unchangeable in magnitude and indicate the existence of positive spatial autocorrelation. In all instances the spatial clustering is statistically significant at level 0.0001 (the significance tests were obtained using 9999 random permutations).

[TABLE 2 about HERE]

5.3 OLS model

The regression analysis begins with the calibration of a global model with the aim to explain the contribution of the four selected socioeconomic indicators to the variation of fertility levels as they are reflected by the Child Woman Ratio. The OLS results are presented in Table 3. The results indicate that fertility (*CWR*) is positively associated with the percentage of married women, the percentage of immigrants and the index of socio-economic conditions and negatively with the percentage of nuclear families. All regression coefficients as well as the intercept term are statistically significant at 5% significance level and their signs are in the expected direction. As all independent variables are measured in deviations from their means, the intercept equals the mean value of the *CWR*. The estimated *F*-statistic is significant and the Multicollinearity Condition Number (*MCN*) of the estimated model is low indicating the absence of global multicollinearity problems. However, the coefficient of determination and the adjusted coefficient of determination of the model have moderate values, 0.345 and 0.337 respectively. This finding indicates that the global model fails to explain a considerable proportion of the fertility variability.

[TABLE 3 about HERE]

A number of statistical tests are also performed to ensure that the residuals of the estimated OLS regression model are homoscedastic, independent and normally distributed. Heteroscedasticity is detected on the basis of three widely accepted tests, the Breusch and Pagan (1979), the White (1980) and the Koenker and Basset (1982) tests. Normality assumption is assessed on the basis of the well-known Jarque – Bera statistic (Jarque and Bera 1987). Finally, the spatial autocorrelation of the residuals is assessed on the basis of the modified Moran's *I* statistic (Cliff and Ord 1972) using the same weights as previously. The results are presented in Table 4 and reveal that the residuals do not have constant variance, the normality assumption is rejected and that the residuals are not independent as they are positively spatial-correlated. Clearly, the main assumptions of the OLS regression model are violated. As a result, the Gauss Markov theorem does not hold. The variances of the estimated coefficients are devaluated and the non-normality of the residuals renders the statistical inference unreliable. The presence of heteroscedastic and spatial autocorrelated residuals indicate the existence of spatial heterogeneity and of spatial effects. The estimated relationship is not stationary across the study area. Ordinary least squares regression is unsuitable in these cases because the spatial context of the data it is not taken into account.

[TABLE 4 about HERE]

A possible solution to the problem could be the application of the non-parametric method of Geographically Weighted Regression which allows for the existence of spatial non-stationarity in the parameter estimates of the regression models, taking into account, therefore, the spatial heterogeneity and the spatial effects of the data.

5.4 GWR model

The quantitative relationship between *CWR* and the selected independent variables is re-estimated at a local level applying the GWR with an adaptive bisquare kernel. To determine the distances between the local areas, the centroid coordinates of each municipality were used. The minimization of the AIC_C criterion identified 109 nearest neighbours to be included in the estimation of each local model. Table 5 presents the summary statistics of the estimated local coefficients, the pseudo coefficient of determination and the AIC_C criterion value. It is evident that GWR considerably improves the explanatory ability of the model. The value of the adjusted pseudo coefficient of determination for the GWR estimation (0.586) is almost doubled compared to the corresponding OLS estimate (0.337) for the adjusted coefficient of determination of the global model, while there is a remarkable reduction in the residuals sum of squares from 338,263 (OLS) to 182,037 (GWR). The good performance of the local model is further supported by the reduction in the AIC criterion as well as the high value of F statistic of the ANOVA test for the improvement of GWR model over the OLS model (Table 6).

[TABLE 5 about HERE]

[TABLE 6 about HERE]

As already said, global residuals obtained by OLS were positively spatial autocorrelated. Moran's I statistics calculated for the local residuals take very low values (approximately 0). Considering 5 nearest neighbours the Moran's I statistic is estimated 0.0813 while in view of 20 nearest neighbours its value becomes 0.0112. The low values of Moran's I statistic indicate that local residuals are independent and GWR model has eliminated the problem of spatial autocorrelation, providing better results. Figure 6 shows the spatial distribution of the local Multicollinearity Condition Numbers obtained from the GWR estimation indicating that local multicollinearity problems do not seem to exist as the criteria used take low values. Fotheringham, Brunsdon, and Charlton (2002) have suggested a simple spatial non – stationarity index of a parameter based on the comparison of the interquartile range of the local estimates with the respective global estimate range of ± 1 standard deviations. If the interquartile range is greater than the global parameter range the parameter could be considered as non –

stationary. As can be derived from Tables 3 and 5 the interquartile ranges for all the estimated local coefficients are outside the range of ± 1 standard deviations of the global values denoting that the parameters vary over the study area implying, therefore, that the relationship between the fertility index and the independent variables is spatial non – stationary.

[FIGURE 6 about HERE]

Local coefficients of determination denote the local explanatory ability of the estimated model. They take values from 0.061 to 0.705 indicating that there is spatial variation in the performance of the model (Figure 7). The median of the local R-Square values (0.468) is greater than the OLS coefficient of determination (0.345) but obviously the relationship between fertility and the assumed determinants is stronger in some regions. The highest R-Square values form a cluster involving the region of Attica and the surrounding areas, which comprise the centre of economic activities in Greece. This cluster contains the most populated urban regions of Greece, that is the capital and the nearby metropolitan municipalities as well as the adjacent regions of Evia, Viotia, and north-east Peloponnesus. On the other hand, the model has poor explanatory ability in Dodekannisos Islands, eastern Crete, central Greece (especially in Fthiotida and Evritania), in some municipalities of Thessaly, north-west Peloponnesus and in Evros. Moderate values of R-Squares are observed for the rest regions.

[FIGURE 7 about HERE]

The statistical significance of the estimated local parameters is assessed using the local pseudo t-statistics (ratio of the local estimates to the corresponding local standard errors). Figure 8 shows the spatial distribution of the local parameter estimates as well as of the local pseudo t-statistics. The local intercept term takes values that are positive and statistically significant across the whole country. The estimated values of the local intercept range from 195.647 to 238.144 (Table 5) and are around the mean of the child woman ratio of the global model due to centering of the independent variables.

[FIGURE 8 about HERE]

5.5 Comparison of OLS and GWR findings

Comparing the OLS and GWR models the following findings can be summarised:

(a) In the global model the percentage of married women has a positive and statistically significant impact on fertility levels. In the local models the positive and statistically significant effects remain for the majority of municipalities. However, in some municipalities of the Dodecanese Islands, Central Greece, Epirus and north-west Peloponnese the relationship between fertility and married women although positive it is not significant. The inverse association between fertility and proportion married estimated for a small number of local areas is not statistically significant.

(b) In the global model the association between the percentage of immigrants and fertility is positively and statistically significant. The GWR application reveals, to some extent, a different picture. Although the positive relationship between fertility and immigrants remains for the greater part of the country, only in 74 municipalities (located in Macedonia, Thrace and in some of the Aegean islands) the effect is statistically significant. Negative associations between child woman ratio and proportion immigrants are found in Crete and North-west Peloponnese but the estimated parameters are not significant (with the exception of two small municipalities in the west part of Crete).

(c) In both global as well as local models, the association between the index of low socioeconomic conditions and fertility is found positive. However, the application of the GWR model reveals that the estimated local parameters are statistically significant only in about half of the municipalities (mainly in Peloponnesus, Western Greece, Crete and some of the Aegean islands). This finding suggests that at least at aggregate level, the relationship between socioeconomic indicators and fertility measures is not always clear and presumably additional qualitative or qualitative factors are also involved.

(d) At global level, the OLS model indicates that there exist a negative significant relationship between the percentage of nuclear families and the levels of fertility. At local level this finding holds only for Crete. In all parts of the country the above relationship turns positive and significant in 67 out of 325 municipalities. Significant positive relationships exist mainly in Western and Central Greece and in some of the Dodecanese Islands.

6. Discussion and conclusion

During the second half of the 20th century Greece has experienced considerable fertility reductions as a result of pronounced socioeconomic, ideational and contextual changes occurred at both national as well as regional level. In 2000 the total fertility rate for the whole country and for 70% of its prefectures laid below the lowest-low-level (less than 1.3 children per woman). Although regional fertility differences have been gradually diminishing and despite the socioeconomic convergence of the Greek local communities due to the undergone integration substantial variations still persist.

There is a body of literature indicating that most social phenomena are not spatially homogeneous but they are usually influenced by spatial effects. Concerning fertility, it is reasonable to expect that not only levels but also structural relationships between fertility outcome and its covariates may differentiate over space depending on the locations' distinct conditions. Spatial nonstationarity of fertility may be attributable to a number of factors such as local attitudes, values, lifestyles and life-course decisions, community characteristics and contextual attributes as well as social geographic integration and proximity implying diffusion of behaviour across nearby regions (Li 1973; Guilmoto and Rajan 2001; Işik and Pinarcioğlu 2006; Schmertmann, Potter, and Cavenaghi 2008; Muniz 2009; Weeks 2010; Basten, Huinink, and Klüsener 2012).

In this context the present paper contributes to the understanding of the regional dimension of Greek fertility with the aim to assess spatial patterns and interrelationships between fertility and selected socio-demographic determinants and to test the presence of spatial autocorrelation and nonstationarity over the Greek local authorities.

6.1 Methodological framework and exploration

The analysis is based on cross-sectional census data (2001) aggregated at local authority level. For the purpose of the study we integrate statistical information from different domains, but the use of a single source of data is considered as strength of the analysis as we avoid effects deriving from possible mismatching between the spatial scale of the phenomenon under investigation and the scales of measurements and observations (Anselin 2001).

Besides the descriptive part of analysis, two types of statistical approaches are used to answering the research questions posed in this paper. First, we apply univariate spatial autocorrelation techniques and second, we estimate global and local linear multiple regression models. With respect to multivariate analysis, in the context of exploratory analysis, we employed three types of linear functional forms to relate the dependent with the independent variables. In the first one, all variables were measured in their natural values. In the second type, all variables were introduced in logarithmic form (log-log model) and in the third one the dependent variable was measured in logarithmic form (semi-log model). It was statistically proved, however, that the performance of the log-log and semi-log regression models was comparatively poor so that the entire analysis was based on the results obtained from the natural functional relation and only these estimates are presented.

Four census-based socio-demographic indicators are employed as explanatory variables: percentage of married women of reproductive age, percentage of immigrants, percentage of nuclear families and a composite socioeconomic index. Their inclusion was decided on the grounds of the availability and reliability of the data as well as their importance in the Greek socio-cultural community milieu. Apart from the aforementioned explanatory variables, in the context of exploratory analysis a number of additional socio-demographic indicators were also incorporated in the models but the results obtained were vague or not statistically significant. For instance, despite the evidence of associations between fertility and geographical mobility (Perez 1991; Pandit 1992; White, Moreno, and Guo 1995; Hank 2001; Kulu 2005) internal migration proved insufficient to explain Greek fertility variations. Also, the provision of kindergarten and day-care facilities produced non-significant and unsettle results, whilst one could expect that high availability of childcare facilities would encourage childbearing (Hank 2001). Variables which resulted in indistinguishable or indefinable parameter estimates and did not contributed to the overall performance of the regression models were not considered.

Due to the small numbers of vital events and risk populations by locality it was not possible to calculate age-specific and consequently total fertility rates. Hence, the response variable of interest in this analysis is represented by the child-woman ratio (*CWR*). Despite its simplicity and importance in geographical population studies, for comparative purposes the child-woman ratio has certain shortcomings. This is so because *CWR* differentials may be influenced by variations in infant and child mortality, internal migration and the age structure of women within the reproductive age range. Empirical research shows that the impact of mortality on *CWR*s is usually limited (Guilmoto and Rajan 2001) while the effect of migration is not always clear. As infant and child mortality rates are very low throughout Greece and the effect of internal migration on fertility is inconsequential regional differences in these two factors are not expected to exert palpable impact on *CWR*s. However, the values of the child-woman rations may be influenced by differences in the age distribution of women of reproductive age across the local populations. This feature may possibly have some effect on the regression estimates but, even so, only to limited extent as the coefficient of variation of the mean age of women in the age-range 15-49 years is very low (0.022).

6.2 Spatial autocorrelation of variables

Descriptive analysis reveals that all variables under investigation exhibit considerable regional variations. The percentage of immigrants shows the highest and the percentage of married women the lowest relative variability. Child-woman ratios range from 60 to 580 children per 1000 women aged 15-49 years. Relatively high values of child-woman ratios are observed in Northern Greece, Crete and most of the small islands of the country.

In this study the univariate spatial dependency of the overall clustering of the data is summarized by the global Moran's *I* statistic. This measure assumes homogeneity over the whole study area (country) so that violation of this assumption implies spatial heterogeneity of the variable outcome. A difficulty in performing spatial statistical analysis of the districts of Greece arises from the particular characteristics of country's geography, that is due to the large number of Greek islands which lack physical boarders. Owing to this feature, the estimation of the Moran's *I* autocorrelation statistics was based on the number of K-nearest-neighbor criterion rather than the alternative contiguity or distance approaches. The results of the analysis show that regardless of the number of neighbors considered, the Moran's *I* statistics for all variables are positive and statistically significant and that their size remains almost stable. Among the covariates, the percentage of married women exhibits the highest spatial autocorrelation and the percentage of immigrants the lowest. Hence, the first finding of this study is that the values of the response as well as the explanatory variables under research are not independent in space but they are spatially correlated, indicating that high (low) values of the variables are clustered with other high (low) surrounded values. The implication of the existence of spatial autocorrelation in the data is that the results of econometric relations are non-optimal; in such cases, elaborated spatial-based procedures and schemes have to be employed (Hordijk 1979).

6.3 Spatial heterogeneity of relations

In this study the hypothesis of spatial homogeneity of the causal relationship between fertility and explanatory variables is tested by applying global (OLS) and local (GWR) regression models. It is well known that the above methodologies rely on different assumptions about the stationarity of the estimated parameters.

Although the OLS estimated parameters are statistically significant and have the expected sign, the overall performance of the model is rather poor (R^2=0.345). In addition, and more importantly, the application of a series of appropriate diagnostic tests reveal that the main assumptions of OLS model are violated, as the regression residuals are not homoscedastic, they are not independent (they are positively spatially correlated) and they are not normally distributed. It should be also mentioned that, according to exploratory analysis, results relying on transformation of the original variables did not obey the OLS hypotheses, either. The presence of heteroscedastic and spatial autocorrelated OLS residuals indicates the existence of spatial heterogeneity and the incidence of spatial effects. In such a case the conventional regression analysis usually leads to misspecification errors and misinterpretation of the results (Anselin and Griffith 1988). Thus, the second finding of this paper is that the relationship between fertility and its covariates is not spatially stationary and therefore a single regression equation (OLS) is proved not suitable to portray the underlying regional structural associations of fertility across the geographical sub-divisions of the country.

To capture the effects of spatial dependency of the data on the associations between fertility and socioeconomic indicators, the assumed linear relations are re-estimated by applying local regression models (GWR) with adaptive bi-square kernel function. Relying on a range of well accepted statistical criteria, our analysis reveals that compared to the OLS regression, the application of GWR almost doubles the size of the overall coefficient of determination, reduces remarkably the residual sum of squares, lowers the value of the Akaike information criterion, eliminates considerably the spatial autocorrelation of the residuals, produces spatially independent local residual estimates and the introduction of the centering of the explanatory variables effaces local multicollinearity problems. The above tests imply that the performance of the local models is superior and this is also supported by the outcome of the non-parametric analysis of variance indicating that GWR model has significant improvement over the OLS methodology. Finally the estimation of the Stationary Index proposed by Fotheringham, Brunsdon, and Charlton (2002) denotes that the parameters of the estimated equations vary significantly over the study area denoting that the relationship between fertility and socioeconomic explanatory variables is spatially non-stationary. Hence, the third finding of our statistical analysis is that in Greece the structural interrelations of fertility and socioeconomic factors are spatially dependent and that the GWR methodology out-performs the standard OLS approach. This finding is in accordance with a number of similar spatially-directed studies on the socio-economic determinants of fertility demonstrating also the benefits of GWR in spatial demographic research (Işik and Pinarcioğlu 2006; Muniz 2009; Kamata, Iwasawa, and Tanaka 2010). Spatial heretogeneity is a reasonable concept of the human behavioural science if one considers that despite the regional convergence of communities in many situations diversions and complexities are still inherent qualities of local societies. If spatial effects are present, a single-average global equation cannot grasp the actual underlying structural relations of the phenomenon under research and in such cases geographically weighted regression is an efficient and appropriate methodological tool to elucidate causalities and responses.

6.4 Implications

Fertility measures at small area units are of interest by themselves in describing local demographic conditions. This information becomes even more valuable when various socioeconomic and contextual indicators are additionally available at local level not only for interpreting regional differentials but also in targeting specific regions and hot-spot areas instead of formulating general broad national policies which may not be effective or well received by local communities.

This study demonstrates that there are considerable spatial fertility differentials between or perhaps within local authorities although the latter cannot be captured by the available statistical information. The study shows that spatial variations in Greece are not random so that spatial effects do play a role in our regression analysis. This becomes apparent when comparing the global and local regression outcomes as the direction or the statistical significance of the effects in many cases are different. The performance of the local models (GWR) vary across the Greek local authorities. The highest explanatory ability of the models are found for the region of Attica (Greater Athens and surrounding areas) which comprises the centre of economic activities in the country and the most urbanised population of Greece. These areas exhibit relatively low fertility but as their populations represent more than half of the total population of Greece, the behaviour of this region tends to influence the overall socio-demographic milieu. On the other hand, the lowest explanatory ability of GWR is found in central Greece and mainly in islands which, due to its specific geography, bring about some difficulties in analysing statistically such data.

As extramarital fertility in Greece is still very low, the percentage of married women of reproduction age exerts the most significant positive effect on regional fertility ratios and this is demonstrated by both OLS and GWR models. Similar results have been reported for non-European populations by Kohli (1977), Weeks (2010) and Kamata, Iwasawa, and Tanaka (2010). However, it is questionable if marriage will continue to play a dominant role in the future if Greece gradually follows the steps of the second demographic transition (Lesthaeghe and Kaa 1986; Sobotka 2008). Nevertheless, it becomes clear from the analysis that marriage and family support (financial, partial exemption from taxes, benefits of third child etc) should be a priority of the population policy in Greece by the central and regional authorities.

Living arrangements, expressed in this study as percentage of nuclear families, is considered as a factor affecting childbearing and childcare facilities at local level. Although nuclear family is becoming the dominant type of family structure in Greece, at in urban areas, the local regression models did not demonstrate a clear picture. This may be partly attributed to the family support system prevailing in the country which seems to have a protective effect on childbearing through the help (not only financial) to young couples offered by the grand parents for rising children.

In 2001, reference year of the study, immigration was a very recent phenomenon for Greece. Hence, the impact of immigrants on the child woman ratios is introduced indirectly via the young age structure of immigrants rather than their direct contribution to births. Recent vital registration data show that a relatively high proportion of births are assigned to migrant mothers (17% in 2006). However, according to empirical research the numbers of immigrant women are not large enough to affect the overall fertility levels (Tsimbos 2008) but update information in the future may reveal a different picture and more robust statistical associations.

Finally, our study suggests that socio-economic differentials explain to some extend regional fertility variations but the inherent associations are not at all times clear or statistically significant. In this paper the deprivation conditions of each local area are expressed by a reduced version of the well-known Human Poverty Index introduced by the United Nations. This composite index, despite its limitations, has proved a useful measure in analysing local health-related subjects (Bagheri, Holt, and Benwell 2009) but is seems that it is not always the case with fertility. In actual life, a mixture of economic and socio-cultural factors is a path of differentiated fertility responses and outcomes among local population groups whose values, life-course decisions and particular conditions, such as cost of living/raising a child or specific district difficulties, cannot be captured by a single three-component aggregate index. Settlements with more or less the same measurable economic attributes may exhibit different fertility levels and dynamics. The use of the Human Development/Poverty Indices at local authority level may be a weakness of the spatial fertility analysis suggesting that more detailed and multidimensional measures have to be elaborated the new census data (2011) or other statistical material become available. By the same token, it would be of great interest to incorporate statistical information of two successive censuses to examine levels, differentials and trends of fertility at district level and in a period of intensive economic crisis of Greece.

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Table 1: Descriptive Statistics of the variables used in the analysis

Variable	Min	Median	Max	Mean	SD	CV (%)
Child – Woman Ratio	60.000	210.558	583.333	212.404	39.916	18.80
Percentage Married Women	40.470	60.579	83.333	60.020	5.288	8.81
Percentage Immigrants	0.038	5.935	24.531	6.471	4.017	62.08
Index of Low S-E conditions	4.206	8.209	14.084	8.440	1.651	19.56
Percentage Nuclear Families	40.000	81.534	100.000	81.078	7.396	9.12

Table 2: Spatial Autocorrelation Analysis: Moran's *I*

Number of Neighbors						
Variable	K=5	K=6	K=8	K=10	K=20	P Value
Child – Woman Ratio	0.2896	0.2894	0.2648	0.2661	0.2713	0.0001
Percentage Married Women	0.5365	0.5333	0.5218	0.5095	0.4696	0.0001
Percentage Immigrants	0.373	0.3744	0.3469	0.3173	0.2435	0.0001
Index of Low S-E conditions	0.4432	0.4246	0.3975	0.3696	0.2918	0.0001
Percentage Nuclear Families	0.4768	0.4609	0.432	0.4151	0.3627	0.0001

Table 3: Global OLS Regression Results

Variable	Coefficient	Std. Error	t – Statistic	P Value
Intercept	212.404	1.803	117.775	0.0000
Percentage Married Women	4.055	0.365	11.107	0.0000
Percentage Immigrants	1.058	0.481	2.199	0.0286
Index of Low S-E conditions	3.680	1.220	3.017	0.0028
Percentage Nuclear Families	-0.568	0.261	-2.175	0.0303
R Squared: 0.345		Adj. R Squared: 0.337		
F – Statistic: 42.089		MCN: 1.677		
Residuals Sum Squared: 338,263		AIC: 3,190.330		

Table 4: OLS Residuals Analysis

Number of neighbors	Residuals Moran's I	Z – value	P –value
K=5	0.2182	7.410	0.000
K=6	0.2188	8.152	0.000
K=8	0.1838	7.976	0.000
K=10	0.1624	8.014	0.000
K=20	0.1524	11.238	0.000
Breusch-Pagan (1979) Heteroscedasticity Statistic: 1,219.877			0.000
White (1980) Heteroscedasticity Statistic: 234.767			0.000
Koenker-Basset (1982) Heteroscedasticity Statistic: 156.943			0.000
Jarque-Bera (1987) Normality Test: 2,549.827			0.000

Table 5: GWR Results

Coefficient	Min	Q1	Median	Q3	Max	Inter. Range
Intercept	195.647	206.937	209.960	214.338	238.144	7.401
Percentage Married Women	-0.773	2.487	3.446	3.812	5.709	1.325
Percentage Immigrants	-2.129	0.591	1.208	1.879	4.773	1.289
Index of Low S-E Conditions	-2.699	1.781	4.194	5.756	19.059	3.975
Percentage Nuclear Families	-4.241	0.257	0.659	1.054	2.616	0.797
Local R Squared	0.061	0.323	0.468	0.604	0.705	
R Squared: 0.647 Adj. R Squared: 0.586	AICc: 3,067.818 Nearest Neighbours: 109		Residuals Sum Squared: 182,037.181			

Table 6: Analysis of variance comparing GWR to OLS models

Source	SS	DF	MS	F
SSE OLS	338,262.6	5		
GWR Improvement	156,225.4	32.97	4,738.833	
SSE GWR	182,037.2	287.03	634.2031	7.4721

Figure 1: Period total fertility rates per woman: Greece 1955-2010

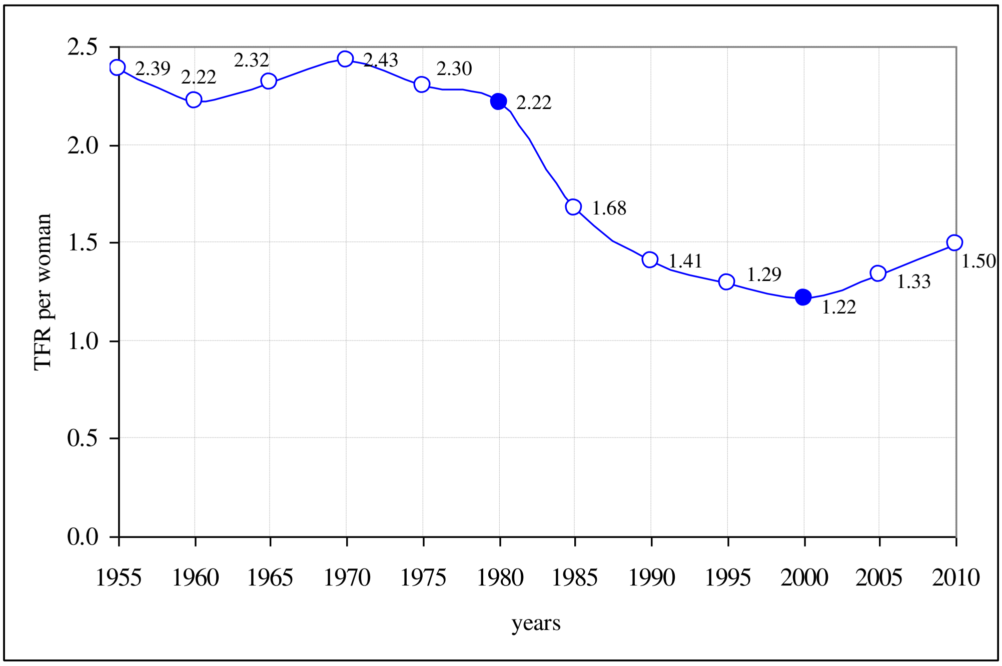
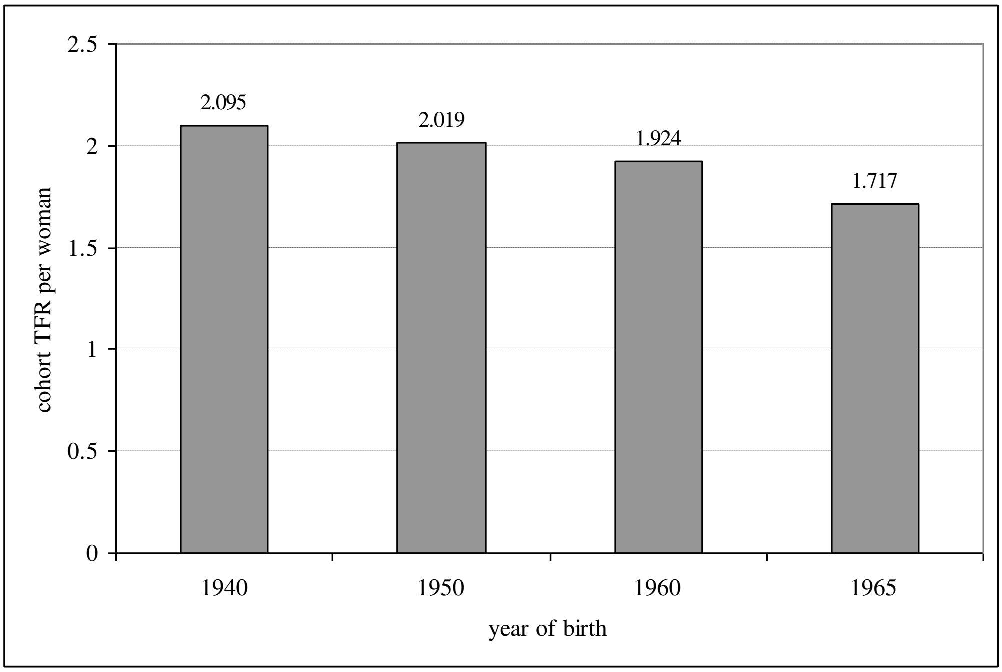


Figure 2: Cohort total fertility tares per woman: Greece 1940-1965 birth cohorts



Source: Frejka and Sardon (2004).

Figure 3: Period total fertility rates per woman at prefecture level: Greece 1981-2001

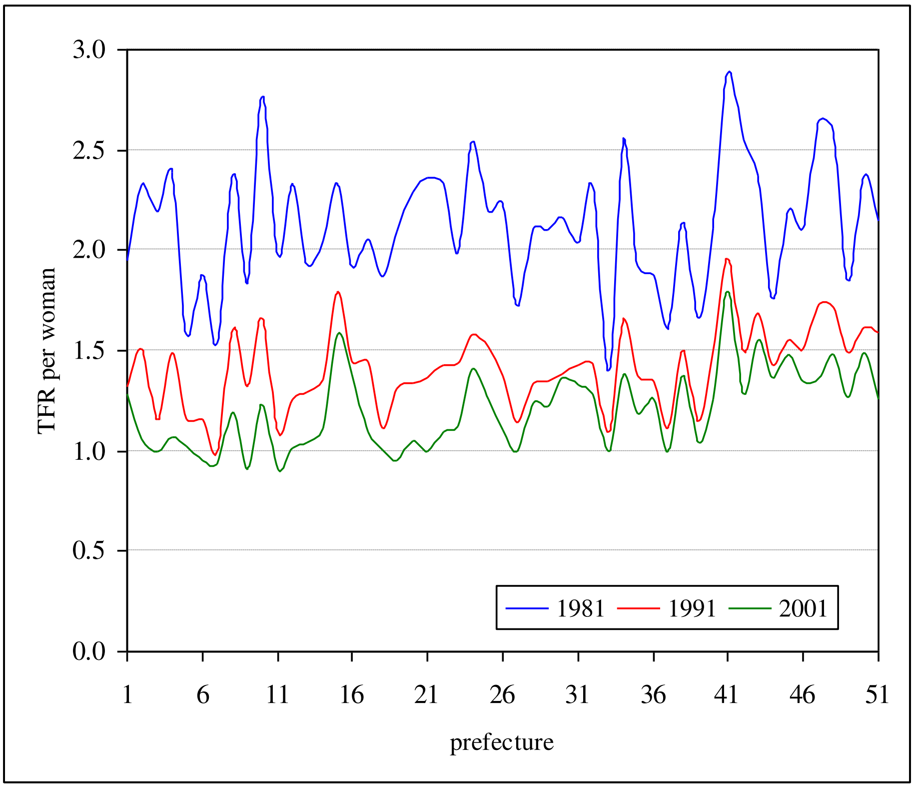


Figure 4: Change in period TFR during 1981-2001 at prefecture level in Greece

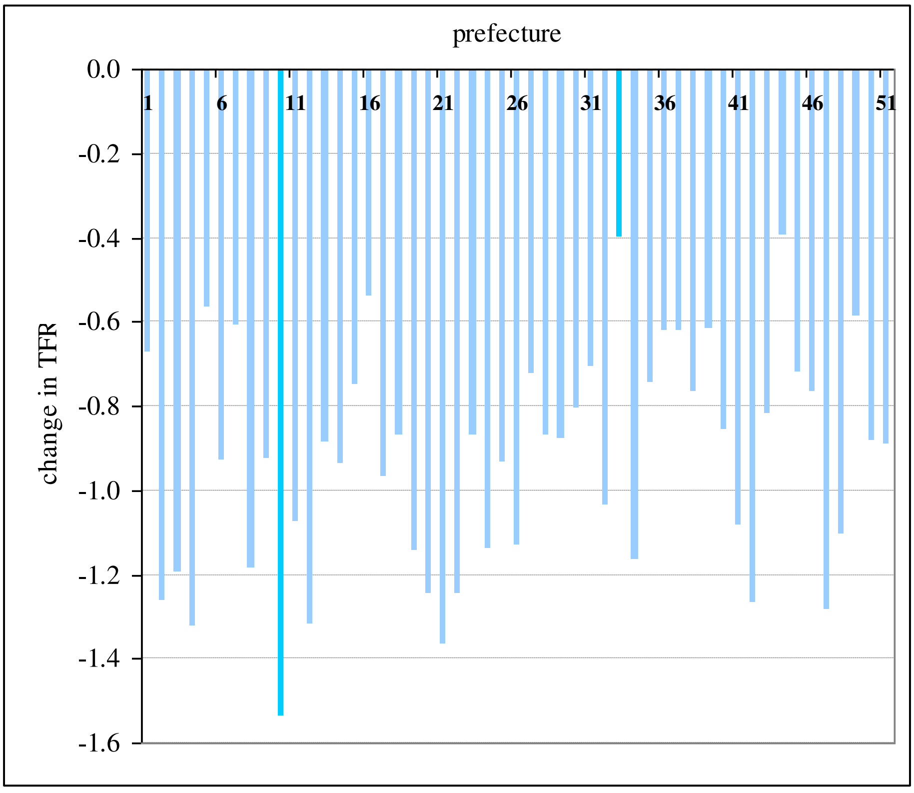


Figure 5: Quantile maps: spatial distributions of the variables

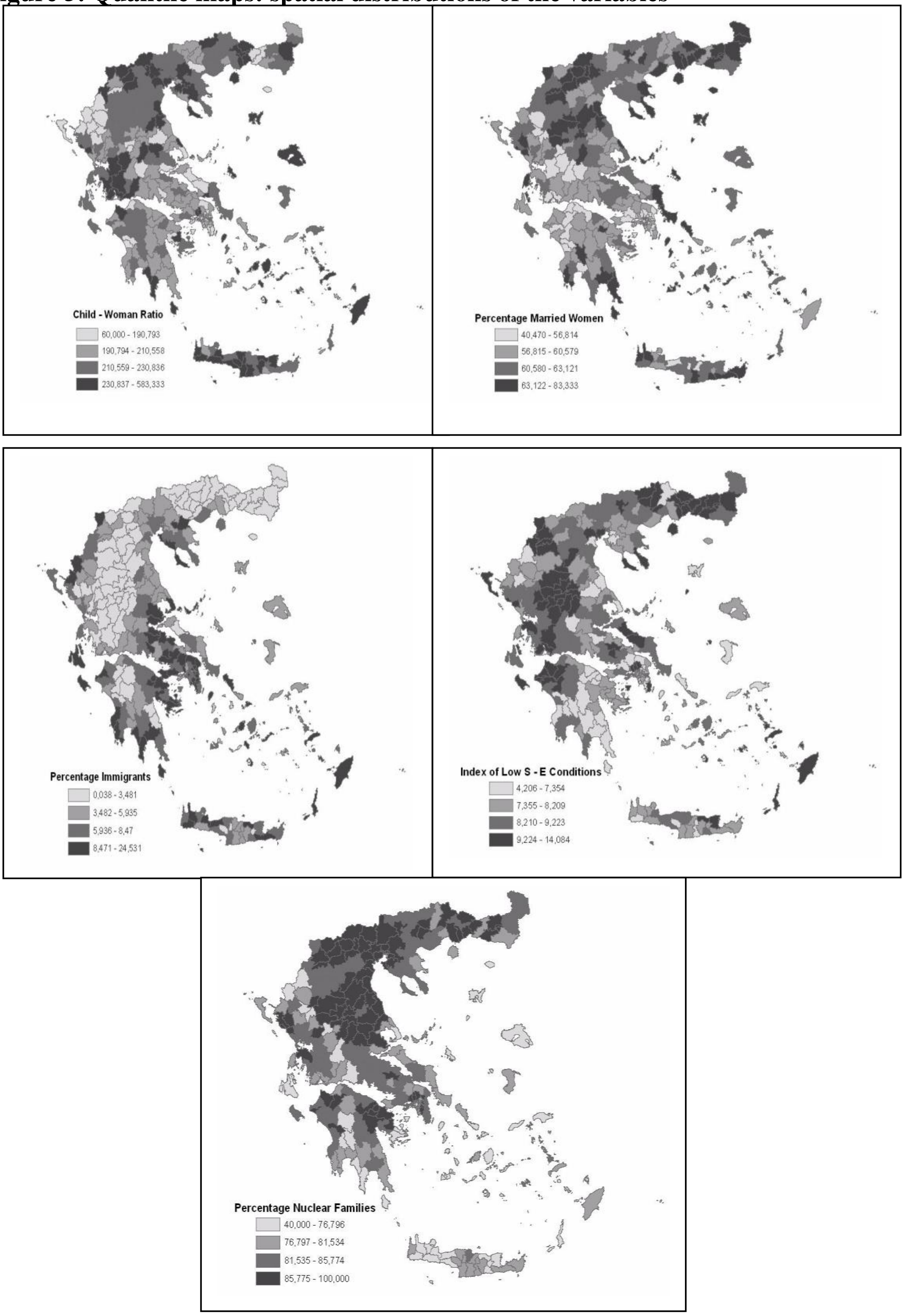


Figure 6: Map of the local condition numbers

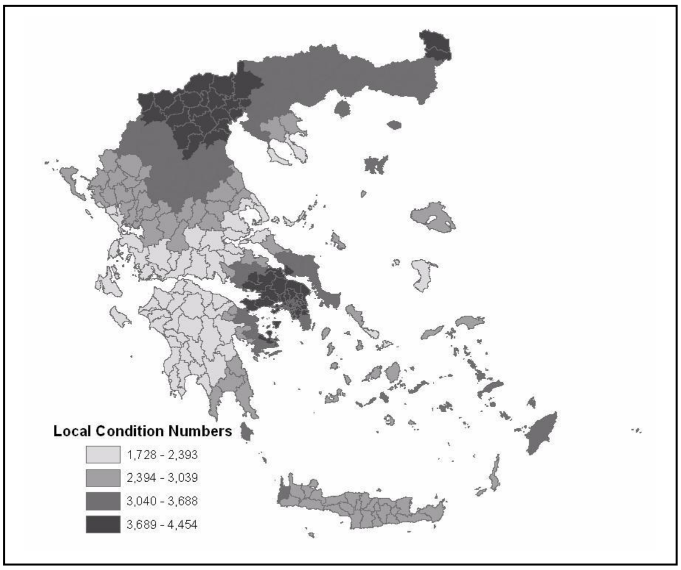


Figure 7: Map of Local coefficients of determination

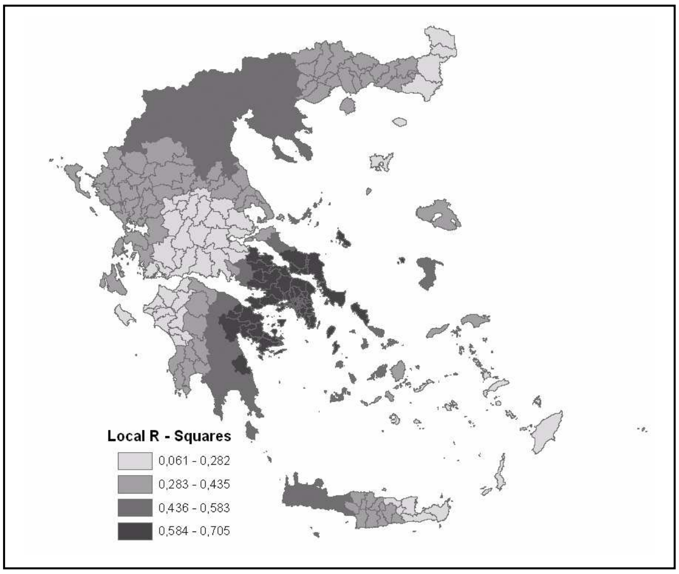


Figure 8: Maps of Local parameter estimates and t – statistics of the GWR regression model

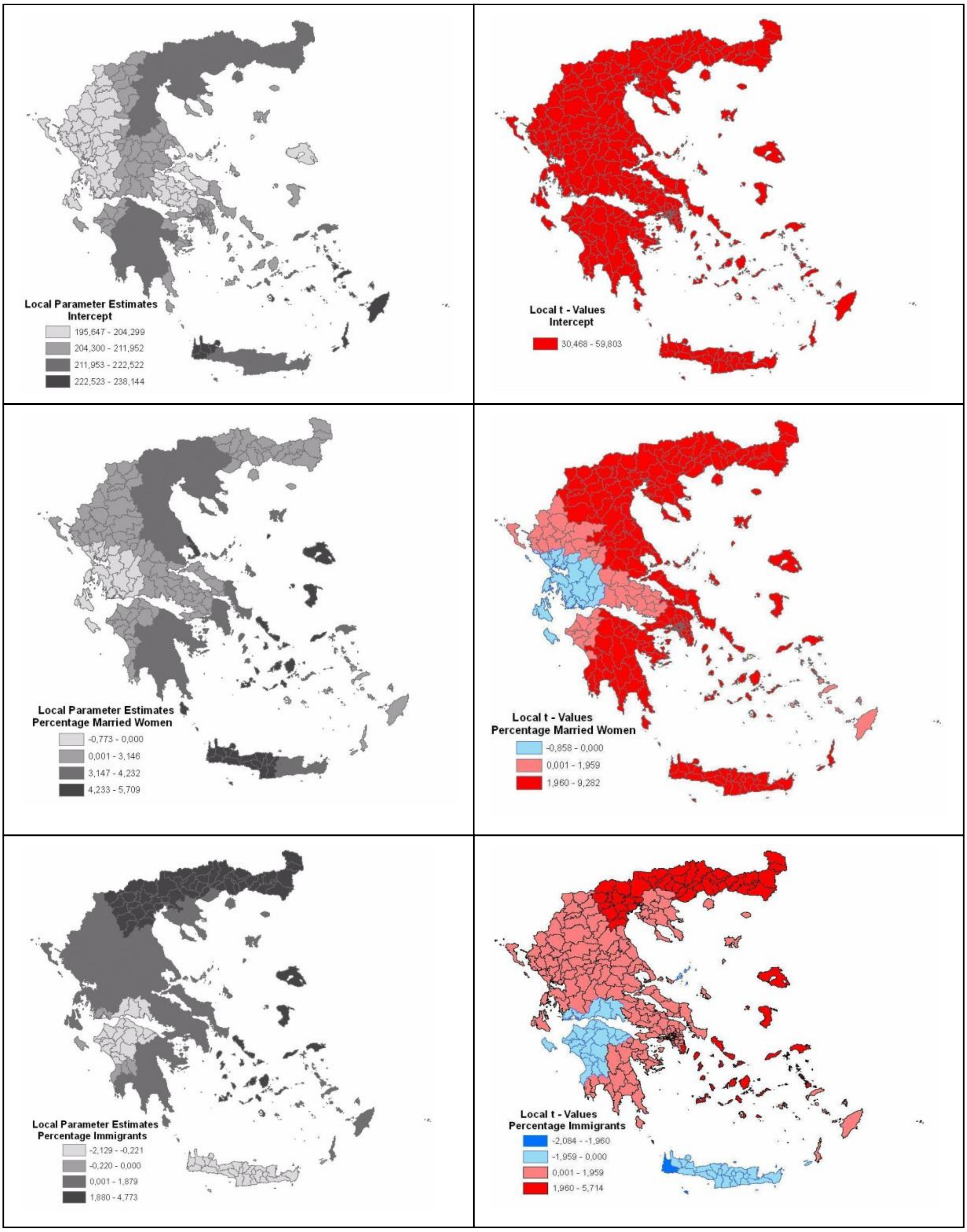


Figure 8: (Continued)