# A Spatial Analysis of Recent Fertility Patterns in Spain

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Spanish fertility displays important geographical heterogeneity and recent migration flows add further spatial heterogeneity and substantially contribute in shaping Spanish fertility at local level. The objective of this paper is to investigate the variability present in fertility across different geographic areas in Spain between 1981 and 2011, shedding new light on the spatial transformations of tempo and quantum dynamics through three decades of major socio-economic transformations. Using data from Spanish municipalities, we define 910 territorial units, ensuring spatial contiguity. The fertility indicators selected encompass fertility by age, birth order, nationality of the mother and age at childbirth. The first part of the analysis addresses issues of contiguity, global and local measures of spatial autocorrelation as well as hot-spots analysis. In a second phase, we apply semi-variance analysis to assess the effect of distance on spatial autocorrelation testing how single regions and population density affect spatial autocorrelation.

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# 1. Background

## 1.1 The Spatial dimension of fertility

Demographic phenomena are inherently spatial as human populations are not randomly located in space but are characterized by specific structural geographical features. In this context, spatial analysis main focus is the role of space in explaining the phenomenon under investigation (Anselin, Florax, & Rey, 2004; Cressie, 1993). In statistical terms, introducing the spatial dimension means focussing on spatial autocorrelation, exemplified by Tobler's First Law of Geography: "everything is related to everything else but near places are more related than far places" (Tobler, 1970).

Although mainstream demography does not devote much attention to the spatial dimension, spatial analysis in social sciences has recently found new vigor, as GIS data are becoming increasingly available and new spatial statistics techniques are being developed (Weeks, 2001). The spatial dimension has proved to be of great importance in understanding the role of personal characteristics and the impact of environment over such attributes (Bocquet-Appel & Jakobi, 1998; Weeks, 2001; Wilson & Woods, 1991). In this context, fertility studies exploring the spatial dimension of fertility are no exception (Brown & Guinnane, 2002; Galloway, Hammel, & Lee, 1994).

The Princeton European Fertility Project, EFP, represents an important pillar in introducing space to explain demographic changes. This project investigates fertility change in European regions from a moderate fertility regime, limited through late marriage and celibacy, to a low fertility regime, regulated through contraception and abortion (Coale & Watkins, 1986 ch.1). In particular, Sharlin (Sharlin, 1986) highlights the spatial differentials of the fertility transition concentrating on urban-rural differentials, as well as regional and settlement size characteristics across Europe.

The spatial argument embedded in the EFP can be extended to contemporary fertility transitions, as changes in economic wellbeing (Corkill, 2001), migration patterns (King & Zontini, 2000) and childbearing behaviour (Devolder & Trevino, 2007) play an important part in impacting fertility. Indeed, recent demographic studies successfully employ formal tools of spatial analysis, such as exploratory spatial data analysis (Anselin, 1999), to investigate recent patterns of fertility change e.g. Tolnay (1995) for Southern US, Bocquet-Appel et al. (1996) for late 19th century Western Europe, Bocquet-Appel et al. (1998) for Victorian England, Weeks(2001) for contemporary Egypt, Potter et al. (2002), and Schmertmann et al. (2007) for Brazil.

In the context of spatial heterogeneity of fertility, Spain is a unique country in Europe as geographical diversity in demographic indicators has a long documented history with substantial regional and provincial variability (Blanes Llorens, 2007; see e.g. Gil-Alonso, Bayona-i-Carrasco, Lopez Villanueva, & Pujadas Rubies, 2013; Leasure, 1963; Livi-Bacci, 1968b; 1968a; Munoz Perez & Recaño Valverde, 2011). Patterns of spatial heterogeneity in fertility have been documented over a span of two centuries, from mid 18th until the mid 20th century, in the EFP (Coale & Watkins, 1986; Leasure, 1963; see Livi-Bacci, 1968a; 1968b). In particular, Leasure(1963) finds consistent heterogeneous patterns of fertility across various Spanish regions, which cannot be solely motivated by differences in industrialization or urbanization patterns, thus hinting at a more profound role of socio-cultural and linguistic identities.

## 1.2 Second Demographic Transition

The theoretical framework applied in this study revolves around the Second Demographic Transition, SDT, theory (R. J. Lesthaeghe & van de Kaa, 1986) to explain the changes in fertility. The onset of the SDT occurred in Western countries around 1955 put into motion substantial changes in the childbearing behavior of Western countries. As Letsthaeghe &van de Kaa(1986) described in their seminal work, during the 1960s, industrialized countries went through a set of changes in childbearing behavior {vandeKaa:2002uj, p. 10}, diplaying:

1. Substantial decline in period fertility, partly resulting from postponement of births, so that (estimated) cohort fertility of currently reproducing women is expected to reach a maximum value well below replacement;
2. Substantial decline in the total first marriage rate associated with an increase in mean age at first marriage;
3. Strong increase in divorce (where allowed) and in the dissolution of unions;
4. Strong increase in cohabitation, even in countries where this was not a traditional practice;
5. Strong increase in the proportion of extra-marital births;
6. Catalytic shift in contraceptive behavior with modern means replacing traditional methods.

This change of childbearing behavior did not occur simultaneously in Western Europe, as some countries showed early signs of change while others lagged in time. The first group of countries, which underwent the changes in SDT, does not include Spain. Indeed, the iberian peninsula entered these changes about a decade later with respect to other industrialized countries. The Francoist dictatorship (1939-1975) with its conservative and pro-familistic structure promoting large families (Linhard, 1983; Ortiz-Gomez & Ignaciuk, 2013) and traditional family roles (Landwerlin, 1994) delayed the start of the SDT for about a decade (R. J. Lesthaeghe, 2010). Decline in period fertility and births deferral started later with respect to other Western and Northern European countries, but marriage and fertility postponement showed striking intensity. As many studies underline, the starting pattern of the SDT for Spanish and Southern European countries was unique for its lack of single living, cohabitation and births out of wedlock (Dalla Zuanna, 2001; R. J. Lesthaeghe, 2010; Micheli, 2000), although they have recently caught up to some extent.

Spain reached under-replacement fertility in 1985 (see van de Kaa, 2002), slightly later than other SDT countries, but has been able to catch up with major childbearing changes rapidly, not only in terms of TFR decrease and Mean Age at Childbearing, MAC, postponement, but also reaching considerable high rates of births outside of wed-lock in few years (van de Kaa, 2002), although much lower than those registered in Nordic countries. The following years, 1990s, saw a steep decrease in TFR, reaching lowest-low fertility levels by the mid 1990s, 1.2 children per woman in 1995 (Cabetas, 2000). MAC rose considerably creating a postponement of fertility sometimes described as "latest—late" fertility regime (Billari, Kohler, Andersson, & Lundström, 2007): in 1980 mean age at childbearing was 28.2, its lowest, increasing in subsequent years to reach 31.56 years old in 2012 (source: INE), the highest in Europe.

## 1.3 Immigration

This picture would not be complete if migration was to be ignored. Recent migratory flows have stirred new interest among demographers to coin the term "third demographic transition" to describe the large migration movements in sub-replacement fertility countries (Coleman, 2005). In Western Europe this phenomenon has become the main driving force behind demographic change in recent decades, impacting the natural rate of increase, fertility rates (Héran, 2004) and transforming its population composition (Coleman, 2006) to the extent that some researchers started investigating whether the effects of "replacement migration" can already be seen (J. R. Lesthaeghe, 2000). In this scenario, Spain went from being a labor exporting country to one of the principal labor importing countries in the mid 1990s (Arango & Finotelli, 2009). Indeed, Spain became an immigration country within a decade, with the foreign population rising from 0.5% in

1981 to 11.2% in 2012, with 5.2 million foreign migrants (source: INE). In Spain immigration is a relatively new phenomenon, but research in the field agrees in establishing migrants's important contribution to fertility change in the last two decades (Castro, 2007; Devolder & Bueno, 2011). Large migrants inflows surely have had a substantial impact on the population and its age structure, especially as the host country was characterised by lowest-low fertility (Espenshade, 1978).

The relationship between fertility and migration is a multifaceted one, where different factors come into play in determining the tempo and quantum of fertility. Indeed, there is no unanimous consensus in the literature with regard to the ideal theoretical framework, as many hypothesis find support but have also been disputed. Kulu (2005) reviewed the existing hypotheses to delineate and picture immigrants' childbearing choices in their host countries. A number of studies apply the "socialisation hypothesis" to model migrants fertility emphasising the role of childhood environment in their native country on future fertility preferences, thus implying that first generation migrants, those born elsewhere than the host country, will display a fertility more similar to their native country. In the literature, there is also evidence of the disruptive effect of immigration, the "disruption hypothesis", as migrants go through a fertility stasis period in the years immediately following their move, due to disruptive factors deriving from migration itself, recuperating the missed fertility only thereafter (Carter, 2000; Goldstein, 1973). On the other hand, literature has also established that migration often triggers childbearing in the years following the move, especially when migration is liked to family formation (Alders, 2000) for all births orders (Andersson, 2004), with migrants fertility often postponed until arrival (Toulemon, 2004) and gradually adapting to that of the host country. The literature has also shown that migrants reproductive behaviour is not only the result of an adaptation to the fertility of the host country, migrants are a selected group, thus "selection hypothesis", with respect to education or marital status (Feliciano, 2005), whose fertility preferences often mirror those at destination (Goldstein, 1973).

The start of immigration in Spain coincided with a recuperation in population growth, which reached levels closed to stagnation in the preceding years. This was due to a long and sharp decline in TFR during the previous years (1975-1995) reaching "lowest-low" levels (Kohler, Billari, & Ortega, 2002). Since the onset of immigration flows, fertility stopped its downward spiral, rising from 1.16 in 1998 to 1.32 in 2012 (source: INE). At least part of this increase in TFR is due to foreign mothers' contribution to fertility, as the proportion of births by foreign mothers has increased remarkably, also thanks to the younger age profiles of migrants (Castro, 2007).

Nevertheless, it is difficult to paint a homogeneous picture of migrants' fertility behaviour as its reality is very faceted (Arango & Finotelli, 2009). In general, fertility differentials between Spanish and foreign women are rather small, with the sole exception of North-Africans, and their fertility tends to increase over time (Devolder, i Valls, & Román, 2002). If compared to fertility in their own country, immigrant women's fertility is lower, with the exception of Moroccan women (Arango & Finotelli, 2009). Nevertheless, immigrant women are at a much higher risk to experience childbirth, especially if they come from Africa. (Castro, 2007). Women migrating from less developed countries represent a more homogeneous group in terms of childbearing behaviour, while other countries of provenance such as Latin America, provide a more kaleidoscopic situation, where fertility levels depend on their socio-economic characteristics, country of provenance, on the time spent in the host country and on the timing of migration (Rosero Bixby, 2004).

The spatial component of migration is a very important factor in understanding its evolution, as migrants are not evenly distributed in Spain (Recaño Valverde & De Miguel, 2011). Most of them settled in the big metropolitan areas of Madrid, Barcelona, Valencia, but also in the Balearic Islands, Huelva, Almeria and Murcia (Recaño Valverde & Roig, 2006). Immigrants are also characterised by a high residential mobility, interlaced with their socio-economic features (Bartel, 1989; Nogle, 1993) and following a South-North path, due to labor related reasons (Arango & Finotelli, 2009).

## 2. Data and Methods

### 2.1 Data

Data on the number of births consist of raw numbers of births by mothers' age group (5 years age groups from 15 to 49) by single year starting from 1981 up to 2011 and by birth order (1 to 3+). From 1996, data on births contain also information on mothers and fathers' nationality (see table).

Data on female population exposures consist of population numbers by five-years age groups measured on the 1st of March of each year. From 1998 to 2012 single year population estimates are available. For the previous period, 1981-1997, three calendar years measurements are available: 1981, 1986 and 1991, which were used to obtain inter year estimates. From 1998 onwards data contain information on mothers and fathers' nationality.

All data are grouped by 910 comarcas and 52 provinces. The province subdivision reflects 2004 NUTS3 categories, while the comarcas are based on a unique grouping of municipalities (LAU2). The high number of LAU2, 8111 municipalities, would create problems in having reliable and continuous fertility indicators, thus this study employs a geographical subdivision based on juridicial areas or comarcas, which guarantee geographical continuity and homogeneity.

Years 1986, 1996 and 1997 have been removed from the results as they show some problematics. Indeed, three of the areas display very high fertility rates for first and second birth order, introducing randomness in spatial autocorrelation computation and lowering sensibly Moran's I Index (even though Moran's I Index remains high, >0.2, and statistically significant).

## 2.2 Measures

In this study several fertility measures are computed to help investigating spatial patterns of fertility. These measures are constructed using the data described in section 3.1. Some considerations are necessary on the assumptions of data and methods applied to obtain the indicators. Birth data and female population exposures cover years 1981 to 2011, but while birth data are provided yearly by municipalities registers, female exposures are measured only in some years before the continuous time series that starts in 1998, thus years 1981, 1986,1991 and 1998 have been used to interpolate and obtain year-by-year estimates of female population.

The data contains information by 7 age groups of the mother, x= [15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49], t calendar years from 1981 to 2011, c=910 comarcas, i=[1, 2, 3+] birth orders and m=[Spanish, Western Countries, Eastern Europe, Latin America, Magreb, Sub-Saharian Africa, Asia , Rest of the World] mothers' nationalities. For each year t, birth order I and comarca c we define:

- Age-Specific Fertility Rate, ASFR:

$$f(x,t) = \frac{B(x)}{P(x)} \quad (1)$$

where B(x) represents the number of births and P(x) the female exposures;

- Total Fertility Rate, TFR:

$$TFR(i) = \sum_{x=x_{\min}}^{x_{\max}} f_i(x) \quad (2)$$

- Princeton Index for order i, and age group x:

$$I_f = \frac{B_x}{\sum_x p_x F_x} \quad (3)$$

where $B_x$ is the number of births by women in age group x, $\mathbf{F}_x$ represents the Hutterites fertility for age group x and $p_x$ the female population in age group x.

- TFR (Calot, 1984) for year n and age a [15,49]

$$TFRG^n = \frac{\sum_a f_a^n F_a^n}{f_a^n} \quad (4)$$

- Mean Age at Childbearing, MAC:

$$MAC = \frac{\sum_{x=x_{\min}}^{x_{\max}} \bar{x} \cdot f(x)}{\sum_{x=x_{\min}}^{x_{\max}} f(x)} \quad (5)$$

- Standard Deviation of Mean Age at Childbearing, sdMAC:

$$sdMAC = \sqrt{\sum_{x=x_{\min}}^{x_{\max}} \left( \frac{\bar{x}^2 \cdot f(x,t,c)}{\sum_{x=x_{\min}}^{x_{\max}} f(x,t,c)} \right) - \sum_{x=x_{\min}}^{x_{\max}} \left( \frac{\sum_{x=x_{\min}}^{x_{\max}} \bar{x} \cdot f(x,t,c)}{\sum_{x=x_{\min}}^{x_{\max}} f(x,t,c)} \right)^2} \quad (6)$$

### 2.3 Method

The main question in this study is if and how fertility is clustered in Spain and whether these clusters, if present, vary over time. The first step in spatial analysis is to build and define neighboring relations between geographical units, the 910 Spanish *comarcas*. Among the spatial units considered, two *comarcas* in the Canary Islands do not have natural neighbors, the *comarca* formed by La Gomera and El Hierro and Fuerteventura. The procedure used to treat these two areas, is to create fictitious connections to the nearest *comarca*, in order not to exclude them from the analysis. In this case the two areas have been 'manually' connected to Tenerife and La Palma, and Lanzarote respectively.

In this paper we have used and tested different types of contiguity definitions between areas to look at the effect of neighborhood effects on spatial association over time. In particular we have used definitions based on distance and boundaries:

Table 1: Summary of the Contiguity neighbors used for the

| Family | Type | Contiguity |
|---|---|---|
| Distance Based | K-Nearest Neighbors (KNN) | 5<br>10<br>15 |
| | Radial Distance | 20 km<br>50 km<br>100 km |
| Boundaries Based | Spatial Contiguity | First Order Queen (FOQ)<br>Second Order Queen (SOQ)<br>First Order Rook (FOR)<br>Second Order Rook (SOR) |

Distance based neighborhood matrices are constructed on centroid distances, $d_{ij}$ between each i and j pair of spatial units .

1. K-Nearest Neighbors ranks spatial units as $d_{ij(1)} \leq d_{ij(2)} \leq \ldots \leq d_{ij(n-1)}$ and creates $N_k(i)$ sets containing the k closest units to i so that:

$$w_{ij} = \begin{cases} 1 & \mathrm{j} \in \mathrm{N}_k(i) \\ 0 & \text{otherwise} \end{cases} \quad (1.a)$$

or, if putting constraints to obtain a symmetric matrix, so that at least one spatial unit is among the k-nearest neighbors of the other:

$$w_{ij} = \begin{cases} 1 & \mathrm{j} \in \mathrm{N}_k(i) \text{ or } \mathrm{i} \in \mathrm{N}_k(j) \\ 0 & \text{otherwise} \end{cases} \quad (1.b)$$

2. One can also set a threshold distance that sets the limit for the direct spatial influence between spatial units:

$$w_{ij} = \begin{cases} 1 & 0 \leq d_{ij} \leq d \\ 0 & \mathrm{d}_{ij} > d \end{cases} \quad (2)$$

Boundaries based contiguity is based on whether spatial units share a boundary or not. The weight matrix can also be standardized according to rows , globally, globally and divided by the number of neighbors or variance stabilized (Tiefelsdorf et al. 1999). In this study we have implemented all the mentioned kinds of standardization in order to evaluate their impact on spatial autocorrelation measures.

3. First Order Queen contiguity denotes a set of boundary points b of unit i, which share at least a single boundary point:

$$w_{ij} = \begin{cases} 1 & \mathrm{b(i)} \cap \mathrm{b(j)} \neq \varnothing \\ 0 & \mathrm{b(i)} \cap \mathrm{b(j)} = \varnothing \end{cases} \quad (3)$$

4. First Order Rook denotes a set of boundary points b of unit i, which share a positive proportion of their boundary, thus having length $l_{ij}$ >0:

$$w_{ij} = \begin{cases} 1 & l_{ij} > 0 \\ 0 & l_{ij} = 0 \end{cases} \quad (4)$$

5. Sphere of influence is defined for a finite point set S, let $d_{ij}$ be the distance from point i to its nearest neighbor j in S, and $C_i$ is the circle centered on i. Then i and j are SOI neighbors iff $C_i$ and $C_j$ intersect in at least 2 places:

$$w_{ij} \begin{cases} 1 & C_i \cap C_j \neq \varnothing \\ 0 & \text{otherwise} \end{cases} \quad (5)$$

6. Gabriel graph neighbors is a sub-graph of the Delaunay triangulation and has the relative neighbor
graph as a sub-graph.

$$w_{ij} \begin{cases} 1 & d_{ij} \leq \min \sqrt{(d_{ih}{}^2 + d_{jh}{}^2)} \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

7. Relative graph neighbors is defined by the relation, i and j are neighbors if there exists an area h so that:

$$w_{ij} \begin{cases} 1 & d_{ij} \leq \min(\max(d_{ih}, d_{jh})) \\ 0 & \text{otherwise} \end{cases} \quad (7)$$

Once the spatial neighbor list has been defined, in spatial analysis it is necessary to set the weight matrix for each relationship. The spatial weight matrix has been constructed so that the weights for each areal item sum up to unity.

$$W_{ij} = \begin{bmatrix} 0 & d_{1,2} & \dots & d_{1,n} \\ d_{2,1} & 0 & \dots & d_{2,1} \\ \vdots & \vdots & \ddots & \vdots \\ d_{m,1} & d_{m,2} & \cdots & 0 \end{bmatrix} \quad (8)$$

A first exploratory measure to evaluate the strength of spatial patterns across the considered variables is Moran's I test (Moran, 1950). In order to measure spatial autocorrelation, Moran's I index is required and is computed on the model's residuals.

Moran's I is the index obtained through the product of the variable considered, let's call it y, and its spatial lag, with the cross product of y and adjusted for the spatial weights considered:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \cdot \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad (9)$$

where n is the number of spatial units i and j, $y_i$ is the $i^{th}$ spatial unit,  is the mean of y, and $w_{ij}$ is the spatial weight matrix, where j represents the regions adjacent to i. Moran's I can take on values [-1,+1], where – 1 represents strong negative autocorrelation, 0 no spatial autocorrelation and 1, strong positive spatial autocorrelation.

Moran's I test for spatial autocorrelation is a global measure of spatial autocorrelation, meaning that it is computed from the local relationships between the values observed for the geographical unit and its neighbors. It gives a global picture of spatial autocorrelation, without considering the change in clusterization among different areas.

It is possible to break down this measure its components in order to identify clusters and hotspots. Clusters are defined as observations with similar neighbors, while hotspots are observations with very different neighbors (Anselin, 1995). The procedure is knows as Local Indicators of Spatial Association or LISA, where the Local Moran's I decomposes Moran's I into its contributions for each location. These indicators detect clusters of either similar or dissimilar values around a given observation. The relationship between global and local indicators is quite simple, as the sum of LISAs for all observations is proportional to Moran's I. Therefore, LISAs can be interpreted both as indicators of local spatial clusters or as pinpointing outliers in global spatial patterns.

The measure for LISAs is defined as:

$$I_i = \frac{(y_i - \bar{y})\sum_{j=1}^{n} w_{ij}(y_i - \bar{y})}{\frac{\sum_{i=1}^{n}(y_i - \bar{y})}{n}} \quad (10)$$

Where the global mean, is assumed to be an adequate representation of the variable of interest y. Hotspot analysis identifies statistically significant hot spots and cold spots. The measures used to do this are Getis-Ord Gi at global and local level. General G, portrays the type of cluster:

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}x_i x_j}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j}x_i x_j} \quad \forall\ \mathrm{j} \neq \mathrm{i}\ (11)$$

In order to understand the effect of distance on spatial autocorrelation and how it varies we measure the semivariance for various variables at different points in time. Plotting the semivariance, thus obtaining a semivariogram, can be particularly insightful as it produces an easily understandable depiction of how the semivariance evolves as distance between centroids rises. The semivariogram can thus be seen as a quantification of the assumption that proximity translates into higher similarity., where nearer areas show higher spatial autocorrelation.

Given $Z(s_i)$ a variable measured at location $s_i$, the semivariance is defined as:

$$\gamma(s_i, s_j) = \frac{1}{2}\mathrm{var}[Z(s_i) - Z(s_j)] \quad (12)$$

This measure has been computed considering the whole Spanish territory, thus 910 *comarcas*, inland Spain and each region.

## 3. Results

1. The first part of the analysis addresses issues of global autocorrelation of the variables described in section 2.2.

All variables considered show a substantial (0.2-0.8), non-random and significant spatial autocorrelation throughout the considered time-frame, with the exception of ASFR for 45-49 group and third birth order 15-19 group, as births in these age groups are unusual. Over time, Moran's `i Index doesn't remain stable but varies, revealing unique patterns (graphs 1).

a. ASFR sees an increase in spatial autocorrelation for middle to late childbearing years, 30 to 39 years old, the age groups where fertility started concentrating fertility after the onset of postponement. Interestingly, since the late 1990s, Moran's I Index for 40-44 age-group became significative as births in this age-group became more common. Parallely, Moran's I index for young childbearing ages, 15 to 24, saw a sizable decrease.

b. Other fertility measures such as TFR, TFRG, Princeton Index and MAC, describe similar increase/decrease patterns. In particular, Moran'I measured for the first birth order is particularly telling as it decreases in periods of economic recession (first half of 1990s) and raises in periods of economic expansion (mis1990s-mid2000s).

2. The second part of the analysis deals with the clusterization of the variables. The LISA plots depict the local indicators of spatial association and help giving an indication of significant clustering of similar values around a specific observation, dividing clusters into four groups. High-High, in red, represents a cluster of observations with high values for the considered variable, Low-Low, in blue, depict a cluster of observations with low values. High-Low, in pink, and Low-High, in light blue, portray clusters of observations with high values surrounded by Low-Low clusters and low clustered values surrounded by High-High clusters respectively.

Once again time plays an important part in shaping spatial autocorrelation features. Indeed, if in 1981 Spain was a country where high and low fertility, measured through TFR, TFRG and Princeton Index, where distributed in two halves, the North with low fertility and the South with high fertility, 2011 shifts the North-South divide into East-West, with the West registering the highest ferility. Interestingly enough, Madrid, the capital, is the middle of the tranformation, showing similar features first with the North, later with the West. MAC also portrays a transformation of its own for at all births orders, from Low-Low clusters solely in the North-East and coastal areas, to an evident North-South divide centered around Madrid, with very high MAC espacially in the North-Eastern regions.

3. The last part of the analysis deals withthe effect of distance on spatial autocorrelation, that is to say, at what distance is spatial autocorrelation highest? At what distance are near areas more similar? At what distance does geography cease to matter? To answer this questions, we applied two different techniques.

a. The first methodology implements correlograms, in particular it exploits Moran's I Index by means of plotting autocorrelation against distance, in this case lags. Graph 2 depicts Princeton Index variation with distance and how this relationship changed over time. Distance matters and as it increases, Moran's I index decreases meaning that the area of influence and of similary for each area is limited to its direct durroundings, around 60 to 70 km. Also, this relationship between distance and spatial autocorrelation transformed through time, increasing the importance of distance, by lowering its threshold.

b. To examine how spatial patterns vary across the course of the considered time-frame we use the semivariogram, in particular we apply the Cressie-Hawkins robust estimator (Schmertmann et al., 2007) for 50 km distance classes up to 1000 km. It is important to underline that in this section we reduced the *comarcas* to inland Spain, thus excluding the islands as, especially the Canary islands, would produce disturbance in the measures. If space were to be irrelevant, then the line in graphs 3 would be flat, meaning that there is no spatial autocorrelation and that near areas are no more similar than distant ones. In this case, positive autocorrelation seen in Moran's I graphs, translates in increasing semivariance. For instance in graph 8 semivariance starts to flatten out after 200km, meaning that after this distance, regions with centroids beyond 200km apart are uncorrelated. Again it is interesting to notice how time has an important role and in changing spatial relationships.

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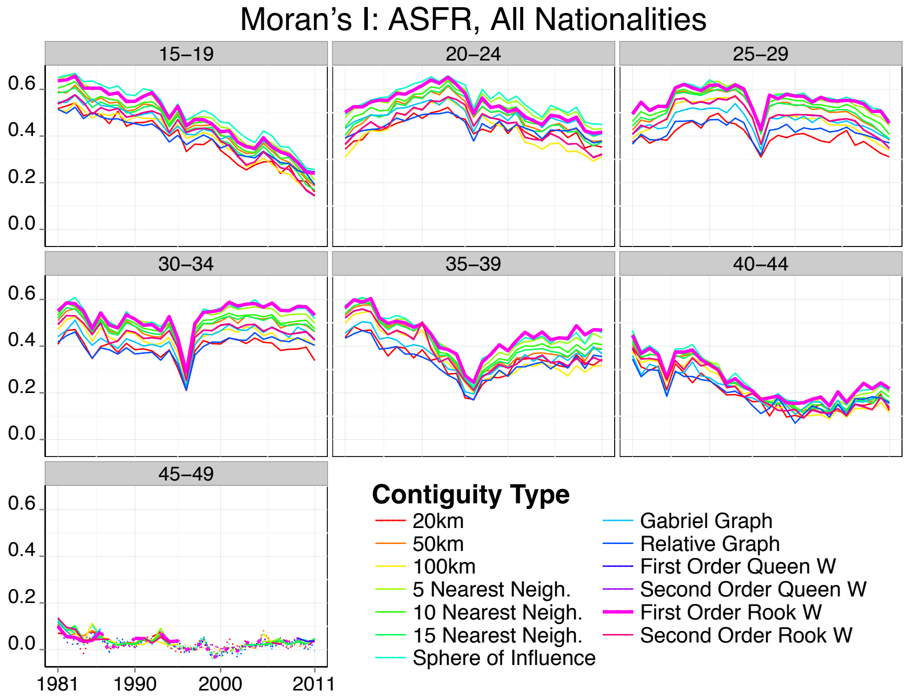
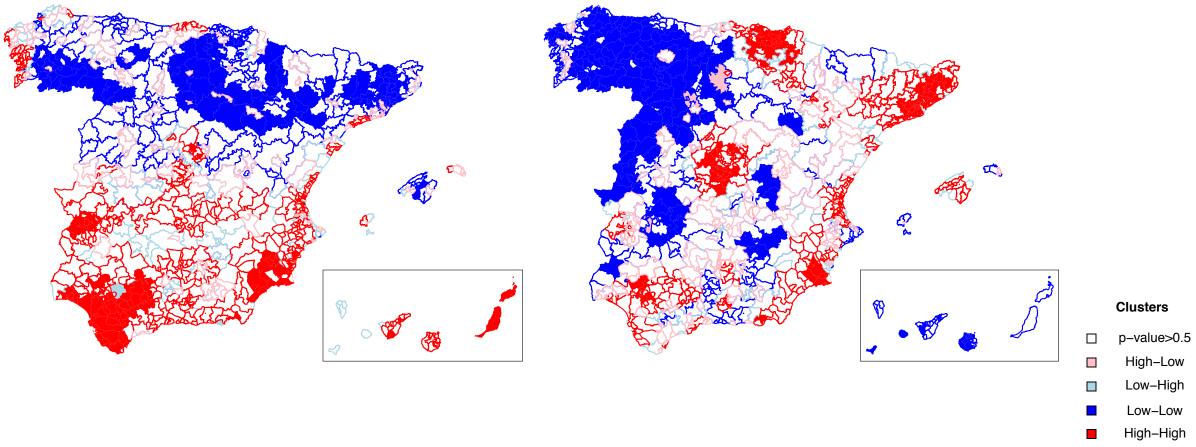
## 5. Selected Graphs and Maps reduced for size limits

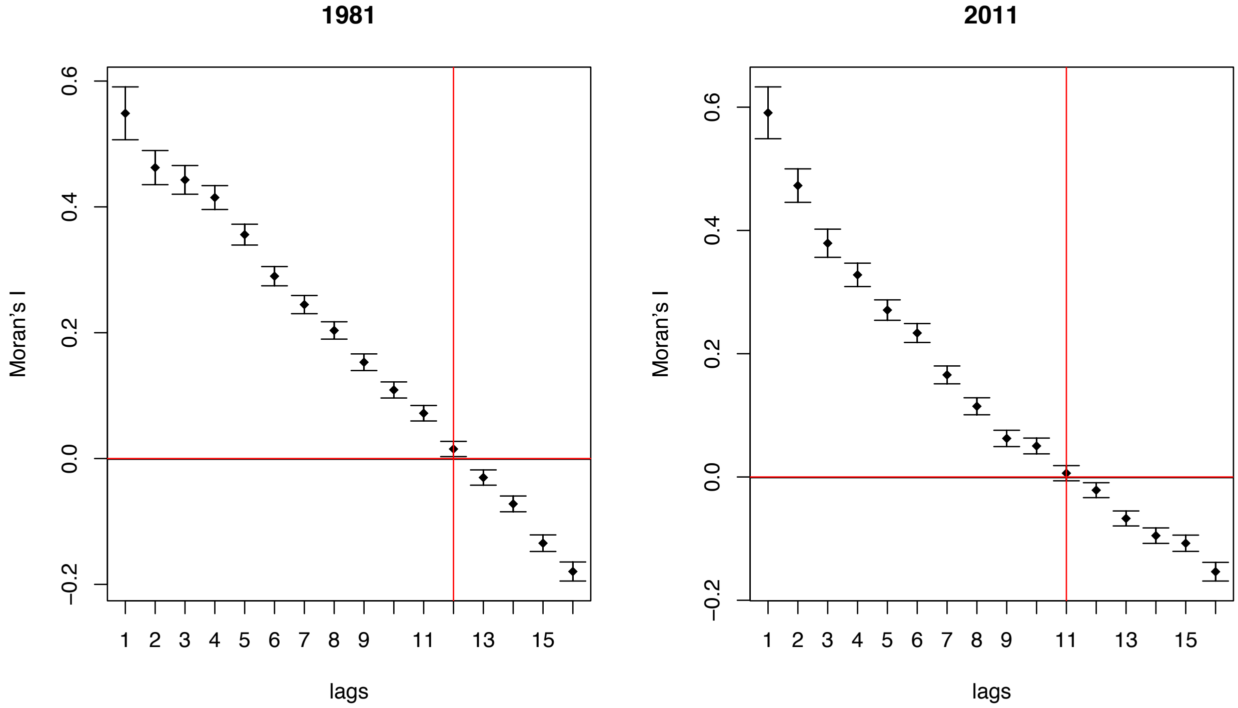
Graph 1: Moran's I index for Age Specific Fertility Rate, for total number of births, all nationalities in different age groups, period 1981-2011.



Map 1: LISA cluster maps for Princeton Index, years 1981 (left) and 2011 (right).



Graph 2: Moran's I computed for incremental lags. Princeton Index 1981 and 2011.



Graph 3: Variogram of Mean Age at Childbearing semivariance variation with incremental distance, years 1981 and 2011.