THE SPATIAL DIMENSION OF SEGREGATION: A CASE STUDY IN FOUR FRENCH URBAN AREAS, 1990-1999*

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Abstract

The aim of this paper is to analyze the intra-urban spatial segregation in terms of socio-professional categories in four French urban areas: Paris, Lyon, Bordeaux and Dijon. Two questions are investigated. First, how does spatial segregation vary across the four urban poles? Second, what are the spatial patterns of segregation within each urban pole? In order to answer these questions, we compute spatial global segregation indices for socio-professional categories in each urban area, together with entropy indices, which are local segregation indices that reflect the diversity within each unit and that can be mapped to show the spatial variations of segregation among the units of the four urban poles. The results highlight the self-segregation of the managers, the specific features of Paris and the complex spatial distribution of segregation.

Keywords: segregation, French urban areas, entropy index

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1. Introduction

Over the post-war period, urban growth has exhibited complex spatial patterns including both population spread and employment suburbanization from the central city towards the suburbs, both in US and European metropolitan areas. An important literature, based on North-American metropolitan areas, has also highlighted the strong link existing between this process of suburbanization and the reinforcement of socio-spatial segregation against poor populations living in the central cities (Kain, 1992; Ihlandfeldt and Sjoquist, 1998). On the contrary, European cities do not usually follow this pattern: populations with high income remain localized in and near the city center while urban sprawl mainly concerns households with modest incomes.

The literature in urban economics identifies three main reasons explaining the formation of segregated cities.

(i) The first one is directly tied to the traditional monocentric model of the "New Urban Economics" (Fujita, 1989). Considering a population of households with heterogeneous income competing for the occupation of urban land traditionally results in an income-based stratification of the urban space according to the distance to the city centre. More recently, some authors have proposed an amenity-based theory that ties location by income to city's specific amenities pattern. These amenities can be located in the city centre (Brueckner *et al.* 1999) as well as at the urban fringe (Cavailhés *et al*., 2003).

(ii) The second main approach of urban segregation links the concentration of low incomes households in some areas to the existence of neighborhood externalities (Schelling, 1978; Bénabou, 1993). As a consequence of the households' preference for living in relative homogeneous neighborhoods in terms of income or ethnic origin, people can run away from some central neighborhoods to more homogeneous suburbs, thus initiating some self reinforcing mechanisms, as suggested by the « flight from blight hypothesis» (Mieszkowsky and Mills, 1993; Mills and Lubuele, 1997).

(iii) Thirdly, the occurrence of segregation can be related to housing policies, such as the low apartment's rents programs intended for low income households. Evidence suggests that these programs are concentrated in some specific areas, whereas the relatively decentralized structure of local governments within cities tends to generate a kind of NIMBY syndrome. The effects of urban zoning and minimum lot size rules must also be emphasized (Duranton, 1997).

While the intensity and characteristics of spatial segregation has been extensively documented for US urban areas (Cutler and Glaeser, 1997) and mainly concerns segregation along the ethnic dimension (Taeuber and Taeuber, 1965; Massey and Denton, 1993), studies investigating the specificities of the segregation phenomenon in European cities in general, and French cities in particular, remain scarce (Rhein, 1998; Guermond and Lajoie, 1999; Préteceille, 2001). In this context, the aim of this paper is to analyze the intra-urban spatial segregation in terms of socio-professional categories in four French urban areas: Paris, Lyon, Bordeaux and Dijon. More precisely, we are interested in answering the following questions. First, how does spatial segregation vary across the four urban poles? Second, what are the spatial patterns of segregation within each urban pole?

In order to answer these questions, two steps are necessary. The first step involves computing global segregation indices for socio-professional categories in each urban area. In particular, we focus on the Duncan and Duncan's (1955) segregation index, its multigroup (Sakoda, 1981) and spatial versions (Wong, 1993, 1998) and White's (1983) index. Since these measures are global, the second step consists in identifying the spatial patterns involved. In that purpose, we compute entropy indices, which are local segregation indices that reflect the diversity within each unit and that can be mapped to show the spatial variations of segregation among the units of the four urban poles.

The paper is organized as follows. In the following section, we discuss the measures of spatial segregation used in this paper. In the two following sections, we present the study areas, the data and the spatial weight matrix used to perform the analysis. The empirical results are divided in two parts: first, we compute global measures of spatial segregation for socio-professional categories in our four urban poles and second, we display the local spatial segregation indices. The paper concludes with a summary of key findings.

2. Measuring residential segregation

Numerous methods have been suggested to measure segregation (see White, 1986; Massey and Denton, 1988; Kaplan and Holloway, 1998 for comprehensive reviews). In a well-cited study on residential segregation indices, Massey and Denton (1988) propose to classify the forms and spatial manifestations of residential segregation into 5 dimensions: evenness, exposure, concentration, clustering and centralization. For each dimension, a distinction can be made between uni-group indices (measuring the distribution of one group compared to the entire population) and multi-group indices (comparing the distribution of one group to that of other groups). Although this distinction has recently been questioned (Reardon and O'Sullivan, 2004), it remains the basis for most empirical studies. In this paper, we mainly focus on the evenness dimension, which is usually considered as the most important aspect of segregation, and we review the multi-group, both global and local, that we use to measure segregation between several classes of population.

2.1 Global segregation indices

Evenness refers to the distribution of one or several groups of population over the spatial units. A group is said to be segregated if it is unevenly distributed over areal units, compared to the whole population or relative to some other group. The most common evenness measures of segregation have been suggested by Duncan and Duncan (1955a, 1955b). When comparing to the whole population, they suggest the following segregation index:

$$IS = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{x_i}{X} - \frac{t_i - x_i}{T - X}\right| \qquad (1)$$

where x_i is the number of individuals in group *X* in unit *i*; t_i is the total population in unit *i*; *T* is the total population and *n* is the number of spatial units in the urban area under consideration. This index ranges from 0 to 1, corresponding respectively to no segregation and perfect segregation. It expresses the proportion of the group that should change their area of residence to achieve an even distribution.

Duncan and Duncan (1955a) also suggest the dissimilarity index that reflects the level of segregation between two population groups, *X* and *Y*. Formally, it can be written as:

$$D = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{x_i}{X} - \frac{y_i}{X}\right| \qquad (2)$$

where x_i is the number of individuals in group *X* in unit *i*; y_i is the number of individuals in group *Y* in unit *i* and *n* is the total number of spatial units. Its interpretation is similar to the segregation index. Note also that it is linked to the Lorenz curve since it represents the maximum vertical distance between this curve and the diagonal line of evenness.

Although widely used in empirical studies, these segregation indices present several drawbacks.

First, they violate the principle of transfers stating that a transfer of households among neighborhoods where their own group (race, social status etc.) is less represented should result in the decline of the segregation measure (James and Taeuber, 1985). On the contrary, the segregation indices are insensitive to the redistribution of minority member among units with proportion of this minority that is above the urban area's proportion.

Second, these measures are affected by the Modifiable Areal Unit Problem (MAUP). Indeed, residential population data are typically collected and aggregated for spatial units (such as census tracts in the US or communes in France) that do not necessarily correspond to meaningful social divisions. As the result, the segregation indices are sensitive to the definitions of the areal units used in empirical studies.

Third, these segregation indices are a-spatial measure since the spatial arrangements of the population and the areal units under consideration is not taken into account. This problem, known as the “checkerboard problem” (White, 1983), is implied by the fact that the spatial proximity of neighborhoods and their composition is ignored while only the composition of the neighborhood itself is considered. In other words, population groups in different units, even if the units are adjacent to each other, cannot interact across boundaries to lower the level of segregation. As a consequence, the segregation indices return of value of 1, indicating perfect segregation for very different situations, for example both for a checkerboard with all the white squares on one side and all the black squares on the other and for a checkerboard were the white and black squares are alternated. With the advent of Geographic Information Systems (GIS) techniques and the growing availability of spatial data, a series of spatial indices have been suggested in the past decade (Morill, 1991; Wong, 1993, 1998, 2003). The indices are considered as spatial because they explicitly use the geographic arrangement of the units in their formulations and because spatial interaction between population groups across areal unit boundaries is accounted for in determining the level of segregation.

The $D(adj)$ index introduced by Morrill (1991) consists in the original segregation or dissimilarity index less the amount of potential interaction between different groups across the unit boundaries. Formally:

$$D(adj) = D - \frac{\sum_{i=1}^{n}\sum_{i=1}^{n}\left|c_{ij}(z_i - z_j)\right|}{\sum_{i=1}^{n}\sum_{i=1}^{n}c_{ij}} \qquad (3)$$

where D is the segregation (1) or the dissimilarity (2) index; z_i and z_j are the proportions of the group between areal units i and j; c_{ij} is the element (i,j) of the contiguity matrix: it is equal to 0 if i and j are not neighbors (i.e. if they don’t share a common border) and equal to 1 otherwise.

Wong (1993, 1998) has further modified this latter index by assuming that the length of the common border also matters: the more important the length of the boundary between two spatial units is, the more intense will be the interactions between those two units. Moreover, the intensity of the interactions is also assumed to depend of the sizes and shapes, or the compactness of the two adjacent units. The lengths of the border, together with the geometric characteristics of areal units, are incorporated in the following way:

$$D(s) = D - \frac{1}{2}\sum_{i=1}^{n}\sum_{i=1}^{n}\left|w_{ij}(z_i - z_j)\right| \cdot \frac{(1/2)\left[\left(P_i / A_i\right) + \left(P_j / A_j\right)\right]}{Max(P/A)} \quad (4)$$

where P_i / A_i is the perimeter-area ratio for areal unit *i*; $Max(P/A)$ is the maximum perimeter-area ration among all areal units and w_{ij} is an element of a general weights matrix defined as $w_{ij} = d_{ij} / \sum_{i=1}^{n} d_{ij}$, where d_{ij} is the length of the shared boundary between *i* and *j* [1].

If the interest relies on multi-group comparisons, as will be our case, Morill (1995) has argued that the methodology consisting in comparing all possible pairs of population groups with two-groups measures does not yield comprehensive results since the multiple groups cannot be treated simultaneously. For that purpose, Sakoda (1981) has suggested a multigroup version of the dissimilarity index *D* for *K* groups defined as:

$$D(m) = \frac{1}{2}\frac{\sum_{i=1}^{n}\sum_{k=1}^{K}\left|N_{ki} - E_{ik}\right|}{\sum_{k=1}^{K} NP_{.k}(1 - P_k)} \quad (5)$$

where $E_{ik} = (N_i - N_k)/N$; N_{ki} is the population count of the k^{th} population group in unit *i*, N_i is the total population in unit *i*; *N* is the total population in the entire urban area and $P_{.k}$ is the proportion of population in group *k*. The interpretation of the multigroup dissimilarity index is the same as the two-group measure and also shares the same limitations in terms of insensitivity to the spatial arrangements of the units. Therefore, Wong (1998) has suggested a spatial version of $D(m)$ based on composite population counts for each unit *i* and each group *j* defined as:

$$CN_{ik} = N_{ik} + \sum_{j=1, j \neq i}^{n} d(N_{kj}) \quad (6)$$

where $d(.)$ is a function defining the neighborhood of *i* and the subscript *k* refers to the units surrounding unit *i*. CN_{ik} therefore consists in a sum of the population in unit *i* and group *k* with the populations of group *k* residing in the units surrounding unit *i*. The function $d(.)$ may take several forms, as simple contiguities of more complex distance-based specifications.

[1] Note that according to Dawkins (2004), the spatial measures of segregation do not resolve the problem of transfer but on the contrary would tend to exacerbate it. They also remain sensitive to MAUP.

White (1983, 1986) has suggested a set of indices measuring directly spatial clustering within and between groups, called *spatial proximity indices*. In a first step, the average distance between members of a social group *X*, P_{XX}, can be computed as following:

$$P_{XX} = \frac{1}{X^2} \sum_{i=1}^{n} \sum_{j=1}^{n} x_i x_j f(d_{ij}) \tag{7}$$

where $f(d_{ij})$ is a function of the Euclidian distance between the centroids of spatial units *i* and *j*. The inter-groups average distance, P_{XY}, is given by:

$$P_{XY} = \frac{1}{XY} \sum_{i=1}^{n} \sum_{j=1}^{n} x_i y_j f(d_{ij}) \tag{8}$$

Then, the relative proximity index between members of groups *X* and *Y*, RPI_{XY} can be computed as following:

$$RPI_{XY} = \frac{XP_{XX} + YP_{YY}}{(X+Y)P_{00}} \tag{9}$$

where P_{YY} and P_{00} represent respectively the intragroup average distance for members of *Y* and the average distance between all the members of the population (*X* + *Y*). They are computed using equation (8). A value of RPI above one indicates the absence of differential clustering, whereas the index would be less than one if members of each group tend to live closer to members of the other than to those of their own group.

2.2 Local segregation indices

All the measures presented so far provide a summary of the level of segregation for the entire urban area. While it appears useful to compare the levels of segregation between different urban areas, as will be performed in section 4, it ignores the spatial variation of the segregation level. Opposite to these global segregation indices, the entropy index can be considered as local since it is able to reflect the diversity within each unit (White, 1986). Therefore, this measure can be mapped to show the spatial variations of segregation or diversity among the units within the urban area. Moreover, it is considered as an evenness measure. Formally, given *K* groups, the diversity level of unit *i* is defined as:

$$H_i = -\sum_{k=1}^{K} \left[\left(N_{ki} / N_i \right) \log \left(N_{ki} / N_i \right) \right] \tag{10}$$

where, as before, N_i is the total population count in unit *i* and N_{ki} is the population count of the *k*th group in unit *i*. When $H_i = 0$ then the unit is dominated by a single group. On the other hand, a high value of this index reflects high level of diversity, i.e. low segregation in each unit. The maximum diversity is $\log(K)$. This index is often scaled by the maximum diversity such as the value ranges from 0 to 1. This is especially useful for comparison purposes.

As for the global indices, the entropy measure is aspatial in nature since it is insensitive to the spatial arrangement of the units and since it is based on the assumption that no interactions occur between units. To allow for interactions between units, Wong (2002) has suggested a spatial version of the local entropy index, based upon composite population counts, as for the spatial multi-group dissimilarity index. Formally, the spatial diversity index for *n* units and *K* groups is defined as:

$$H_i(s) = -\sum_{k=1}^{K}\left[\left(CN_{ki} / CN_i\right)\log\left(CN_{ki} / CN_i\right)\right] \tag{11}$$

where:

$$CN_{ik} = N_{ik} + \sum_{\substack{j=1 \\ j\neq i}}^{n} d(N_{kj}) \text{ and } CP_i = P_i + \sum_{\substack{j=1 \\ j\neq i}}^{n} d(P_j) \tag{12}$$

In equations (11) and (12), N_{kj} is the population of group *k* in unit *j* and N_j is the total population in unit *j*; CN_{ik} and CN_i are the composite population counts. This index may also be scaled by maximum diversity, i.e. $\log(K)$ so that all the values fall between 0 and 1.

3. Data and spatial weights matrix

Our study focuses on four French urban areas for 1990 and 1999: Paris, Lyon, Bordeaux and Dijon. Urban areas are defined by the French National Institute of Statistics and Economic Studies (INSEE) as a set of contiguous communes offering at least 5 000 jobs and that is not situated in the peri-urban area of another urban pole. The locations of these urban areas in France are shown in map 1.

[Map 1 around here]

Table 1 displays the share in total French population of these four urban areas for 1990 and 1999. The urban pole of Paris contains the capital. Moreover, with 11 million people (almost 20% of national population), Ile-de-France is the largest French urban area. The other urban areas are ranked according to their population, with the urban areas of Lyon, Bordeaux and Dijon being respectively ranked 2nd, 7th and 24th in 1990 and 1999.

[Table 1 around here]

The urban areas of Paris, Lyon, Bordeaux and Dijon contain respectively 1603, 296, 191 and 214 communes or municipalities. In all four areas, the central communes are further subdivided into smaller units, called IRIS. The acronym IRIS stands for *Ilots Regroupés pour l'Information Statistique* (clustered blocks for statistical information) and is an infra-communal level division available for all urban communes of at least 10 000 inhabitants and most communes of 5000 to 10 000 inhabitants. It is a small district, defined as a group of adjacent blocks of houses. They are subdivided into three types of zone (INSEE, 2000):

- Residential IRIS: IRIS-2000 with populations of 1800 to 5000 inhabitants. They are homogeneous in respect of types of housing.
- Business IRIS: IRIS-2000 clustering of more than 1000 employees and with twice as many salaried jobs as resident inhabitants.
- Miscellaneous IRIS: IRIS-2000 covering large areas and for special purposes (woods, parkland, docklands, etc.).

In the case of Paris, the urban pole contains communes located in 5 different regions: Ile-de-France (the capital region), Picardie, Haute-Normandie, Centre and Champagne-Ardenne. The urban pole of Paris contains 5 470 IRIS. For Bordeaux, Lyon and Bordeaux, the total number of areal units in these three cases becomes respectively 724, 452 and 312.

For each urban pole in 1990 and 1999, we consider segregation in terms of socio-professional categories. Six different categories are considered: (i) farmers, (ii) craft workers, merchants and company directors (iii) managerial staff and superior intellectual professions, (iv) intermediary professions, (v) employees and (vi) low qualified workers. These data have been compiled by INSEE at the communal and at the IRIS level.

In the following sections, spatial weights matrices need to be defined in order to compute the spatial measures of segregation. For the spatial versions of the two-group segregation index (Morill, 1991), of the multigroup dissimilarity index (Wong, 1998) and for the local spatial entropy indexes, we use a simple contiguity matrix where each element (i, j) is equal to one if i and j share a common border and 0 otherwise. Otherwise, as suggested by Wong (1993, 1998), this simple contiguity measure is replaced by the length of borders between i and j in order to compute the index $D(s)$.

4. Empirical results

4.1 Global segregation indices

In the European and more particularly in the French context, the segregation issue arises essentially in socio-economic terms. Compared to the North-American literature, the reference to ethnic segregation appears to be secondary. This doesn't mean that ethnic minorities are not affected by urban segregation, but that their situation is mainly the result of some discrimination on the labor market affecting their income or/and professional status. Among the six categories available from the INSEE database, the farmers have been neglected since their residential location is directly tied to the availability of agricultural land. The five categories that are considered are therefore: (ii) craft workers, merchants and company directors, (iii) managerial staff and superior intellectual professions, (iv) intermediary professions, (v) employees and (vi) low qualified workers[2].

The Duncan segregation indices presented in table 3 indicate the relative unevenness of the spatial distribution of each group compared to the whole population. Two groups exhibit a strong spatial specialization: the managers on the one hand and low qualified workers on the other hand. It appears that the two spatially more clustered groups are the two socially more polarized, in terms of income as well as professional status. This structure is common to all urban areas and for both years: the "socio-economic distance" between groups clearly results into a systematic stratification of urban space. It should also be noted that in the four cities the managers present the strongest spatial specialization. Two main explanations can be drawn from urban theory. First, highest income people can afford to offer the highest rents at most desirable locations. Second, this feature can indicate the preference of richest people for homogeneous neighborhoods within which they can live near to each other. The notable importance of the Duncan index for this group surely indicates that this second explanation is of some importance within French urban areas.

The relation between spatial income disparities and urban size is confirmed: the unevenness of managers and workers groups is the most important for Paris. Comparing 1990 and 1999, it appears that the spatial polarization of these two groups has increased significantly only within the Paris urban area, while stability prevails in other cities.

[Table 3 around here]

[2] All the segregation indices used in the following developments were computed using the GIS-applications developed by Apparicio (2000) (for Map Info) and Wong (2003) (for ArcView).

The first two columns of table 4 displays the results obtained by computing the multi-group dissimilarity index between the socio-professional categories. While Paris appears to be the most segregated area for both 1990 and 1999, it is furthermore the only urban area where segregation has increased between 1990 and 1999.

[Table 4 around here]

The preceding results drawn from the simple Duncan indices and the multigroup index only consider the socio-economic composition of neighborhoods. However, according to the "checkerboard problem", more attention must be paid to the spatial arrangement of spatial units. Three sets of additional measures are therefore considered here: Wong's modified Duncan and multigroup indices, and White's spatial proximity index.

We first consider the results provided by Wong's spatially modified segregation index. As stated in preceding sections, this index consists in the original Duncan segregation index less the amount of potential interaction with other groups across the units' boundaries. Thus, for both years, a subsequent table (table 5) indicates the percentage of decrease in the Duncan index attributable to possible inter-group interactions between adjacent spatial units. For all urban areas and years, the lowest decrease is observable for the craft workers and managers' group. For this latter category, it indicates a strong trend toward spatial clustering for this category: the spatial clustering of managers-specialized municipalities enhances the segregation of this socio-economic group. Generally, the spatial pattern of municipalities amplifies the segregation pattern resulting from the social specialization of municipalities: the homogeneity of adjacent spatial units primarily affects the municipalities exhibiting a "top" or "down" social polarization, while those composed essentially of medium-income people (employees or intermediary professions) benefit from a more diversified potential of interactions with their nearest neighbors.

[Table 5 around here]

Similarly, columns 3 and 4 of table 4 display the spatial multigroup index for 1990 and 1999 and columns 5 and 6 the differences in percentage between the spatial and the non-spatial versions. Considering the potential of spatial interaction between spatial units notably enhances the contrasts between the four urban areas. The potential inter-group interactions appear to be very small within Bordeaux and to a lesser extent within the Paris urban area, with significantly lower values of spatial-attributable reductions of the Duncan index for each socio-professional group than the three other cities. The spatial configuration of municipalities within Bordeaux and Paris strongly reinforces the process of urban segregation.

By contrast, the situation of Dijon exhibits a much stronger diversity of potential inter-group interactions between adjacent areas, with a reduction maximum of 32% of the multigroup segregation index in 1990. Clearly, for a medium-sized city like Dijon, the between-municipalities inter-group interactions strongly reduce the impact of the socio-economic specialization of each municipality.

The Wong-modified index only uses information about the first-order contiguous units, and thus potentially ignores spatial clustering processes operating at a larger scale. It can be of interest, thus, to complete the preceding comments by the computation of the spatial proximity indices proposed by White (1983), whose main advantage is the use of a matrix of distances between each pair of spatial units. The results are displayed in tables 6 to 9. In order to save space, a small number of results are presented. Each table proposes three types of measures for each the four groups considered (in rows):

- The average intra-group proximity between the members of each group, computed using equation (7) with a linear function of the distance d_{ij}, $f(d_{ij}) = d_{ij}$,
- the average inter-group distance between the managers and each of the three other groups, computed using equation (8) with a linear function of the distance d_{ij}, $f(d_{ij}) = d_{ij}$,
- The relative proximity index of the managers' group with respect to each of the three others categories, computed using equation (9), with P_{XX}, P_{YY} and P_{00} computed using a negative exponential function of distance : $f(d_{ij}) = e^{-d_{ij}}$

The intra-group average distance clearly discriminates the low-skilled workers category, with the highest average distances in all urban areas on the one hand, and the managers group, with a significantly lower intra-group distance than the three other categories on the other hand. This feature reinforces the presumption of a systematic preference of managers for homogeneous neighborhoods. Remembering also that these two groups exhibit the strongest values of both Duncan and Wong indexes, this indicates a notable difference in the geographic pattern of spatial clustering between these two categories. Two explanatory factors can be proposed. First, the degree of centralization can explain partially the low average distance between managers, while low-skilled workers can be expected to live within less central areas. Second, this feature may reflect a large-scale clustering pattern of the managers' residential location that would contrast with the development of several local clusters of workers-specialized municipalities, dispersed within the urban area.

The inter-group distances of managers with each other group do not differ strongly, even if a slight excess can be noted concerning the low-skilled workers category.

Nevertheless, compared to the intra-group average distance, the values clearly indicate a trend to spatial clustering between members of the managers group.

The first two average distances cannot be used in a comparative framework between the four urban areas, since they strongly depend on the urban size. The relative proximity index, expressed as a number without dimension, appears to be more suitable. The results indicate a general tendency of each pair of groups to cluster to each other, with all values above unity. Furthermore, the most important values are observed when comparing managers and workers. One more time, the urban area of Paris exhibits the highest values, especially concerning the comparison between workers and managers: 1.215 in 1999.

[Tables 6 to 9 around here]

4.2 Local segregation indices

While the measures presented in section 4.1 provide a useful summary of the level of segregation within the four urban poles of Paris, Lyon, Bordeaux and Dijon, they cannot provide any information on the spatial distribution of segregation. For that purpose, we compute, for each areal unit i of these urban poles (i.e. communes or IRIS), the diversity index defined in (10) and its spatial counterpart defined in (11) for 1990 and 1999[3]. The maps are presented with the diversity index and/or the spatial diversity index standardized by maximum diversity so that all the values fall between 0 and 1. In other words, this standardization allows comparing the observed situation with the best possible situation where each group has the same share within each unit.

Consider first map 2 that displays the diversity index for socio-professional categories in the city of Paris in 1990 and its spatial counterpart. The same categories have been adopted for comparison purpose. For the standard diversity (first map), IRIS below the river "La Seine" display on average lower levels of diversity than IRIS above the river. There is therefore some north-south pattern with relatively mixed neighborhoods in the north and low diversity in the south. The second map displays the spatial diversity index applied to nationality. Several features deserve attention. First, there is a striking smoothing effect when one uses the spatially adjusted entropy index. This is because the contiguous neighborhoods are taken into account when computing the diversity index for one unit i. Second and as a consequence, the clusters of high and low diversity appear more clearly. A cluster of high diversity appears in the North corresponding to some IRIS belonging to the 3rd, 9th and 10th "arrondissements". On the contrary, a cluster of low diversity corresponds to some IRIS

[3] The programs computing the diversity index and its spatial counterpart have been written using Python 2.3. They are available upon request from the authors.

belonging to the 6th, 14th and 15th "arrondissements". They also are more extended than those according to the traditional diversity index because of the computation method. All the remaining maps will be presented for the spatial diversity index[4].

[Map 2 around here]

Maps 3a and 3b display the spatial diversity indices for socio-professional categories in Paris for 1990 and 1999 respectively with a series of zoom for the most centrally located areas. Again, the same categories have been adopted to allow for comparison between the two years Globally, low levels are rather observed in the center and higher levels in the periphery, especially in 1990. The centrally located areas display however quite complex patterns of low and high diversity areas. Diversity decreases in 1999 compared to 1990, a result that is consistent with the global segregation indices computed previously.

[Maps 3a and 3b about here]

Maps 4a and 4b represent the spatial diversity indices for the urban pole of Lyon for 1990 and 1999 respectively with a zoom on the central city of Lyon. The geography of Lyon metropolitan area exhibits a strong East/West contrast, with the highest values of socio-professional diversity in the west side, corresponding to the location of high income households, whereas the east side of the area, where can be found lower income households, presents lower levels of diversity. The centrally located areas present the lowest levels of diversity, with a clear tendency to social homogenization of the center between 1990 and 1999. It seems that social diversity has decreased near to the city center between 1990 and 1999, thus reinforcing the process of social homogenization of the central part of the area.

[Maps 4a and 4b about here]

In the case of Bordeaux (maps 5a and 5b), the pattern of low socio-professional diversity (map 4c) follows narrowly the river's downstream side layout ("La Garonne"): the insufficient number of bridges within Bordeaux explains the poor accessibility of the riverside areas, leading to a "gate effect" around the river. Between 1990 and 1999 there is a clear tendency to the reduction of socio-professional diversity in the central part of the urban area, including the central city of Bordeaux and some important contiguous municipalities such as Mérignac, Pessac Talence…(in the west side of the area). High levels of social diversity can still be observed, in 1999, only the south-east outer fringe of the urban area.

[Maps 5a and 5b]

[4] The maps displaying the traditional diversity indices are available upon request from the authors.

Finally, in the case of Dijon (maps 6a and 6b), a clear center-periphery pattern appears, with diversity in terms of socio-professional categories is very high everywhere, except in some IRIS of the center and some communes in the South-East. Indeed, these communes concentrate high levels of workers since they are specialized in truck farming.

[Maps 6a and 6b about here]

5. Conclusion

Using data about four French urban areas, we have proposed an empirical framework aimed at measuring some aspects of urban segregation. In the French context, more attention has been paid to the socio-economic dimension of segregation than to the ethnic dimension widely studied in the North American literature. Data related to socio-professional status were thus preferred as a basis to understand the segregation process operating within Paris, Lyon, Bordeaux and Dijon.

Four main conclusions can be raised from the computation of the global and local segregation indexes:

- The “socio-economic distance” between groups appears to be clearly correlated with the segregation pattern. The two more segregated groups being the managers, occupying the top of the social stratification, and the low-skilled workers down of the hierarchy. Several features have revealed a specific behavior of managers looking for self-segregation, notably the systematic high distance with each of the other groups.
- The second conclusion deals with the specific features of Paris, compared to other cities. Although the structure of segregation is comparable with smaller urban areas, there is evidence that the segregation pattern of Paris strongly amplifies the general trends. More specifically, between 1990 and 1999, Paris exhibits a trend of increasing socio-spatial polarization between managers and low-skilled workers, while stability prevails in other cities.
- The geographic clustering of socio-economic-composition-related similar spatial units significantly amplifies the socio-economic specialization of neighborhoods, the likeness of adjacent spatial units affecting primarily the municipalities exhibiting a “top” or “down” social polarization. The segregation pattern of Paris strongly differs from other cities from this point of view.
- The spatial diversity indexes related to socio-professional status exhibit complex patterns, often identifying some very specific distressed areas with low social diversity levels.

One can think these features of urban segregation to be related to some specific features of urban growth, such as urban sprawl or “metropolitanization”. Some authors (Sassen, 1991; Von Kempen, 1994) have stressed the hypothesis of the “dual city”: the process of social polarization occurring specifically in the largest cities, and explained by the socio-economic changes related to the globalization process, could partially explain the evolution of urban segregation. Such a hypothesis could explain the specific features of the Paris urban area between 1990 and 1999, compared with the three smaller cities studied in this paper. The confirmation of this hypothesis is led for further work.

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Tables and figures

Table 1: Descriptive statistics on population

	% of French total; 1990	% of French total; 1999
Paris	19.18	19.73
Lyon	2.71	2.88
Bordeaux	1.49	1.58
Dijon	0.55	0.58

Table 3: Duncan segregation indices, 1990 and 1999

	Paris		Lyon		Bordeaux		Dijon	
Socio-prof. categories	*1990*	*1999*	*1990*	*1999*	*1990*	*1999*	*1990*	*1999*
(ii) Craft workers	0.214	0.195	0.181	0.178	0.185	0.151	0.252	0.199
(iii) Managerial staff	0.306	0.321	0.297	0.280	0.273	0.264	0.285	0.275
(iv) Intermediary professions	0.125	0.125	0.125	0.121	0.14	0.129	0.138	0.135
(v) Employees	0.122	0.128	0.103	0.092	0.110	0.103	0.134	0.126
(vi) Low qualified workers	0.233	0.245	0.208	0.217	0.206	0.218	0.204	0.210

Table 4: Multigroup dissimilarity indices

	Non-spatial		Spatial		Difference in %	
	1990	*1999*	*1990*	*1999*	*1990*	*1999*
Paris	0.212	0.218	0.161	0.173	-24.06%	-20.64%
Lyon	0.199	0.187	0.146	0.144	-26.63%	-22.99%
Bordeaux	0.191	0.179	0.146	0.136	-6.28%	-18.43%
Dijon	0.205	0.193	0.139	0.132	-32.19%	-31.60%

Table 5: Difference between the Duncan and Wong segregation indices

	Paris		Lyon		Bordeaux		Dijon	
Socio-prof. categories	*1990*	*1999*	*1990*	*1999*	*1990*	*1999*	*1990*	*1999*
(ii) Craft workers	-1.25%	-1.13%	-0.55%	-0.56%	-1.62%	-1.32%	-1.59%	-1.51%
(iii) Managerial staff	-1.17%	-1.34%	-1.01%	-1.07%	-1.09%	-1.51%	-1.40%	-1.45%
(iv) Intermediary professions	-2.96%	-2.82%	-2.40%	-1.65%	-2.86%	-3.10%	-3.62%	-3.70%
(v) Employees	-4.22%	-4.25%	-2.91%	-2.17%	-4.54%	-5.82%	-5.22%	-4.76%
(vi) Low qualified workers	-2.75%	-2.02%	-1.92%	-1.38%	-2.91%	-2.29%	-3.43%	-2.38%

Table 6: White's spatial proximity indices; Paris

	Intra-group proximity (km)		Inter-group distance with managerial staff group (km)		Relative proximity index with managerial staff group	
	1990	*1999*	*1990*	*1999*	*1990*	*1999*
(vi) Workers	14.102	15.321	9.987	9.888	1.164	1.215
(v) Employees	11.823	12.899	9.856	9.881	1.141	1.121
(iv) Interm. Professions	12.345	13.543	9.720	9.690	1.123	1.122
(iii) Managerial staff	9.754	9.474				

Table 7: White's spatial proximity indices; Lyon

	Intra-group proximity (km)		Inter-group distance with managerial staff group (km)		Relative proximity index with managerial staff group	
	1990	*1999*	*1990*	*1999*	*1990*	*1999*
(vi) Workers	7.747	8.412	7.678	8.541	1.163	1.204
(v) Employees	6.729	7.320	6.596	7.191	1.059	1.072
(iv) Interm. Professions	6.911	7.356	6.651	7.178	1.034	1.035
(iii) Managerial staff	5.653	6.094				

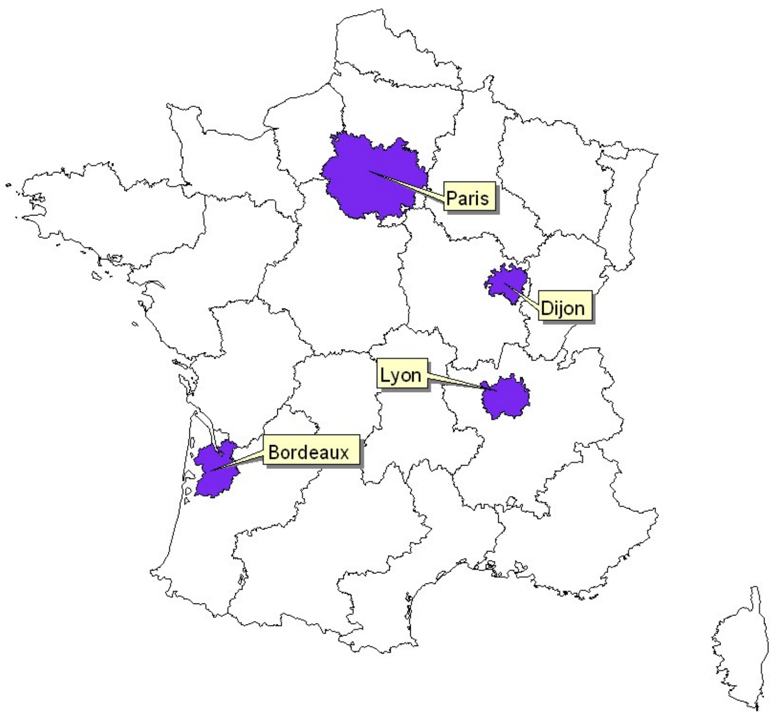
Table 8: White's spatial proximity indices; Bordeaux

	Intra-group proximity (km)		Inter-group distance with managerial staff group (km)		Relative proximity index with managerial staff group	
	1990	*1999*	*1990*	*1999*	*1990*	*1999*
(vi) Workers	8.413	8.765	7.619	8.019	1.181	1.186
(v) Employees	6.690	7.084	6.244	6.702	1.065	1.072
(iv) Interm. professions	6.260	6.661	6.022	6.385	1.029	1.030
(iii) Managerial staff	5.302	5.426				

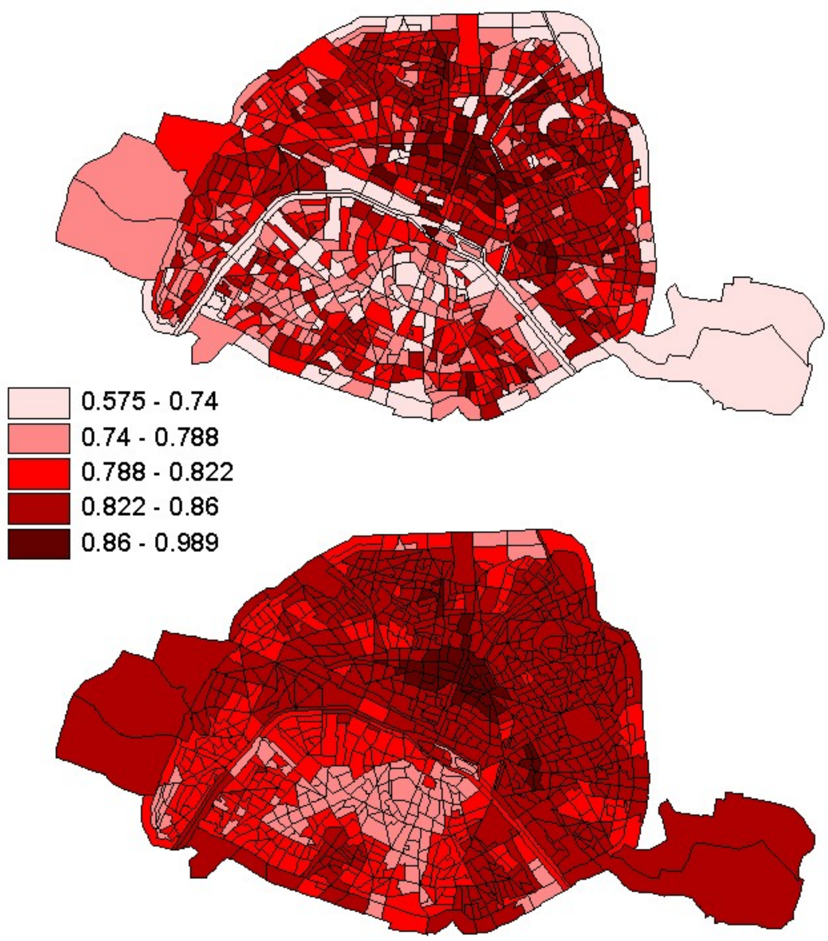
Table 9: White's spatial proximity indices; Dijon

	Intra-group proximity (km)		Inter-group distance with managerial staff group (km)		Relative proximity index with managerial staff group	
	1990	*1999*	*1990*	*1999*	*1990*	*1999*
(vi) Workers	5.280	5.602	5.599	5.898	1.072	1.076
(v) Employees	4.331	4.794	4.340	4.806	1.029	1.030
(iv) Interm. Professions	4.354	4.732	4.391	4.821	1.014	1.013
(iii) Managerial staff	3.686	3.949				

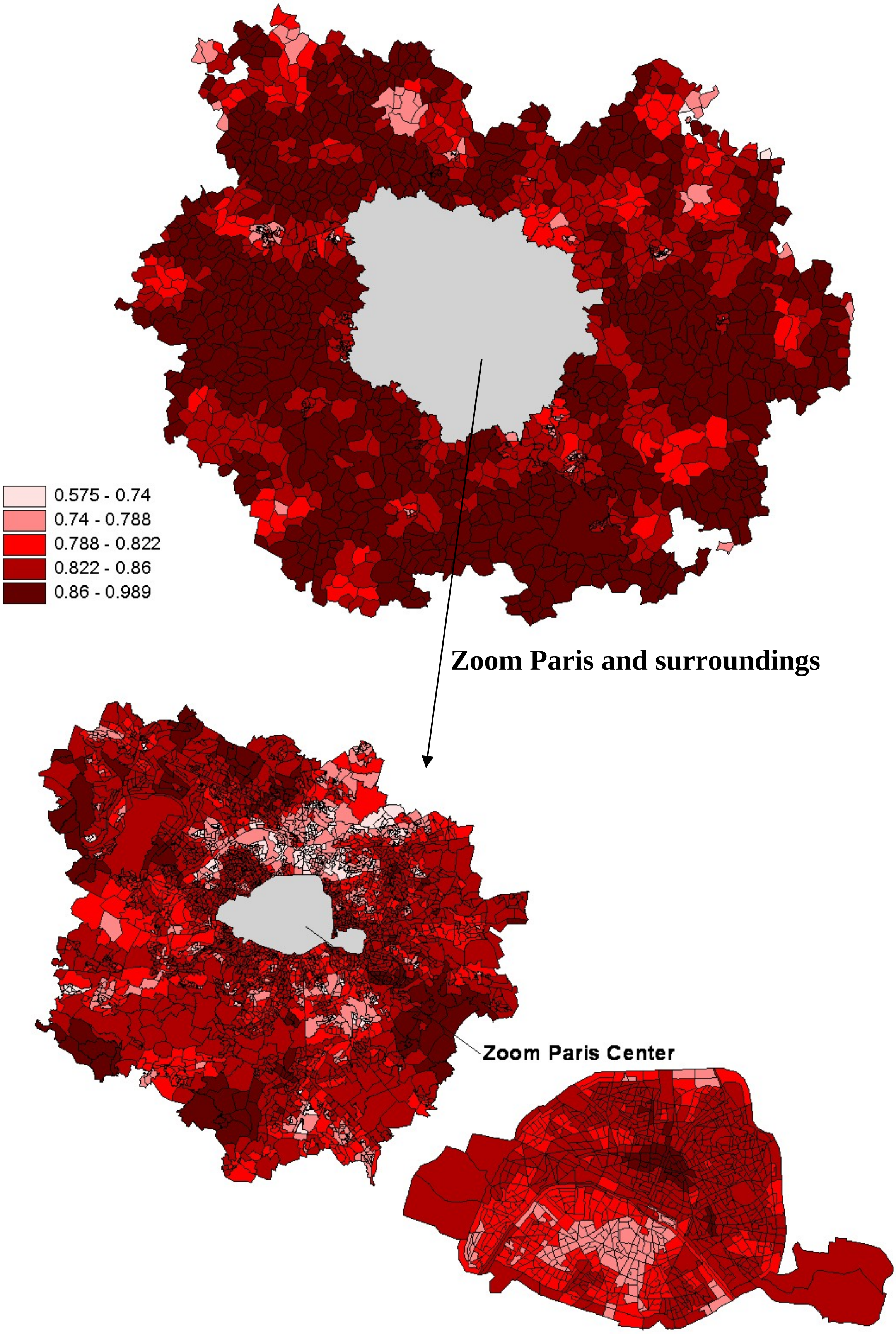
Map 1: The four urban poles in France



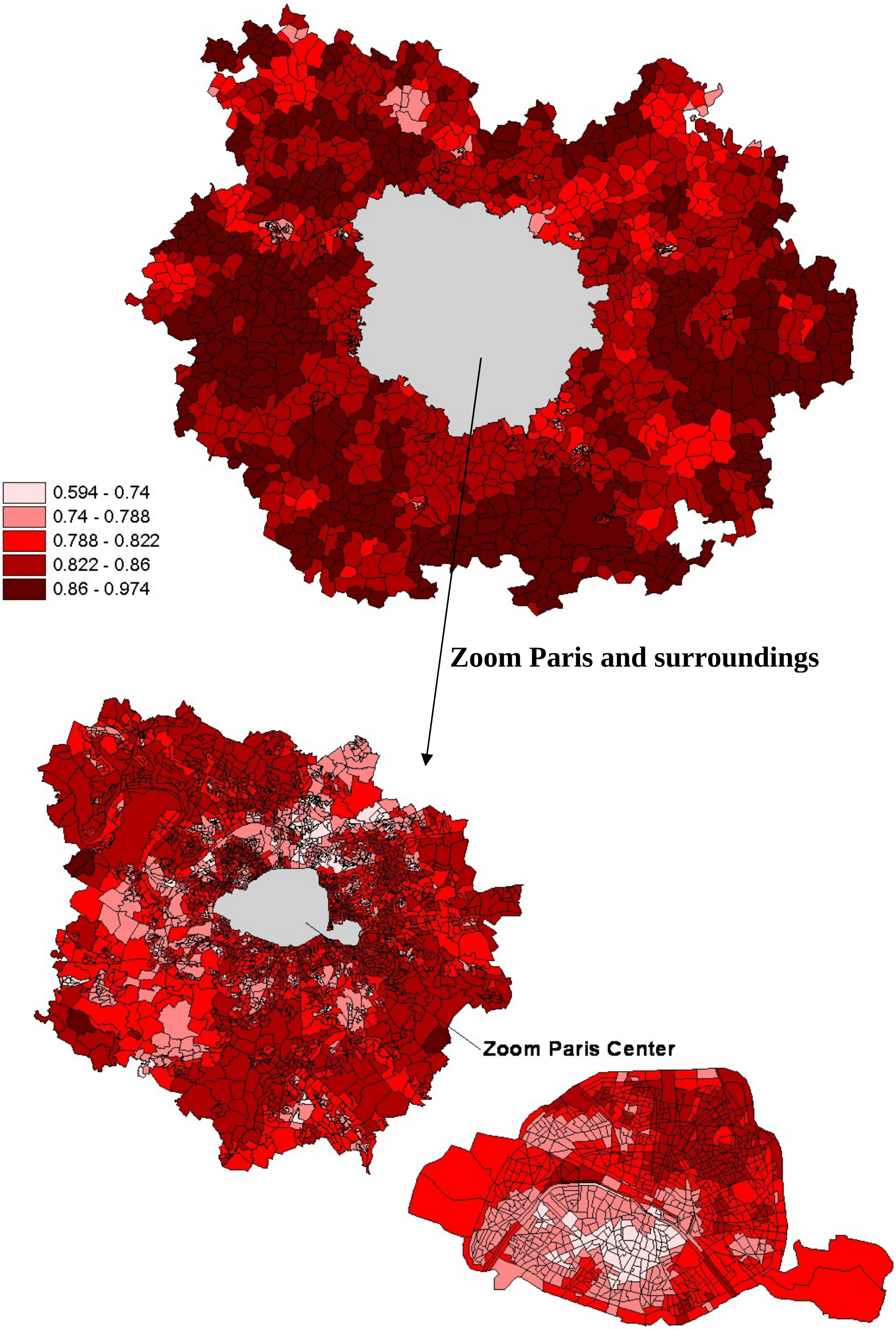
Map 2: Standard diversity and spatial diversity index in Paris; 1990



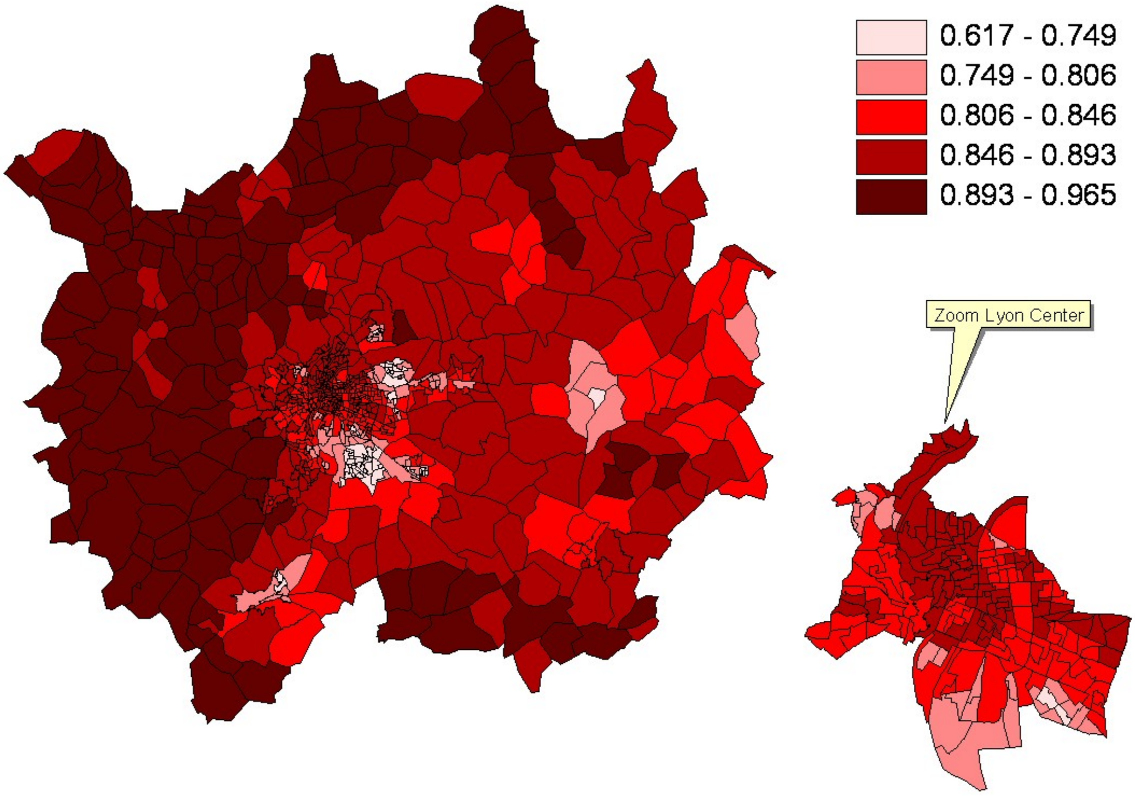
Map 3a: Spatial diversity index for socio-prof. categories in Paris; 1990



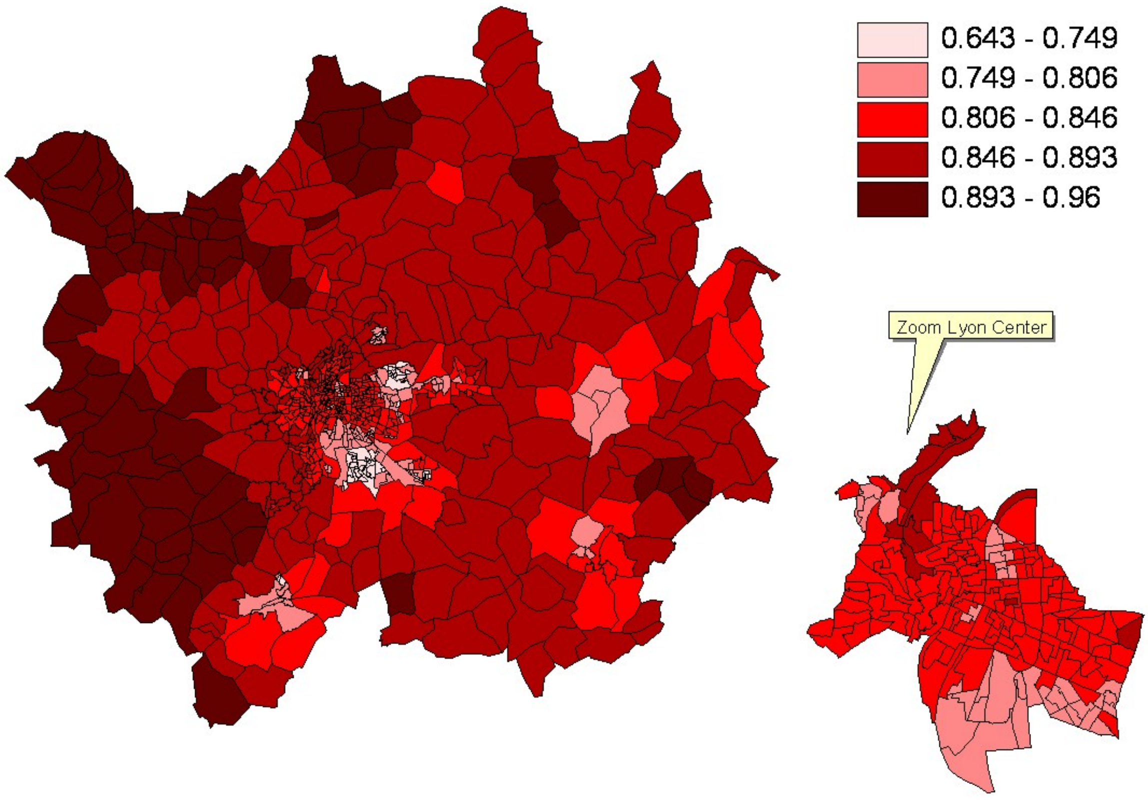
Map 3b: Spatial diversity index for socio-prof. in Paris; 1999



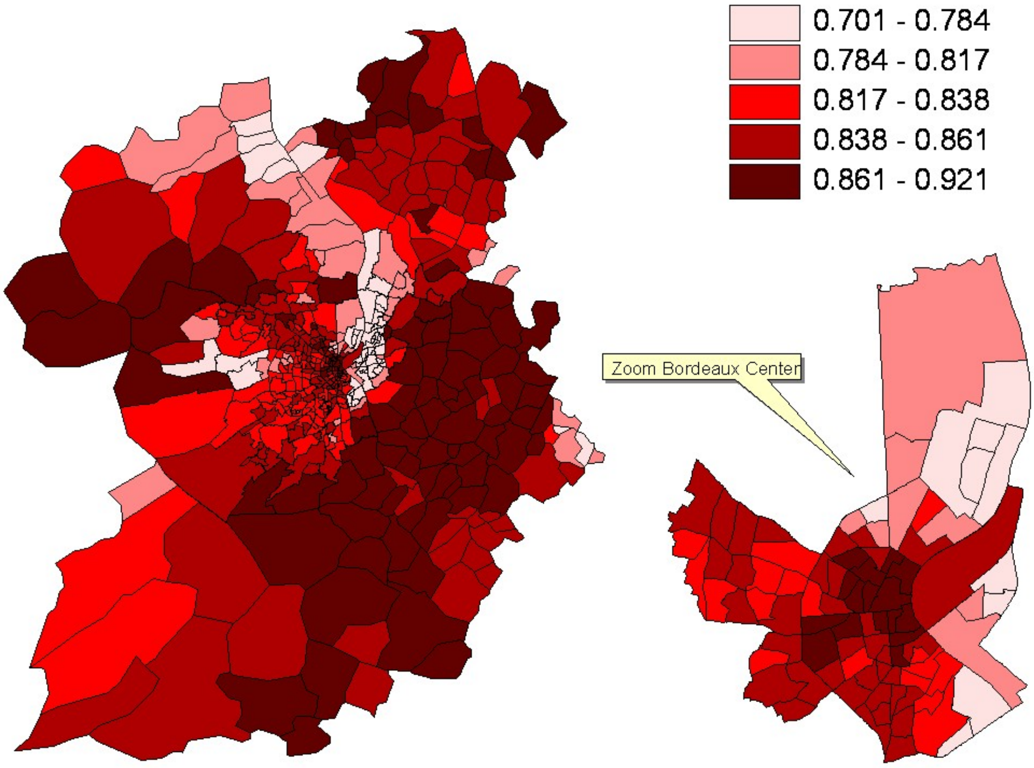
Map 4a: Spatial diversity index for socio-prof. categories in Lyon; 1990



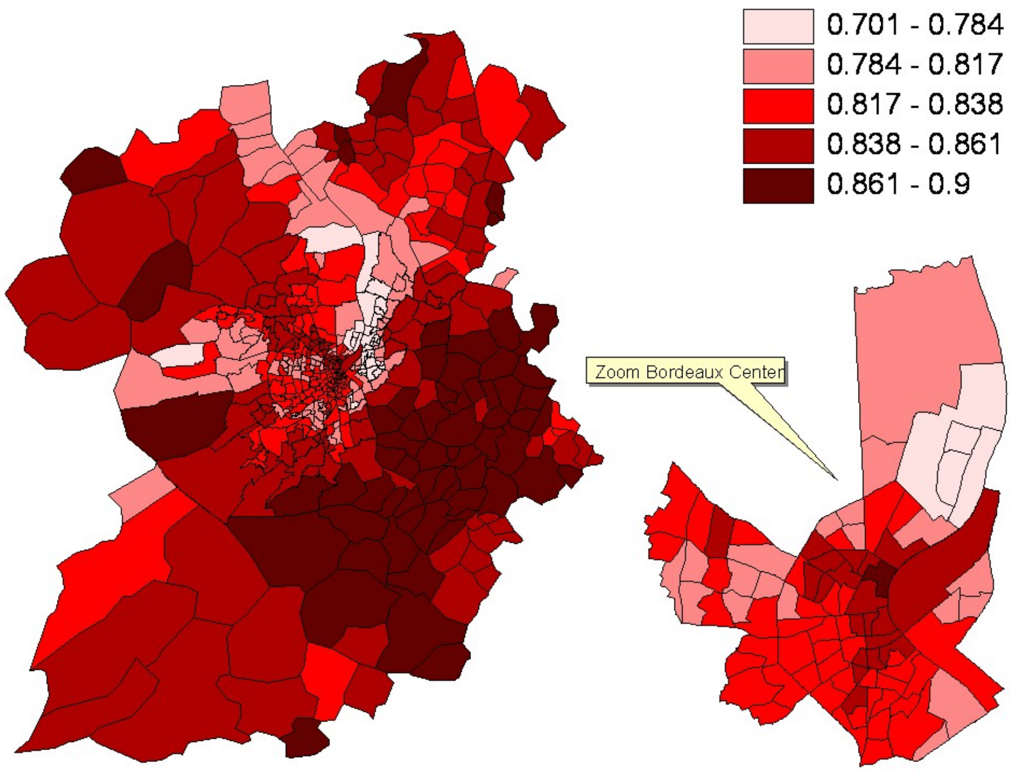
Map 4b: Spatial diversity index for socio-prof. categories in Lyon; 1999



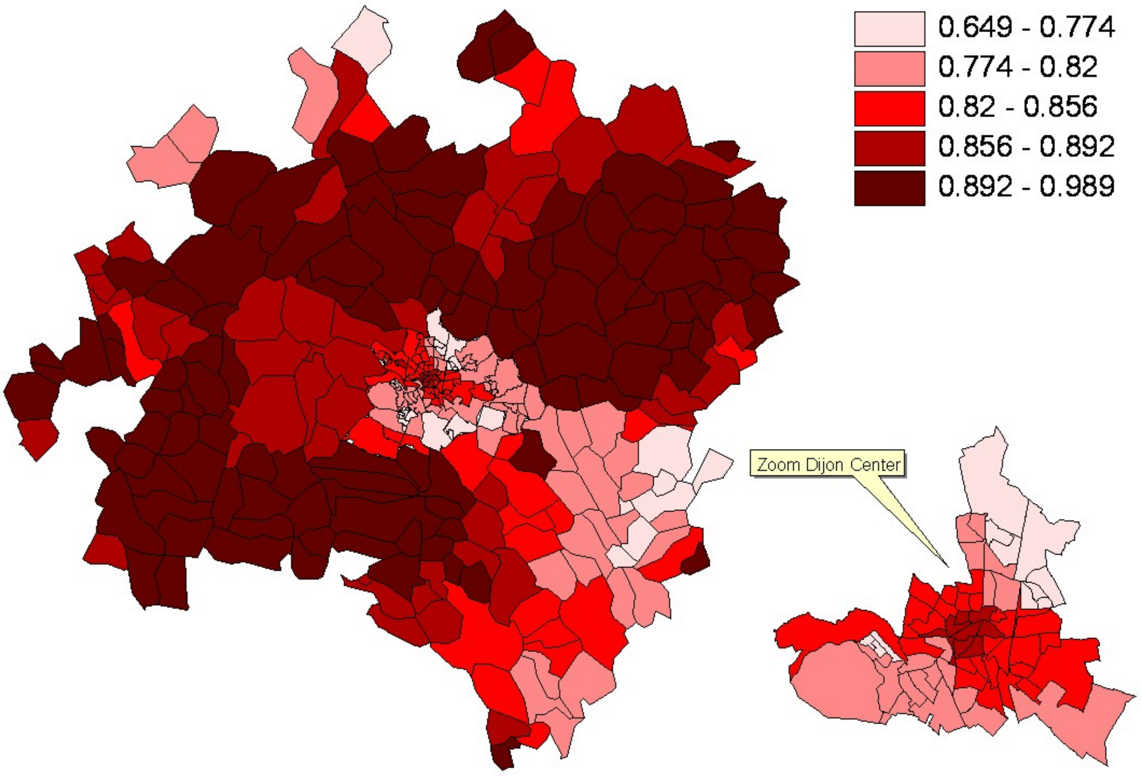
Map 5a: Spatial diversity index for socio-prof. categories in Bordeaux; 1990



Map 5b: Spatial diversity index for socio-prof. categories in Bordeaux; 1999



Map 6a: Spatial diversity index for socio-prof. categories in Dijon; 1990



Map 6b: Spatial diversity index for socio-prof. categories in Dijon; 1999