45th Congress of the European Regional Science Association

Vrije Universiteit Amsterdam
23-27 August 2005

Segregation measures and spatial autocorrelation. Location patterns of immigrant minorities in the Barcelona Region.

Joan Carles Martori, Quantitative Regional Analysis Research Group, University of Vic, Sagrada Familia 7, 08500 Vic (Barcelona), Spain. martori@uvic.es

Karen Hoberg, University of Vic. karenhoberg@natureco.es

Jordi Suriñach, Quantitative Regional Analysis Research Group, University of Barcelona, Av. Diagonal 690, 08034 Barcelona, Spain. jsurinach@ub.edu

ABSTRACT

Given the important growth of immigrants in Spain, it would be interesting to study its distribution throughout the urban area. Statistics suggest different large traditional indices allowing us to quantify the segregation of minority groups. Segregation can be measured from different dimensions and a new segregation perspective can be obtained with innovative indices including spatial statistics elements, as well as global and local indicators of spatial association (LISA). Through the application of these tools in Barcelona and its metropolitan region, its usefulness in the analysis of resident segregation in a town is shown and segregation patterns can be found. A special focus is put on the relationship between segregation indices and global spatial association measures. The results point out that the segregation differs depending on the observed group and that there exists correlation between some spatial association measures and segregation indices. The combination of all these elements represents a constructive process in the analysis of the distribution of immigrants in the urban zones, and its convenience extends to different areas like sociology, economics, city planning or housing policies.

Key words: immigrants; residential segregation; spatial statistics; Barcelona Region.

JEL Classification: C10, R14, R23.

1. Introduction

When special issues of the *Tijdschrift voor Economische en Sociale Geografie* (1997) and *Urban Studies* (1998) on segregation were published, the situation in Spain was different since immigration just started. Now, less than ten years later, this country is economically closer to the European Union, it is one of the old members, and has lost the traditional status of emigration country, becoming a very attractive place for immigrants. On the one hand, the economic situation gives a chance to a huge amount of low paid labour force, and on the other hand northern Europeans can find a pleasant place for retirement or a convenient first residence. As a consequence, the percentage of immigrant population has risen in a small period of time (e.g. in Barcelona municipality the immigrant population increased from 53,428 in 2000 to 167,223 in 2003) accompanied by the social instabilities already experienced by other European countries. The best proof of this change, in economic terms, is the increase in the amount of transfer money from immigrants to their home countries (from 420 millions € in 1996 to 3,436 millions € in 2004), whereas the reception of transfers from Spaniards living in other countries stagnates.

Despite the European experience in this subject, it has been in the United States of America where the racial and ethnic composition of the population has been a suitable place to develop migration theories. Therefore, it is in this country where segregation measures are considered an important part of the regular administration statistics. Residential segregation, which in the worst case is perceived as a real ghetto, usually goes hand in hand with social and economic segregation, therefore being its cause and effect at the same time. In the beginning, segregation was the object of sociologic studies, just remember the School of Chicago in the 1920s, but soon other approaches from different sciences, such as Economics and Geography, developed.

During many decades, the indices used to measure the segregation level of a population group incorporated simply formulas from statistics in order to detect the different distribution between groups. In the late eighties and nineties, the general technological acceleration also gave new impulses in this field, by using together geographic information systems (GIS), data base information and digitalized maps, which makes extremely complex calculations possible. In consequence, the new spatial perspective of segregation takes into account detailed information of the exact localization of population groups within urban areas, as well as the characteristics of the units and the relationship with the neighbour units.

Another successful approach has been done from Spatial Statistics investigating the distribution of variables in the space. Thus, these techniques are a fruitful way to study the localization and possible segregation of immigrants although they have not been fully exploited, yet.

There are two other factors that provide this research with a special interest: the migration situation in Spain, which has to manage important changes in a very short period of time; and the very heterogeneous composition of immigrants in economic terms, especially in a metropolitan area like Barcelona.

The present paper is structured around four questions:

- Which pattern of localization do immigration minorities in Barcelona follow?
- Is this pattern unique or are there some differences between nationality groups?
- Analyzing the residential segregation and localization patterns, is the combination of traditional segregation measures with global and local spatial statistics useful?
- Which is the statistical relationship between segregation indices and spatial autocorrelation measures?

The organization of this paper is as follows: First of all, we present a survey of the common measures in its different dimensions and then we connect them with a local indicator of spatial association. In the next part, we introduce the methodology of the case study, followed by the results of the different segregation indices for immigrant groups in Barcelona and its metropolitan region. After that, the relationship between segregation indices and global spatial association measures is explored. In the final part we summarize the findings and we present some conclusions.

2. A brief survey on residential segregation indices

In this part we would like to present the different indices we used in the case study and we would like to give some more details about segregation measures in spatial statistics. As pointed out before, segregation can be described with five different dimensions as identified by Massey and Denton (1988): evenness, exposition, concentration, clustering and centralization. In addition, another possibility to examine the localization patterns of different population groups are the indicators of spatial association. We are going to present the local Moran statistics and the global indicator of spatial association (Anselin, 1988, 1995), and for a graphic representation we bring in a LISA cluster map.

2.1. Non spatial measures

Evenness indices

The evenness measures compare the spatial distribution of different groups in urban areas. One of the most well-known indices is the Segregation Index, introduced by Duncan and Duncan (1955a, 1955b). It compares the distribution of one minority group with the distribution of the rest of the population in an urban area. The formulation is as follows:

$$IS = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{x_i}{X} - \frac{t_i - x_i}{T - X}\right| \quad 0 \le IS \le 1 \qquad (1)$$

where x_i is the population of group X in unit i, X is the total population of group X in the urban area, T_i is the total population of the unit i, and T is the total population of the urban area.

The index ranges from 0, which means no segregation, to 1, which means maximum segregation. In the same way, the result can be expressed as a percentage indicating the proportion of the minority group members that has to change its area of residence in order to achieve an even distribution. This conceptualisation has been criticised by Cortese *et al* (1976) because it does not take into account the new obtained space, but it gives a very practical idea about the amount of uneven distribution.

A different criticism can be made based on a broad research on immigrant segregation in the Barcelona Region (Martori and Hoberg, 2004), where high segregation levels of European Union residents in coastal areas were found. In this case, segregation refers to *voluntary* segregation in residential areas and not an *involuntary* segregation due to lack of economic resources. This should be taken into account in future researches, especially when focusing on the relationship between poverty and segregation.

Another very common index is the Dissimilarity Index (Duncan and Duncan, 1955a). The formula is very similar to the first one, but it compares the distribution of one group with another, usually one minority group with the majority or reference group. The difference in the results between this second approach and the Segregation Index depends on the amount of population not corresponding to none of the observed groups. The higher this amount, the larger the difference. Besides, the Dissimilarity Index can be used to measure the dissimilarities between two minority population groups. In addition, some spatial versions based on the dissimilarity index exist, but will be dealt within the spatial measures.

There are different evenness measures derived from other disciplines, as there is for example the Gini index related to the Lorenz curve used to expose uneven distributions, the entropy index or the Atkinson index with its different shape parameters.

Exposure indices

This dimension is based on the potential contact between the individuals living in an area. In general there are two ideas behind: the possibility of interaction and the situation of isolation. The first one, known as exposure index (Bell, 1954), expresses the probability that one member of the minority group interacts with a member of the reference group. The second one, the isolation index (Bell, 1954; White, 1986), measures the probability for a member of a minority group to interact with another member of the same group. In this research we used the isolation approach, but adjusted by the number of population of the group, with the purpose to allow comparison between different groups. This is the eta-squared index (Streans and Logan, 1986), varying between 0, minimum segregation, and 1, maximum segregation, expressed by the following formulation:

$$\eta^2 = \frac{xPx - P}{1 - P} \quad 0 \le \eta^2 \le 1 \qquad (2)$$

where $xPx = \sum_{i=1}^{n} \left(\frac{x_i}{X} \right) \left(\frac{x_i}{t_i} \right)$ $\quad 0 \le xPx \le 1$,with n the number of spatial units and P the proportion of the group in the urban area.

Concentration indices

In this context, concentration refers to the relative amount of physical space occupied. The underlying idea of this measure is that minority groups are usually living in denser areas (e.g. less square metres per individual) due to their lower economic resources. We used the Delta Index (Duncan et al, 1961), which compares the relative density of a unit with the proportion of a group living in the same unit. It is analogous to the segregation index, expressed in percentages, as it indicates the proportion of the group that is supposed to move to other areas in order to achieve an even distribution. The formula, whose result ranges from 0 to 1, with 0 representing no segregation, is

$$DEL = \frac{1}{2} \sum_{i=1}^{n} \left| \frac{x_i}{X} - \frac{a_i}{A} \right| \qquad 0 \le DEL \le 1 \qquad (3)$$

where a_i is the area of the unit, and A the total area of the urban area.

Furthermore there are two other measures, proposed by Massey and Denton (1988): the Absolute Concentration Index and the Relative Concentration index. They connect the situation of the minority group with the one of the majority group, and consider elements like the minimum and maximum possible density.

Centralization indices

Centralization is linked to the idea that in many urban areas the city centre is one of the most run-down areas because it is used as business district but it is not a residential place. Consequently, no investment is done and a process of gentrification takes place. Nevertheless, many local governments, generally in Europe, are becoming aware of this problem and lately there is a clear trend to renewand to inhabit city centres. Due to this fact, this dimension may lose its original scheme. The simplest centralization index expresses the percentage of members in the considered group living in the centre, measuring the amount of people living in the supposed deprived spatial units. More precise indices count the distance of every unit to the central area. This is the case of the Absolute Centralization Index that examines the distribution of one minority group around the centre. It varies between –1 and 1, where the negative values indicate a tendency to live in outlying areas and positive values indicate a closer residence to the centre. The improbable case of a 0 score indicates a uniform distribution throughout the urban area. All this measures involve the question of how to define the city centre. The formulation is:

$$ACE = \left(\sum_{i=1}^{n} X_{i-1} A_i \right) - \left(\sum_{i=1}^{n} X_i A_{i-1} \right) \quad -1 < ACE < 1 \; (4)$$

where X_i is the accumulated proportion of group X in the unit, and A_i the accumulated proportion of the units area.

2.2. Spatial measures

We consider that spatial measures include in its calculation some kind of spatial weight matrix, because this matrix captures any measure of potential interaction between two units, while the purely geometric characteristics (e.g. distance) are less important. This interaction between individuals of different groups is more essential from the segregation point of view.

Spatial evenness indices

The Dissimilarity Index has been developed introducing spatial elements. There is a simply modified D index (Morill, 1991, 1995) including information about the contiguity of the spatial areas, and the boundary modified D index including the longitude of the border between different areas (Wong, 1993, 1999). The index we used is somehow more sophisticated and can be calculated with the use of geographic information systems. It is the Dissimilarity Shape Modified Index (Wong, 1993, 1999) that takes into account the compactness, which refers to the relationship between the perimeter and the area of a unit, and it is based on the idea that the geometric form of a spatial unit affects the probability of interaction between the populations living in different units. Its formulation is:

$$D(s) = D - \frac{1}{2}\sum_{i=1}^{n}\ \sum_{j=1}^{n} w_{ij}\left|z_i - z_j\right| \frac{\frac{1}{2}\left[(p_i / a_i) + (p_j / a_j)\right]}{máx(p_i / a_i)} \qquad 0 \le D(s) \le 1 \qquad (5)$$

where D is the Dissimilarity Index,

$w_{ij} = \frac{d_{ij}}{\sum_{i=1}^{n} d_{ij}}$ and z_i is the proportion of the group in the unit i, d_{ij} the length of the common border between two spatial units, p_i the perimeter of unit, A_i the area of unit, and *Max (p/a)* is the maximum relation between perimeter and area.

Clustering indices

In general clustering indices measure the degree to which minorities live disproportionately in contiguous areas. In the calculation this means, at least, a binary matrix stating whether two units have the condition of neighbourhood . A first approach is the Absolute Clustering Index that expresses the average number of group members in contiguous units as a proportion of the total population in those neighbour units. Consequently, it ranges between 0 and 1. The formula is:

$$ACL = \left\{\left[\sum_{i=1}^{n}(x_i / X)\sum_{j=1}^{n}(c_{ij}x_j)\right] - \left[X / n^2 \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\right]\right\} / \left\{\left[\sum_{i=1}^{n}(x_i / X)\sum_{j=1}^{n}(c_{ij}t_j)\right] - \left[X / n^2 \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij}\right]\right\} \qquad (6)$$

$$0 \le ACL \le 1$$

where t_j is the total population in unit j, c_{ij} is the value of the of the spatial weights matrix between unit i and j, with $c_{ij} = 1$ in case of neighbourhood, $c_{ij} = 0$ in other case.

There are two other indices proposed by White (1986), namely the Spatial proximity index and the Relative clustering index comparing the average distance between group members.

Other spatial measures

Spatial autocorrelation can be defined as the coincidence of value similarity with location similarity. High o low value for a random variable tend to cluster in space (positive spatial autocorrelation), or locations tend to be surrounded by neighbours with dissimilar values (negative spatial autocorrelation). It’s clear that this concept is basic to study the localization patterns of immigrant minorities in an urban area. The most common measure for spatial autocorrelation is the Moran’s statistics (Moran, 1948). Formally, Moran’s I for n observation on a variable (in our case immigrant population), is expressed as:

$$I = (N / S_o)\sum_{i=1}^{n}\sum_{j=1}^{m} c_{ij}(x_i - \mu)(x_j - \mu) / \sum_{i=1}^{n}(x_i - \mu)^2 \qquad (7)$$

where μ is the mean of the x variable, c_{ij} are the elements of the spatial weight matrix and S_0 is a normalizing factor equal to the sum of the elements of the weight matrix.

This measure is a global statistic because it is a summary value for an entire study area. It is reasonable to suppose that the magnitude of spatial autocorrelation of immigrant distribution does not have to be uniform over the area. In other words, it is likely that the magnitude of spatial autocorrelation is high in some parts but low in other parts of a urban area.

In this sense our attention has focused on local indicators of spatial autocorrelation, or LISA. Following the definition of Anselin (1995), a LISA is an indicator that allows the detection of significant patterns of local autocorrelation (i.e. association around and individual location, such as hot spots and spatial outliers). Again, it is clear that these situations are very important to discover localization patterns of immigrant minorities in an urban area. The local Moran statistic for unit i is defined as:

$$I_i = \frac{(x_i - \mu)}{m_0}\sum_{j=1}^{n} c_{ij}(x_j - \mu)$$

with $m_0 = \sum_{i=1}^{n}(x_i - \mu)^2 / n$

where the summation over j is such that only neighbourhood values of unit i are included.

3. Data and methodology

In this part we will provide some relevant details about the procedures in our research in order to ensure a correct interpretation of the results.

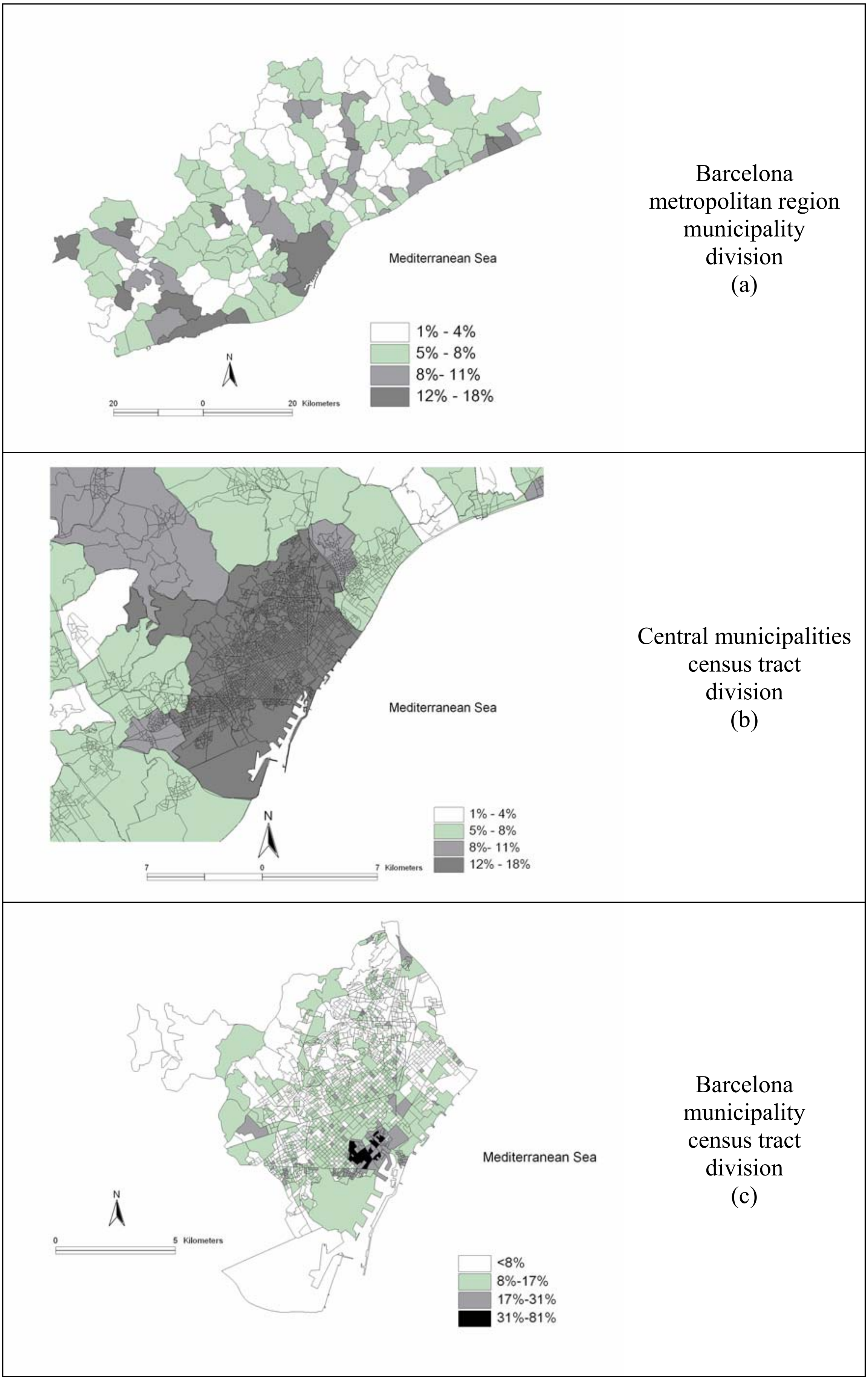

Figure 1. Barcelona metropolitan region, different divisions. Immigrant percentages.

As far as the data is concerned, we used the information from the register of the municipalities corresponding to the year 2003. It does not come from the Spanish Census bureau because the last census took place in 2001 and due to the important increase of immigrants we preferred to deal with updated data (i.e. Bureau Statistics Barcelona). In addition, different processes are used to obtain the data in both procedures gathering, therefore, different results. Traditionally the number of immigrants in Spain is, due to legal reasons, more accurate in the continuous register, which benefits our study. Altogether, there are 1,491 census units in Barcelona town and 3,478 in the metropolitan region.

Concerning the spatial units, as explained in the previous chapter, the calculations need spatial units within an urban area. In our case we use census units (i.e. census tract), which, according to Spanish electoral law, includes between 500 and 2,000 residents aged over 18. Obviously, the results of the indices are influenced by the unit size since the smaller the units are, the higher is the index value. The Spanish census tract size is an intermediate size between districts and blocks. To define the metropolitan region of Barcelona we used the legal administration division including 164 municipalities (Figure 1a).

In relation to the set up of different population groups, we used the criteria based on the nationality of the individuals as pointed out in the municipality register. The majority, or reference, group in this research are the Spanish nationals. We calculated the indices for all groups representing at least a 3% of the foreigners in Barcelona city. Establishing this value, we covered almost a 70% of the immigrants living in the metropolitan region. Because of the different behaviours in settlement between the nationals of geographically similar countries, we did not aggregate them in wider groups e.g. continents.

To study the global and local spatial autocorrelation, some technical decisions are very important. In our case, the spatial weight matrix is a row standardized matrix with a rook criterion. The variable is the Empirical Bayes rate of the immigrant population proposed by Assunçao and Reis (1999) which uses a variable transformation adjusted for population density. This point is very important in our case because the immigrant distribution has a strong relationship with population density in the census tract[1].

[1] Other technical details are, the software we used is MapInfo by means of an application for the calculation of the indices (Apparicio, 2000) and a scripts application for *ArcView* (Wong and Lee, 2001). The global and local Moran's I and the maps have been elaborated using *Geoda* (Anselin, 2003).

4. Results

The migration situation in Spain differs, as explained in the introduction, from other European countries due to three main reasons: the recent economic development, the historical links with the ancient colonies and the attractive climate and lifestyle of the country. Hence, we can detect a large group of Latin-Americans, a very huge Moroccan community, other European nationals, and finally, Chinese and Pakistanis, who find in Spain allocation for their commercial activities. Other growing immigrant communities are nationals from central Africa, that use Spain as the entrance to the European Union, and nationals from East European countries and the former Soviet Union, a common circumstance in most EU countries.

En general, when we compare the percentage of immigrants between municipalities in the metropolitan region of Barcelona (figure 1a) we find the highest values in Barcelona centre, and in a few municipalities in the northern and southern coast (e.g. Calella, Pineda, Sitges, Castelldefels). Regarding Barcelona municipality (figure 1c), the highest percentages of immigrants are only found in the central part of the town. The numbers are very high, being between a 31% and an 81%, and we might call it a multi ethnic neighbourhood as Amersfoort (1992) proposes. Historically, from 19th century, the centre of Barcelona has been occupied by the poorest working class, living in buildings which need repairs.

According to official information represented in table 1, the city of Barcelona counts with 1,582,738 inhabitants in the year 2003, of who 167,223 are foreigners, representing a 10.5% of the total population. The biggest immigrant communities are the ones from Ecuador (1.72%), Colombia /0.8%), Morocco (0.76%) and Peru (0.71%). The rest of national groups analysed in this paper are the Dominicans, the Italians, the Argentines, the French, the Philippines, the Chinese and the Pakistanis.

In the metropolitan region of Barcelona, the situation is somehow different: the percentage of immigrants is lower, thus, only an 8% of over four and a half million inhabitants is not Spanish. The most important group in this area is the Moroccans with 1.54% of the total population, followed by the Ecuadorians (1.23%).

Table 1. Population of immigrant groups (% of total immigrant population)

	Total Population	Total Immigrant Population	Ecuador	Colombia	Morocco	Peru	Argentina	Pakistan	Italy	Dominican Rep.	France	The Philippines	China
Barcelona Municipality	1,582,738	167,223	16.28	7.59	7.15	6.69	5.83	5.82	4.40	3.65	3.19	3.14	3.12
Barcelona Region	4,615,918	372,330	15.29	6.74	19.03	4.65	5.24	3.44	3.50	2.56	2.79	1.53	3.53

Source: Bureau Statistics Barcelona.

Table 2. Segregation indices and Moran's I for each immigrant group

Immigrant group	Ecuador	Colombia	Morocco	Peru	Argentina	Pakistan	Italy	Dominican Rep.	France	The Philippines	China	Average
Barcelona (n =1.491)												
Index of segregation	0.389	0.351	0.597	0.384	0.353	0.807	0.370	0.579	0.424	0.784	0.599	0.512
Dissimilarity shape modified	0.384	0.348	0.594	0.382	0.351	0.805	0.369	0.577	0.423	0.783	0.598	0.510
Eta-squared	0.018	0.007	0.035	0.007	0.006	0.085	0.004	0.015	0.006	0.074	0.011	0.024
Delta	0.675	0.654	0.745	0.689	0.635	0.879	0.634	0.773	0.633	0.872	0.782	0.724
Absolute Centralization index	0.196	0.291	0.453	0.255	0.358	0.660	0.379	0.393	0.355	0.724	0.388	0.404
Index of absolute clustering	0.017	0.008	0.008	0.007	0.006	0.006	0.005	0.004	0.003	0.003	0.003	0.006
Moran's I	0.249*	0.123*	0.522*	0.209*	0.343*	0.655*	0.497*	0.365*	0.538*	0.620*	0.151*	0.388
RMB (n =3.478)												
Index of segregation	0.464	0.411	0.522	0.536	0.425	0.843	0.463	0.619	0.502	0.845	0.665	0.572
Dissimilarity shape modified	0.463	0.410	0.520	0.535	0.425	0.843	0.463	0.618	0.501	0.845	0.665	0.571
Eta-squared	0.022	0.008	0.040	0.009	0.007	0.073	0.005	0.013	0.007	0.070	0.018	0.024
Delta	0.896	0.865	0.825	0.918	0.845	0.975	0.842	0.926	0.802	0.954	0.945	0.890
Absolute Centralization index	0.823	0.763	0.515	0.886	0.683	0.933	0.737	0.842	0.690	0.945	0.801	0.783
Index of absolute clustering	0.012	0.005	0.015	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.003	0.004
Moran's I	0.431*	0.260*	0.453*	0.402*	0.415*	0.637*	0.546*	0.392*	0.564*	0.626*	0.422*	0.468

*Note: * significance 5% (999 permutations). Contiguity weight matrix. Rook criteria.*

4.1 Segregation indices

Beginning with the evenness measures, we can observe that there is a very small difference between the results of the Segregation Index and the results of the Dissimilarity Shape Modified Index, thus we focus mainly on the second one. In Barcelona, we found the highest values for this measure (table 2) for the Pakistanis with 0.805, the Philippines with 0.783 and the Chinese with 0.598; the lowest level of segregation has been found for the Colombians (0.348), the Argentines (0.351) and the Italians (0.369). The non weighted average is 0.51 representing an outstanding segregation level.

Regarding the exposure measure, in general, we found very low results,the highest corresponding again to the Pakistanis (0.085), followed by the Philippines (0.074) and the Moroccans (0.035). In the Concentration Index, with usually higher results than the Segregation Index, the average segregation level is fitted in 0.724. The national groups range between the highest values for the Pakistanis (0.879), the Philippines (0.872) and the Chinese (0.782), and the lowest ones for the French (0.633), the Italians (0.634) and the Argentines (0.635).

In the centralization index there are two very high results, indicating a more centralised settlement for the Philippines (0.724) and the Chinese (0.66). The less centralised nationalities are the Ecuadorians (0.196) and the Peruvians (0.255). The values for the Index of Absolute Clustering are influenced by the total number of each minority group. Thus, the most segregated results are those for the Ecuadorians (0.017), the Colombians and the Moroccans (0.008 each). The lowest results are those of the French, the Philippines and the Chinese (0.003 each).

The division of values of each index in quartiles allows a first relative classification of most segregated immigrant groups:

- The Philippines and Pakistan: high evenness, exposure, concentration and centralization.
- Morocco: high exposure, clustering and centralization.
- China: high evenness and concentration.
- Ecuador and Colombia: high clustering.

In the metropolitan region we generally found higher values in nearly all dimensions. This is due to the fact that an important part of the groups is living in Barcelona city which implies a natural bias between centre and metropolitan region. In the evenness measures, the most segregated group are the Philippines with a 0.845, followed by the Pakistanis (0.843) and the Chinese (0.665). The Moroccans are the only group with a lower value in the metropolitan region (0.522) than in Barcelona centre (0.597). This result is in accordance with the fact that the Moroccans are more spread in the metropolitan region and not mainly located in Barcelona. Regarding the exposure, the eta-squared index indicates that the Pakistanis are the highest segregated group (0.073) and the Italians the lowest (0.005).

In the centralization index the highest results correspond to the Philippines (0.945), the Pakistanis (0.933) and the Peruvians (0.886). The Moroccans are the less centralised with a value of 0.515. In the clustering measures all the results are lower or equal to the city centre ones, with exception of the Moroccan's (0.015), being the highest of all.

With the same methodology as Barcelona municipality, we can establish an order for the minority groups in the Barcelona Region case:

- Pakistan and the Philippines: high evenness, exposure, concentration and centralization.
- China: high evenness and concentration.
- Morocco: high clustering and exposure.
- Ecuador and Colombia: high clustering.

After these results, we can see that the non spatial and spatial measures of residential segregation are useful for describing the situation in separation terms between the Spanish community and the immigrant population. However, to describe the localization patterns we need more details. In this sense it is possible to combine these measures with local measures of local autocorrelation. We present the cluster map with high-high and high-low situations, hot spots and outlier situations, in black, in the Moran Scatter Map (Figure 2). From the planning point of view (e.g. localization of social assistance) it is clear that these situations are the most important.

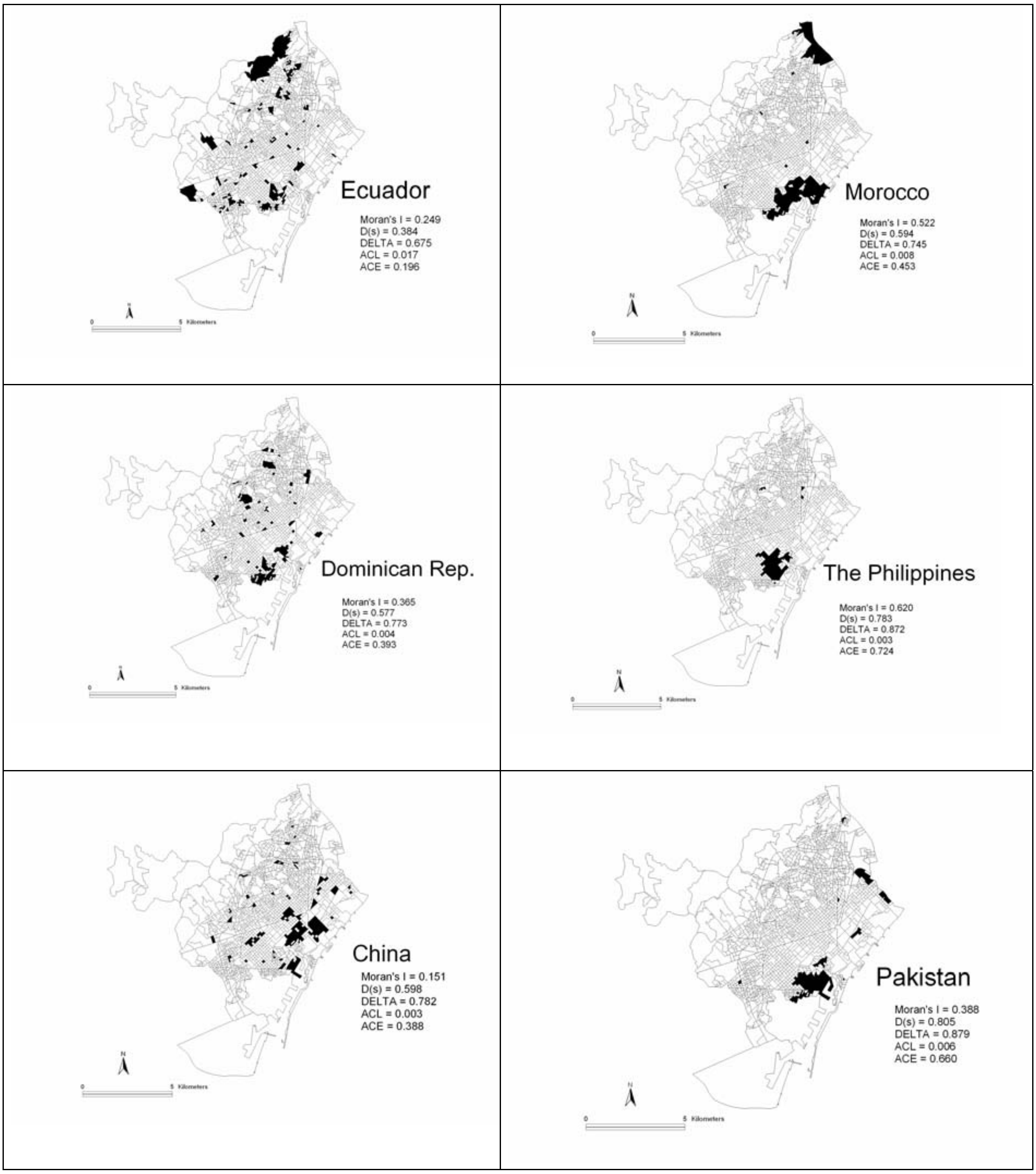

Figure 2. Cluster maps for more segregated groups. Only high-high and high-low situations. Significance 5% (999 permutations). Contiguity weight matrix. Rook criteria

At a first glance the Ecuadorians, the Dominicans and the Chinese present a more diffuse situation than the Moroccans, the Philippines and the Pakistanis that have a more clustered distribution. The situation of the Philippines can be described as follows: the significant areas are situated in the intersection between the central district *Ciutat Vella*, *Sants* and *L'Eixample*, all of them with a higher percentage of immigrants than the average. The Moroccans share some of these areas but they also spread to the eastern part of the central district and, at the same time, a few units can be found in the northern part of the district *Nou Barris,* which is one of the outer suburbs of the town with blocks of flats. Regarding the situation of the Pakistanis, we find the same concentration of significant units in the central part, but some spread units in the east, corresponding to the district *Sant Martí*.

In the other cases, the more spread ones, we find small clusters for the Ecuadorians in different areas all over the town. The Dominicans represent very spread high-high and high-low areas in the municipality, with some important clusters in the western part of the central district. Finally, for the Chinese we detect different distributed significant areas in nearly all district, but not in the outer suburbs, with a concentration in the central district and the middle central district.

Additional information can be obtained calculating the percentage of individuals of each group living in this hot spots and outlier situation. There are two groups that concentrate more than 60% of its population in these units: the Philippines (62.76%) and the Pakistanis (60.52%); the other group with high percentage is the Moroccans with 48.64%. In this sense we can establish a relationship between the results for the segregation indices and these proportions. Nevertheless, it is not so evident in the other cases, for example with the Dominicans (35.05%). In the case of the Ecuadorians and the Chinese the figures are especially different 17.63% and 19.82%.

4.2. Exploring the relationships between segregation indices and global spatial association measures

Segregation measures and spatial autocorrelation statistics are useful to describe a situation of immigrant minorities and, possibly, some relationship between them. These relationships can be clearer for spatial segregation measures because they incorporate spatial weight matrix and other spatial elements (e.g. longitude of the border between different areas). This situation suggests a question about the possible linear relationship between these two types of measures.

Exploring the correlation matrix between all segregation measures applied in this paper and the Moran's I, the response is that the relationship only exists in four cases. The correlation

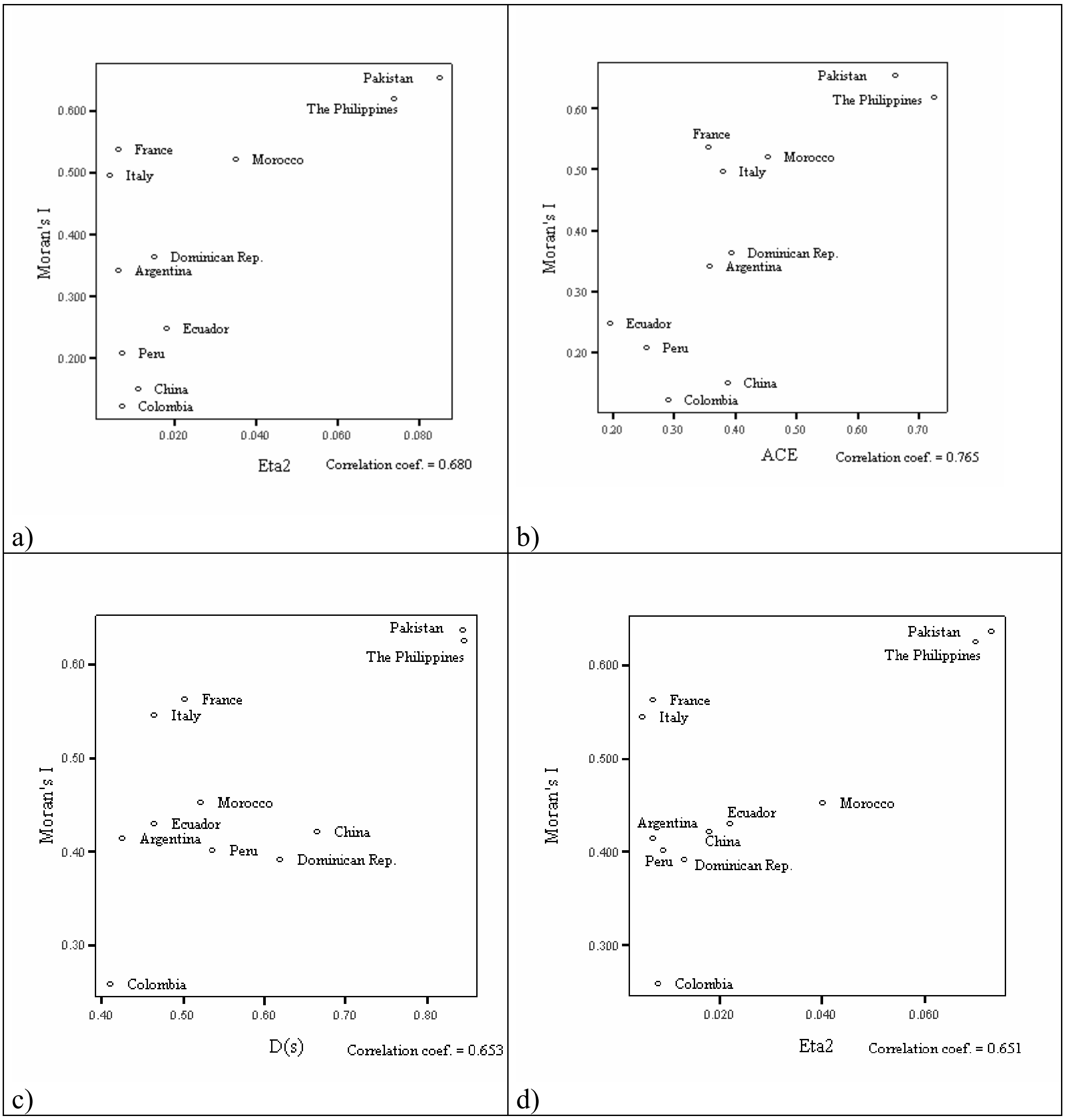

Figure 3. Scatter plots between segregation measures and Moran's I, only significant correlation coefficients.

coefficient with the Moran's I is only significant for Exposure and Centralization indices for the Barcelona case and Dissimilarity shape modified and Exposure indices in the Barcelona Region case (Figure 3). With these results it is not clear the relationship between segregation and spatial autocorrelation measures. Only in the case of the Exposure Index, the linear relationship is clearer. With these poor results we can not discard that the linear correlation between these two types of measures are spurious.

5. Summary and conclusions

In this paper we present a combined strategy to find out localization patterns of population groups (i.e. immigrant minorities) in an urban area. This approach includes non spatial and spatial measures of residential segregation and spatial autocorrelation statistics. As it is shown, the case of Barcelona Region presents a different situation from other populated cities in Europe because of the fast growth of immigrant population and the diversity of origins. It is the first study of south European urban area, while in North America and other European countries there is a large tradition of research on this topic.

The most segregated groups are Pakistanis and Philippines with relative high level segregation in four dimensions, in both cases, the Barcelona municipality and its region. At the same time, these groups exhibit the highest values for Moran's I, although the correlation analyses are not conclusive.

By means of LISA indicators and its cluster map we found that the localization patterns are diverse and we find out two opposite situations: dispersed and concentred. Therefore, the spatial autocorrelation statistics are useful to detect areas with the need for social assistance for immigrant groups.

Regarding the statistical relationship between segregation indices and spatial autocorrelation measures, the results suggest the need of more case studies and simulation experiments.

References

Amersfoort, H. van (1992), Ethnic Residential Patterns in a Welfare State: lessons from Amsterdam 1970-1990. *New Community* 18, pp. 439-456.

Anselin, L. (1988), *Spatial Econometrics: Methods and Models.* Boston, MA: Kluwer Academic.

Anselin, L. (1995), Local Indicators of Spatial Association-LISA. *Geographical Analysis* 27, pp. 93-115.

Anselin, L. (2003). GeoDa 0.9 User's Guide. Spatial Analysis Laboratory, University of Illinos, Urbana-Champaign, IL.

Apparicio, P. (2000), Residential Segregation Indices: A Tool Integrated into Geographical Information System. *European Journal of Geography* 134, pp. 1-19.

Assunçao, R.M. and Reis, E.A. (1999), A New Proposal to adjust Moran's I for Population Density. *Statistics in medicine* 18, pp. 2147-2162.

Bell, W. (1954) A Probability Model for the Measurement of Ecological Segregation. *American Sociological Review* 32, pp. 357-364.

Cortese, C.F., Falk, F.R., Cohen, J.K. (1976), Further Considerations of the Methodological Analysis of Segregation Indices. *American Sociological Review* 41, pp. 630-637.

Duncan, O.D. and Duncan, B. (1955a), A Methodological Analysis of Segregation Indexes. *American Sociological Review*. 41, pp. 210-217.

Duncan, O.D. and Duncan, B. (1955b), Residential Distribution and Occupational Stratification. *American Journal of Sociology* 60, pp. 493-503.

Duncan, O.D., Cuzzoert, R.P. and Duncan, B. (1961), *Statistical geography. Problems in analyzing areal data.* Glencoe, Illinois: The free press of Glencoe.

Friedrichs, J. (1998), Ethnic Segregation in Cologne, Germany 1984-94. *Urban Studies*.35, pp.1745-1763.

Giffinger, R. (1998), Segregation in Vienna: Impacts of Market Barriers and Rent Regulations. *Urban Studies*. 35, pp. 1791-1812.

Kemper, F-J. (1998), Restructuring of Housing and Ethnic Segregation: Recent Developments in Berlin. *Urban Studies* 35, pp. 1765-1789.

Martori, J. C. and Hoberg, K. (2004), Indicadores Cuantitativos de Segregación Residencial. El caso de la Población Inmigrante en Barcelona. *Geo Crítica / Scripta Nova. Revista electrónica de geografía y ciencias sociales* 8. http://www.ub.es/geocrit/sn/sn-169.htm

Massey, D. S. and Denton, N. A. (1988), The Dimensions of Residential Segregation. *Social Forces* 67, pp. 281-315.

Moran, P.A.P. (1948), The Interpretation of Statistical Maps. *Journal of the Royal Statistical society. Series B* 10, pp. 243-251.

Morrill, R. L. (1991), On the Measure of Geographical Segregation. *Geography Research Forum* 11, pp. 25-36.

Morrill, R. L. (1995), Racial Segregation and Class in a Liberal Metropolis. *Geographical Analysis* 27, pp. 22-41.

Musterd, S. and Deurloo, R. (2002), Unstable Immigrant Concentrations in Amsterdam: Spatial Segregation and Integration of Newcomers. *Housing Studies* 17, pp. 487-503.

Peach, C. (1998), South Asian and Caribbean Ethnic Minority Housing Choice in Britain. *Urban Studies* 35, pp.1657-1702.

Stearns, L.B. and Logan, J.R. (1986), Measuring Trends in Segregation: Three Dimensions, Three Measures. *Urban affairs quarterly* 22, pp. 124-150.

White, M. J. (1986), Segregation and Diversity Measures in Population Distribution. *Population Index* 52, pp. 198-221.

Wong, D .W. S. (1993), Spatial Indices of Segregation. *Urban Studies* 30, pp. 559-572.

Wong, D. W. S. (1999) Geostatistics as Measures of Spatial Segregation. *Urban Geography* 20, pp. 635-647.

Wong, D.W.S. and Lee, J. (2001) *Statistical Analysis with Arc View GIS*, New York: John Wiley & Sons.