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LOCATION QUOTIENT AS A LOCAL INDEX OF RESIDENTIAL SEGREGATION. THEORETICAL AND APPLIED ASPECTS[1]

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1. Introduction

The location quotient (LQ), a ratio of ratios, is a widely known geographic index (Isard, 1960). It is used to measure and map relative distributions or relative concentrations of a character in a subarea compared to the area as a whole (Wheeler, 2005). Originally adopted in regional economic studies (Crawley *et al.*, 2013), recently it has been proposed as a local index in studies of residential segregation of foreign population (Apparicio *et al.*, 2008; Iglesias-Pascual *et al.*, 2019). In this field of studies, the LQs are particularly useful when applied to a metropolitan area where they allow to identify the spatial units in which a population group is under-represented (LQ<1) or conversely, over-represented (LQ>1). Despite their apparent simplicity, the location quotients present some slippery features this contribution tries to reflect on. The caveats refer principally to the choice of the reference population, the distribution cut-offs for maps and comments, and their aspatial nature.

This paper examines some different ways to compute the LQs and their results, by using data on residents by citizenship in the metropolitan area of Milan. Stocks of the annual resident population on 1st January 2020, provided by the Statistical Municipality Office of the city and by Istat, are broken down by municipality and sub-municipal areas. Therefore, we analyse and compare the statistical distributions of the LQs of selected foreign population's groups, obtained with the aforementioned approaches. Finally, we propose an alternative measure, the Locational Differential Index (LDI), to take account of density, conveying the spatial component, absent in location quotients (Bressan *et al.*, 2008).

[1] All authors contributed to conceive the idea and develop the application. In particular, F. Benassi wrote Sections 1 and 2, S.M.L. Rimoldi wrote Sections 3 and 4, and M. Crisci wrote Sections 5 and 6.

2. Residential segregation: concept and measures

The concept of residential segregation generally is used to indicate the spatial separation of two or more groups of a population within a given spatial environment, most frequently an urban context (Feitosa *et al.*, 2007).

This general definition evokes a multidimensional process that found in literature various attempt to measure it, applied to various phenomena. It should be noticed that no consensus has been found among scholars about which is the optimal index, although some requisites seem to be necessary: 1) it must not be distorted by the relative size of the minority group in the population as a whole; 2) it must not depend on the overall size of the population and of the area; 3) it must not depend on the number of sub-areas into which the overall area is divided; 4) it must be standardizable, so as to vary between 0 and 1, where 0 indicates the situation in which in each sub-area the ratio between the groups is the same as that observed for the whole region, and 1 corresponds to the situation in which the groups are clearly separated in the sub-areas; 5) it must be sensible to the movement of one or more units from one sub-area to another; 6) it must be invariant to scale transformations in the composition (i.e. either an increase in the absolute level of a particular group in all sub-areas, or an increase in the absolute level of all groups in a particular sub-area).

According to Massey and Denton (1988), the segregation indices can be classified into the categories illustrated in Table 1, according to the dimension they aim to capture.

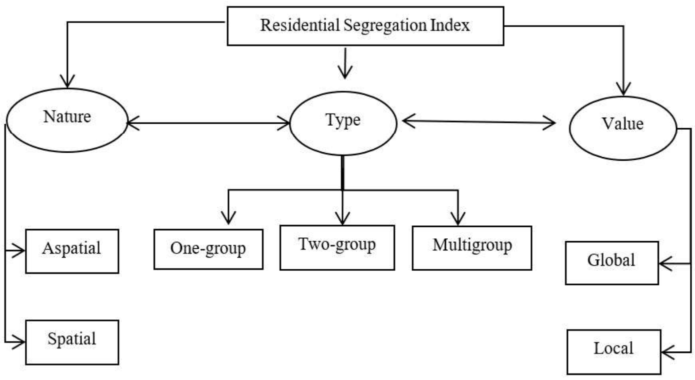
Then, segregation indices can be classified by their essential features (Figure 1): type (one-group, two-group, multigroup), nature (either spatial or aspatial), and value (local or global). According to their type, the one-group indices measure the distribution of a population group compared to the total population, while the two-group indices compare the distribution of two different population groups, and finally, the multigroup indices analyse the distribution of several population groups simultaneously. Considering their nature, aspatial indices are independent from the spatial information about location (shape and/or size of spatial sub-units, and their contiguity), while, on the opposite, spatial indices are based on the spatial setting of sub-units. Finally, as far as their value is concerned, global measures provide a summary value for the area as a whole, while the local measures provide one value for each of the spatial sub-units of the area.

Table 1 – *Dimensions of segregation.*

Dimension	Description
Evenness	Evenness represents the distribution of groups across the spatial sub-units of an area. Evenness indices measure a group's over or under-representation in each spatial sub-unit: the more unevenly a group is distributed across these spatial sub-units, the more segregated it is.
Exposure	Exposure is the degree of potential contact between members of the same group or between members of two groups inside the spatial sub-units. It measures the probability that members of one group will encounter members of their own group (isolation) or another group (interaction) in their spatial unit. Isolation and interaction are complementary: the least isolation (i.e., the highest interaction) means the least segregation.
Concentration	Concentration refers to the physical space occupied by a group. The less of the area a group occupies, the more concentrated it is. According to Massey and Denton (1988), segregated minorities generally occupy a small portion of the area.
Clustering	Clustering refers to another spatial feature, contiguity. The more contiguous spatial sub-units a group occupies -thereby forming an enclave within the overall area- the more clustered and therefore segregated it is.
Centralization	Centralization indices measure the degree to which a group is located in or near the center of the area, which is typically the central business district in a metropolitan area. The closer a group is to the city center, the more centralized and thus segregated it is.

Source: adapted from Martori and Apparicio (2011).

Figure 1 – *Segregation measures by their essential features.*



Source: adapted from Benassi et al. (2016).

Then, by considering in the meantime the two classifications introduced above (by dimensions and by nature), a tentative (not exhaustive) list of the most used indices of segregation has been suggested by Apparicio *et al.* (2008). Here, the

Location Quotients are classified as 'local' indices of segregation but they are not associated to a specific dimension of residential segregation.

3. Location Quotient and residential segregation

Local Quotient (LQ) is a widely known geographic index founded on the work of Walter Isard (1960) that is considered the father of regional science. It is used to measure and map relative distributions or relative concentrations of a character in a subarea compared to the area as a whole (Wheeler, 2005). Originally adopted in regional economic studies (Isard, 1960; Crawley *et al.*, 2013), more recently it has been proposed as a local index in the study of residential segregation of foreign population (Apparicio *et al.*, 2008; Brown and Chung, 2006).

There are different ways to compute LQ. With reference to residential segregation, we initially refer to the definition proposed by Apparicio *et al.* (2014):

$$LQ_i = \frac{x_i/t_i}{X/T} \qquad i = 1, \dots, n \tag{1}$$

given i the spatial sub-unit of the area, x_i the population of group X in spatial sub-unit i, t_i the total population in spatial sub-unit i, X the population of group X in the overall area, T the total population in the overall area. According to the formula (1), LQ points to evaluate the geographic dimension of the index, answering the question "where group X is over/under-represented compared to the average".

However, the (1) can be simply transformed into:

$$LQ_i = \frac{x_i/t_i}{X/T} = \frac{x_i}{t_i} \cdot \frac{T}{X} = \frac{x_i/X}{t_i/T} \tag{2}$$

which aspires to evaluate the pattern of group X, answering the question "how group X behaves compared to the overall population". According to both (1) and (2), LQ appears to measure the dimension of evenness, in segregation.

Indeed, despite their apparent simplicity, the location quotients present some other slippery features. These caveats concern principally the identification of the reference population, their distributions' cut-offs (paying attention to the absence of an upper limit of the LQ) and, accordingly, the way of mapping and commenting on them, all aspects that become crucial in studying residential segregation.

As far as the first caveat is concerned, that is the reference population, it should be observed that traditionally, segregation indices are based on the "spatial assimilation theory" (Massey and Denton, 1988; Massey, 1985) , which extends the concept of assimilation to spatial behaviour (i.e., spatially segregated ethnic groups as far as they become culturally, socially and economically assimilated to the majority group, they tend to spread out in the city).

In the case of LQ we can follow several approaches with fascinating implications. First, by assuming that the population is divided into two groups, X (foreigners), and

Y (Italians), the LQ aims at evaluating the pattern of X (minority group) in comparison to Y (majority group); it becomes a two-groups index in the dimension of evenness. Second, when groups are more than two, considering the foreign population as a pseudo-total population, the LQ of a particular subgroup X of foreigners is a one-group index that tell us which spatial units i the group X is over/under-represented compared to total foreign population. Finally, we can compare group X to total population but X; this way to calculate the LQ removes the redundancy of group X in calculating the average pattern of total population, and this is particularly important when dealing with sizeable groups. To summarise, LQ can be viewed as a mono or two -groups measure of residential segregation; it is a local measure, but aspatial; LQ has no upper limit in each kind of computation; in the study of residential segregation, LQ's interpretation (referring to spatial assimilation theory) can be ambiguous.

To illustrate the caveats partially faced by some scholars (Crawley *et al*., 2013), and to deepen the LQ distributions' cut-offs and the way of mapping and commenting on them, we use the case study of the Metropolitan area of Milan, in the next section.

4. Case study: The Milan Metropolitan Area

The geographical data refer to the Milan Metropolitan Area (MMA), including the city of Milan and the municipalities of the provinces of Milan and Monza-Brianza: the city of Milan is divided in 88 sub-areas, the NILs (*Nuclei di Identità Locale*), while the rest of the area is considered at municipality level, for a total of 187 units. To highlight differences in the spatial patterns, the MMA is split into five areas, as a result of an aggregation of NIL and municipalities: two areas inside the municipality of Milan (the City center and the Rest of the city); and three areas outside the city of Milan (the hinterland), including the other municipalities of the MMA (the First belt, the Second belt and the Rest of the Metropolitan area). We consider the resident population by country of origin at 1.1.2020; data come from the population register (*Anagrafe*) and Istat. To illustrate the LQs, we identified the two sub-population of Romanians (69,051 individuals) and Chinese (49,006 individuals), the first showing a dispersal pattern outside the city center, the second showing a sparsely clustered pattern.

Figure 2 – *Location quotients of Romanians in the MMA (1.1.2020), by different reference population.*

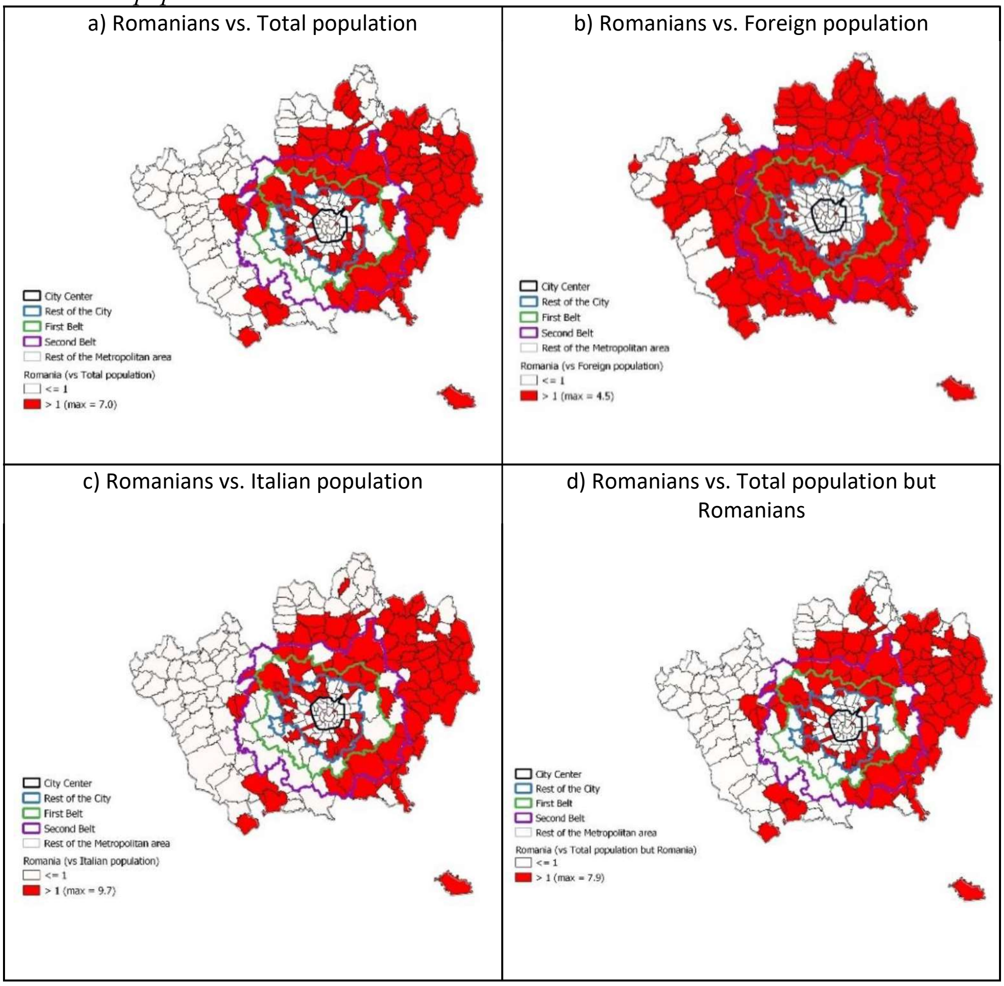
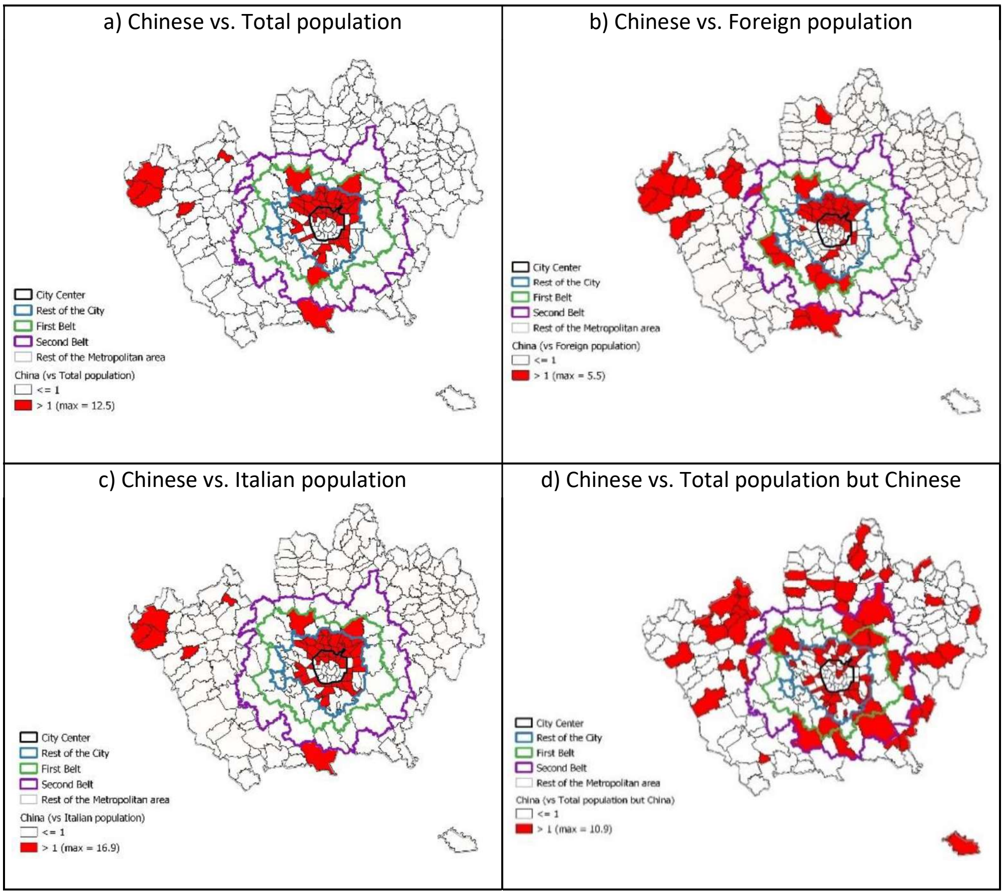


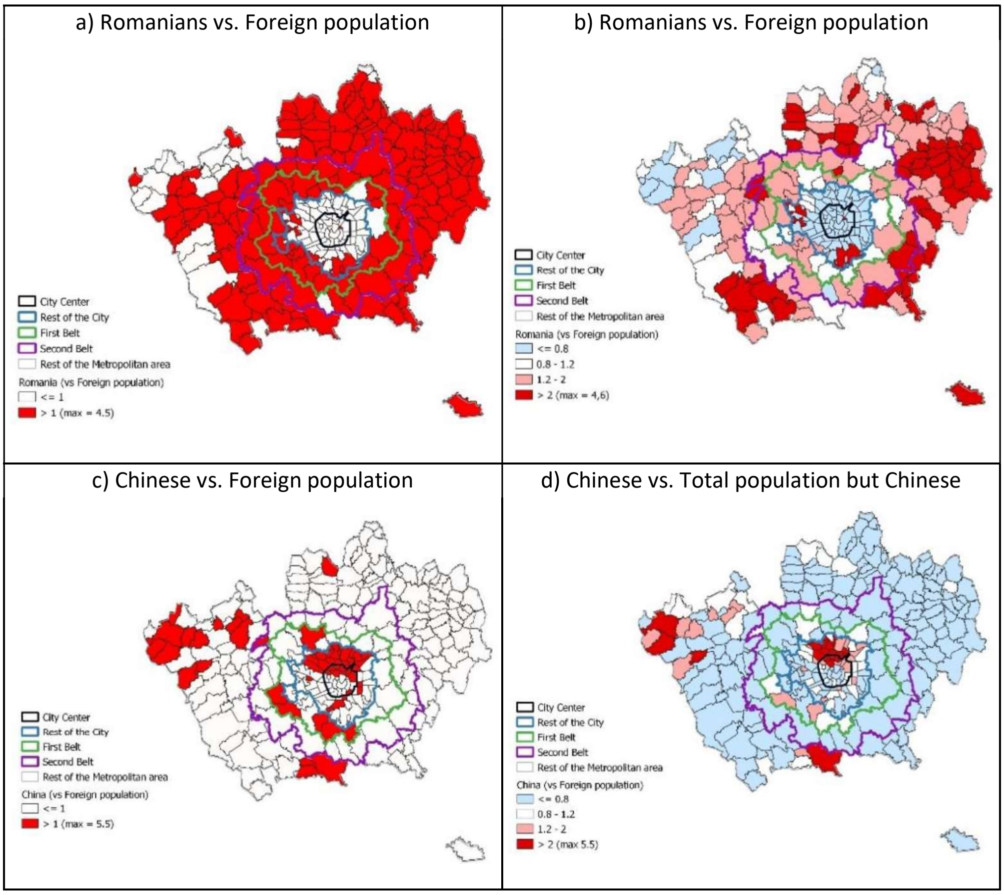
Figure 2 clearly shows how changing the reference population leads to different interpretations of the phenomenon. Notice the negligible differences between figures (a), (c), and (d), due to the relevant size of the majority group (Italians) compared to the size of Romanians; this circumstance is not very frequent, see, for example, the traditional segregation studies concerning the US population that analyse ethnic segregation of large groups like Blacks or Hispanics versus Whites. Therefore, limiting the attention to Figure 2 (a) and (b), we can conclude that Romanians' residential pattern concentrates outside the city centre and in the north-eastern and southern parts of the metropolitan area, when compared to total population, while it emerges that, compared to foreign population, Romanians show a diffusive residential behaviour outside the city centre.

Figure 3 – *Location quotients of Chinese in the MMA (1.1.2020), by different reference population.*



From Figure 3, differences in interpretation of LQs are more expressive. In particular, the residential pattern of Chinese compared to the total population but China (d), lets emerge a more diffusive behaviour, although visibly clustered (in part also in the city centre), and shows that what is relevant is the difference with the Italians (c).

Figure 4 – *Location quotients of Romanians and Chinese in the MMA (1.1.2020), by different cut-offs.*



Up to now we have just scraped the slipperiness of the information potential of LQs. We have, in fact, only discriminated between the under-representation (LQ < 1) and the over-representation (LQ > 1), where LQ = 1 represents the condition of evenness. Indeed, we can assume that evenness is achieved in a range of values "fairly" close to 1, and we can be interested to let emerge those situations where the group appears remarkably over-represented. Notice that here the interest is more focused on "where".

Taking as an example the LQs of Figures 2 (b) and 3 (b) (reference: foreign population), Figure 4 illustrates how the picture (and interpretation) changes, by adopting different cut-offs of the LQ's distribution. More specifically, it has been compared a binary LQs representation (LQ <= 1 or LQ > 1) and a LQs representation with four cut-offs: <= 0.8, indicating under-representation; 0.8-1.2, indicating evenness; 1.2-2, indicating over-representation; >2, indicating relevant over-representation. For example, Figure 4 (b) reveals that Romanians tend to concentrate at the borders of the Metropolitan area, especially in a cluster of municipalities in the eastern part of the metropolitan area, while the under-representation of Chinese is largely diffused in the three areas of the MMA hinterland and the Southern part of Milan municipality. Therefore, the adoption of a cut-offs scale that remarks the groups' over-representation suggests the interpretation of the LQ as a concentration index (although aspatial), rather than an evenness index. Remarkable groups' over-representation in some sub-units suggests the interpretation of LQ as concentration index, although in an aspatial form.

5. A proposal to account for population density

Local measures are always affected by problems of robustness, that is the extreme variability due to small or even rare populations in local contexts. In fact, a low density in a certain sub-unit of an area can amplify the relative presence of a certain group of a population, even though the size of the group in that sub-unit is modest or even irrelevant. Therefore, to control for density, we advance the proposal of the Locational Differential Index (LDI) (Bressan *et al.*, 2008), as follows.

Given P_i^K the population of group K in the sub-unit i, $P_i^{\overline{K}}$ the whole population but K in sub-unit i, P^K the population of K in the whole area, $P^{\overline{K}}$ the whole population but K in the whole area, and the d_i the total population density ($d_i = P_i/A_i$, with A_i the surface area of i), then:

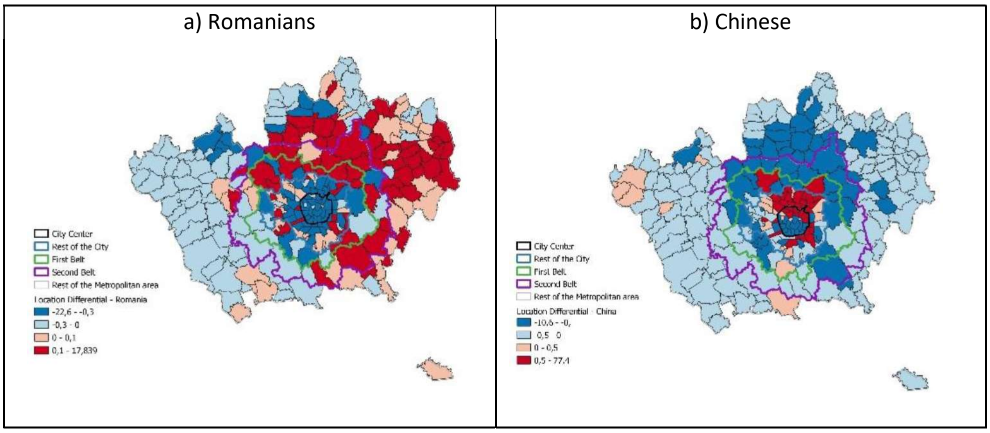
$$LD_i^K = 100 \cdot \left(\frac{P_i^K}{P^K} - \frac{P_i^{\overline{K}}}{P^{\overline{K}}}\right) \cdot d_i \qquad (3)$$

with $-\infty \leq LD_i^K \leq +\infty$.

Notice that LDI compares the share of each group in sub-unit i to the share of the rest of the population, weighting for density.

The introduction of density can change a lot the picture of a group distribution over an area. To visualise the effect, we recall the example presented in previous section (Figure 5).

Figure 5 – *Locational differentials of Romanians and Chinese in the MMA (1.1.2020).*



Notice that, accounting for population density, Romanians result more concentrated in some north-eastern municipalities (namely Monza and nearby) where the LQ indicated under-representation. Chinese result strongly over-represented only in the municipality of Milan, above all in some Northern and Southern neighbourhoods.

6. Conclusions

According to literature (Massey and Denton, 1988; Apparicio *et al.*, 2008), LQ can be viewed as a one or two -groups measure of residential segregation; it is a local measure, but aspatial; LQ has no upper limit in each kind of computation.

Moreover, LQ is a local but aspatial index, computed as a ratio of ratios; in the research strand of residential segregation, it can be related to different dimensions (evenness and concentration), producing a different kind of index (one or two groups).

LQ can be very difficult to map and interpret because it has no upper limit; empirical applications conducted on the Milan Metropolitan Area have shown how, in the field of (urban) residential segregation, the interpretation of maps ambiguously depends on the cut-offs scale adopted.

Finally, the absence of a spatial feature enhances ambiguous interpretation.

Provisional results of our ongoing research on the LQ's upper limit make us trust in the possibility of identifying an empirical maximum; this will be the object of our next study.

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SUMMARY

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