5-3-2016

Measuring Segregation Patterns and Change: a Co-Location Quotient Approach

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Recommended Citation

Vorotyntseva, Natalia, "Measuring Segregation Patterns and Change: a Co-Location Quotient Approach" (2016). *Doctoral Dissertations*. 1066.
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a Co-Location Quotient Approach

Natalia Vorotyntseva, Ph. D.

University of Connecticut, 2016

There are many segregation measures introduced and utilized in geographic research up to this date. Because residential segregation can be defined in more than one way the measure's formulation is dependent on the particular definition the researcher is trying to reflect. Another distinctive feature of the quantitative exploration of segregation is the role of geographic scale. In contrast, global indices focus on overall level of spatial separation of population in the urban area while local indices assume that the index magnitude varies from place to place across the city. The main purpose of this study is to introduce a new measure of segregation that focuses on the lack of interactions of the population groups and to explore its properties.

The proposed measure is a modified co-location quotient (CLQ) that was originally applied to point data as a measure of spatial association between two categorical variables. The first part of this dissertation introduces two versions of modified CLQ that are applicable to categories of areally aggregated population. One is the global measure that captures the overall exposure of one population group given the presence of another group. The local version of the measure describes levels of exposure for every single spatial unit. Both, global and local quotients have two basic specifications – two-group CLQ and same-group CLQ. Each variant of the measure allows the option to include the neighborhood size in computation, which theoretically defines the space within which people have the possibility for interaction.

The use of CLQ in the proposed mathematical configuration expands the discussion of dimensions of segregation by suggesting the connection between different dimensions that are covered by co-location measure. Using publicly available data from U.S. Census Bureau on racial composition of population CLQs were computed for thirty urban areas, where twenty nine are metro areas and one is Washington

D.C. The basic units of analysis are census tracts and block groups that contain aggregated population counts. Three decennial releases are used: 1990, 2000 and 2010.

The results suggest an overall, but uneven, increase in the exposure of white people in given urban areas. Patterns of concentration for white people remained stable over the time span. But the concentration of black people shows a substantial decrease indicating an increasing exposure of blacks in the global sense. Conversely, same-group CLQs for whites and for blacks indicate unequal experiences for these two population groups in America.

Additionally, various visualization techniques related to co-location measure were explored. The pointillist approach, suggested in this study, is found to be particularly effective technique for displaying CLQ results compared to widely utilized choropleth mapping.

Measuring Segregation Patterns and Change:
A Co-Location Quotient Approach

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A Dissertation

Submitted in partial Fulfillment of the

Requirements for the Degree of

Doctor of Philosophy

at the

University of Connecticut

2016

APPROVAL PAGE

Doctor of Philosophy Dissertation

Measuring Segregation Patterns and Change:
A Co-Location Quotient Approach

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ACKNOWLEDGEMENTS

I must express my deepest gratitude first and foremost to my advisor, Robert Cromley without whom this project would not have been possible. His consistent and encouraging guidance from the very beginning of my graduate studies has led to successful completion of every step of this dissertation. I would also like to thank my committee members Daniel Civco, Chuanrong Zhang and Dean Hanink who were my teachers in various classes and whose subject expertise was extremely helpful to me throughout the entire process.

The Department of Geography at the University of Connecticut, including my fellow graduate students, faculty members and staff members, created an excellent environment which I truly enjoyed while pursuing my research and learning about the field of Geography from multiple perspectives.

I would also like to thank my family and friends for their active support during my ups and downs as a graduate student. I truly appreciate my parents for the frequent conversations that made the long physical distance between us seem to disappear. My friends have supplied me with a great deal of optimism and positive energy that I carried through my work.

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CHAPTER ONE

Introduction

1.1 Residential Segregation in the United States

The residential segregation can be defined as the degree to which two or more population groups reside in separate neighborhoods within the urban setting. The residential segregation studied in this dissertation considers the locational split of population based on racial characteristics. In the United States, a special role is given to the segregation pattern of blacks as a consequence of the historic treatment of African-Americans. The abolition of slavery was legally transferred to segregation laws that posed unequal access of blacks to public goods and services (Frazier and Margai, 2003). After segregation laws and any kind of racial and ethnic discrimination were finally prohibited by the Civil Rights Act of 1964, the phenomenon of segregation persisted in the American society for decades to come.

The importance of studying the residential segregation can be understood through the examination of its consequences, most often having negative effects on the socioeconomic situation in the segregated neighborhoods. However, the consideration of the outcomes is incomplete without a closer look at the factors that stimulate the tendency of society members to reside in different parts of the city based on their racial and ethnic origin. Although interrelated, there are four prevalent factors that are attributed to cause and hold the state of residential segregation in the society. They include prejudice and discrimination, income inequality, stereotypical thinking and self-segregation (Allen and Turner, 2011). Except for the self-segregation which sometimes can stimulate the development of lively economy in the neighborhood, the other three mentioned causes drive the local socioeconomic conditions to poverty, joblessness, high crime rates and deteriorated moral behaviors.

It is important to note that when segregation is considered in terms of the place of residence, it is called residential segregation. Residential location is a primary source of information about people’s quality of life such as the accessibility of the goods and services, their type and quality, educational attainment opportunities, employment, housing options, health risks, level of crime residents are exposed to and general socioeconomic status (Massey and Denton, 1985). In conclusion, the residential segregation of minorities is a consequence of not just a history of the United States, but mainly a result of the ongoing economic trends and public policy decisions. Residential segregation aggravates the socioeconomic appearance of cities and the society as a whole.

1.2 Problematic Character of Studying Residential Segregation

The negative outcomes that emerge from segregation pose the need of employing the analytical tools and methods to estimate accurately and adequately the extent of the phenomena within geographic areas and its relative importance in shaping the socioeconomic conditions of the areas under investigation. A comprehensive analysis of segregation has been traditionally realized through computing index values for geographic areas of interest. The ways to measure the level of the phenomena are based on the information about the population composition residing within neighborhoods and the assumption regarding how the population is supposed to be represented in the area in case of the absence or presence of segregation. As was noted by White (1983), defining the extent of segregation spatially does not assure the same level of limited social interactions between social groups. Arguments for and against usage of specific indices stem from at least two different sources.

First, there is a discussion on how residential segregation is physically defined. Massey and Denton (1988) identified five different dimensions of segregation. One of the dimensions is evenness which defines over- and underrepresentation of population groups across the urban area. Another dimension is exposure which refers to the amount of the potential interaction between the social groups within an urban environment. The dimension of concentration is defined in terms of the space occupied by the majority or minority members relative to their population size. Following this definition, the population group is concentrated if it occupies a smaller area compared to another group. A similar notion informs the dimension of centralization, but here the focus is on the tendency of population group to occupy central city areas. The fifth dimension is clustering, defined as a tendency to form contiguous areas containing minority population groups. Thus, according to Massey and Denton, segregation is a complicated social process that should be studied using all five defined “axes”. Although their ideas have been revised, the discussion on the dimensional nature of segregation has persisted (Reardon and Firebaugh, 2002).

In parallel with the discussion on the dimensions of segregation and properties of the measures, the question of using global versus local methods has been widely discussed. Until recently, the study of segregation has been dominated by global measures. In general, global methods were the primary quantitative approach the scientists were using and developing until GIS era introduced the opportunity to process large data sets in a much more easily manageable way. Local methods are proposed as an alternative, in which the measure is based on a subset of observations in the data set. Overall, local segregation measures aim to increase the informative value of the measure by evaluating its spatial variability and enlarge the geographic scale of observation of the social phenomena.

Even though the problem of measuring the level of residential segregation has been addressed from different perspectives for more than half a century, several fundamental problems still persist. One issue is that the multidimensional nature of segregation complicates the development of new measures, since any measure assigned to one dimension has to be in the set of other measures capturing the rest of the defined dimensions. At the same time, one of the promising ongoing research trends in Geography is the spatial interaction approach, which appears to be one of the factors that produce the spatial pattern observed at some point in time. The view of residential segregation as an idea about the lack of potential interactions between population groups has not been sufficiently explored, and as a rule is attributed to the exposure dimension. One of the problems that this dissertation will investigate is the incorporation of the spatial interaction approach into measuring the levels of residential segregation.

Another question that merits further investigation is the local character of segregation. The ability to characterize the degree of spatial variation of the phenomenon within the urban area, to identify the areas of high and low levels of potential interactions between population groups, can provide insight into the nature and possible causes of segregation in a given urban setting. Local spatial statistics techniques are gaining popularity within the scientific community as effective in reaching a larger scale when exploring the phenomenon throughout the spatial domain of the territory.

This dissertation will approach the problem of measuring segregation by introducing the co-location quotient as another method of inquiring about the spatial distribution of population by their racial or ethnic categories. The investigation into the use of co-location quotients for analyzing segregation patterns is outlined in the next section.

1.2 Dissertation outline

Following the introduction section, Chapter Two will provide the overview of the literature related to the measurements of residential segregation focusing on main trends in the analysis of the phenomenon.

Chapter Three will describe the data used for the analysis and the methods that will be employed in this dissertation to identify the levels of residential segregation. The study area consists of major US Metropolitan areas and territory of Washington, D.C. defined by Census Bureau in 1990 census. Metropolitan areas are split by finer areal units – census tracts at one scale, and block groups at another. The method that is introduced and discussed with respect to the analysis of segregation is the co-location quotient approach.

Chapter Four will focus on computing of introduced global co-location quotient. Levels of residential segregation will be computed and contrasted for selected metropolitan areas.

Global quotient is a summary statistic that provides the estimation of segregation on average across the urban extent.

Chapter Five will be designed to employ local version of co-location quotient to demonstrate the application of local index compared with its global counterpart and also to compare the general use of global and local measures.

Chapter Six will pay attention to cartographic visualization of the segregation measures. The question of mapping segregation indices is attributed mostly to local statistics. The chapter will demonstrate the examples of alternative display that can be more widely employed for mapping of segregation.

Finally, Chapter Seven will present the results of the analysis, followed by summary of the major findings in the current work. Based on the findings, conclusions will be made. The discussion will include challenging questions pertaining the topic of residential segregation and the problem of its measurement and visualization.

CHAPTER TWO

Literature Review

2.1 Overview of the Socioeconomic Conditions Underlying Residential Segregation

The United States has a long history of contested racial and ethnic relations. A special role is given to the segregation pattern of blacks as a consequence of historic treatment of African-Americans. Even after the abolishment of slavery, segregation laws were enacted that gave African-Americans unequal access to the public goods and services such as education and employment (Frazier and Margai, 2003). Even after segregation laws involving any kind of racial and ethnic discrimination were finally prohibited by the Civil Rights Act of 1964, the phenomena of segregation persisted in the mind and geography of the American population, and was maintained by ongoing changes in society from decade to decade.

Allen and Turner (2011) provide four causes of the emergence and persistence of segregation in American society (see also Figure 1). First, is the consequence of prejudice and discrimination that affect the views of the majority group members. This includes the “racial threat” hypothesis, where the majority group tends to utilize various regulations in order to limit the minority members’ rights in places where their relative proportions are rising (Tolbert and Grummel, 2003). Such regulations reinforce the level of segregation in the area. Another cause of segregation is considered to be the significant inequality of income between minorities and majorities that results in different consumption levels of goods and services. A particularly relevant example is the gap in housing affordability, which has a direct effect on residential mobility. Thus, even if economic changes would seem to favor relocation, the minority group members are unable to change their place of residence and have to survive in an impoverished neighborhood. For instance, the process of suburbanization, that occurred after World War II and was promoted by Federal Highway Policy and mortgage programs led to the massive outmigration of urban population to the suburbs (Wilson, 1987). However minority groups tended to be less residentially mobile, less financially sufficient, and still subject to racial discrimination; thus their migration to suburbs was not significant. This change has led to the increased concentration of minorities in inner city neighborhoods (Ellison and Martin, 1998).

The third reason for the persistence of segregation is the personal decision of minorities to choose the place of residence in their own group's neighborhoods that are culturally and ethnically close (Varady, 2005). This leads to the formation of ethnic enclaves. This form of segregation is sometimes regarded as producing a positive effect, with lively economic activity concentrated in attractive urban areas (Edin *et al*., 2003; Varady, 2005). Finally the fourth cause of segregation that Allen and Turner (2011) cite is the presence of specific attitudes of different racial or ethnic groups towards each other. It in some way intersects with the first and the third explanations mentioned above, since those attitudes in some cases produce the unwillingness to interact with members of other groups and result in prejudiced opinions (Schuman *et al*., 1998).

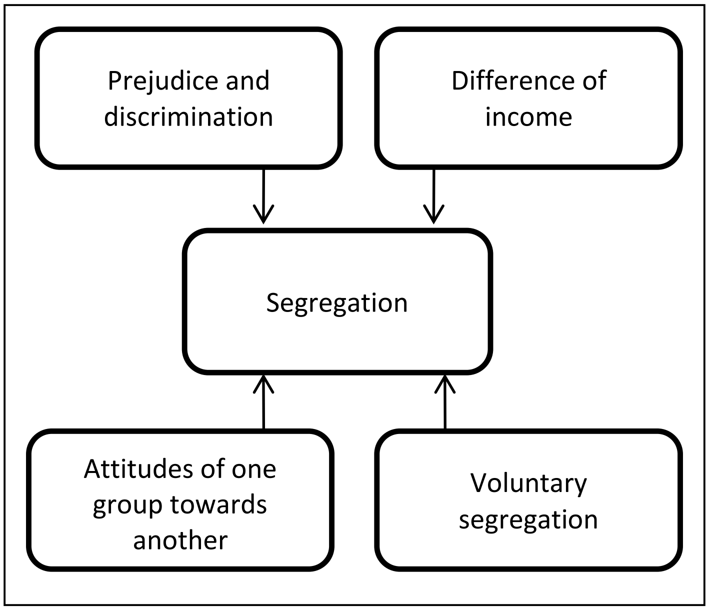


Figure 2.1 Causes of Residential Segregation (adapted from Allen and Turner, 2011)

Eventually such opinions transform into stereotypical thinking that can be expressed in the discriminatory practices, such as refusing to rent residential apartments in white neighborhoods to minorities (Farley *et al.*, 1994; De Sena, 1994).

2.2 Socioeconomic Outcomes for Segregated Neighborhoods

Much of the research (Wilson, 1997; Massey and Denton, 1993; Quillian, 2012) concurs that relatively high levels of segregation in urban areas result in negative socioeconomic conditions that disadvantage the neighborhood residents in all the aspects of their lives. One of the major outcomes of the segregation and concentration of minorities in a neighborhood is the persistence of poverty. Wilson (1987, 1997) argues that the racism by itself cannot explain the poverty and inner-city social dislocation. In fact, Wilson attributes the increase in black poverty primarily to the major changes in the US economy during that period, including the shift from manufacturing to the service economy and the increasing proportion of white women in the workforce. At the same time the black population was primarily employed in manufacturing and was left behind in the job market arena. Indeed, as Massey and Denton (1993, p.12) confirm: "…underclass communities were created only where increased minority poverty coincided with a high degree of segregation – principally in older metropolitan areas of the northeast and the midwest." Arguing against the conservative approach of seeing the problems of ghetto underclass in terms of individual characteristics of specific population groups, Wilson (1987) exemplifies the liberal perspective of approaching the problem at the level of the societal organization. He stresses that public policy decisions that deal with the problems of poverty and joblessness, should aim at changing the social and economic situation instead of focusing on ghetto underclass cultural conditions.

Applying his study to the black ghetto communities, Wilson notes the degradation of the family institution in black ghettos as another factor for negative outcomes resulting from single-mother headed families, high rates of divorces, out-of-wedlock births and financial dependency on welfare. High crime, especially violent crime, constitutes the most dramatic consequence that emerged from social dislocation, long-term poverty and unemployment of black community residents. Finally, high unemployment rates that infected inner city areas are at the root of most of the above-mentioned outcomes that socially paralyze black ghetto communities. Furthermore, the long duration of joblessness in ghetto communities creates the stereotypical and prejudiced attitude towards black job seekers. Focusing on the example of Cooke County of Chicago, Wilson (1997) showed that employers generally consider blacks from inner city neighborhoods as unable to work effectively. However, surveys suggest that those companies that hire through the independent skills tests for entry-level jobs usually get a pool with a higher proportion of blacks than those companies that hire through the interview appointments. The negative outcomes that emerge from black segregation and its consequences raise the need for employing the analytical tools and methods to accurately and adequately estimate the extent of segregation within geographic areas and its relative importance in shaping the socioeconomic conditions of the areas under investigation.

2.3 Overview of Racial and Ethnic Segregation Measures

As will be demonstrated, the problem of measuring the level of racial segregation is addressed from different perspectives. Geographers are primarily interested in measuring the level of segregation in space. As was noted by White (1983), defining the extent of segregation spatially does not assure the same level of limited social interactions between social groups. At that time he also addresses the weakness of existing measures that kept failing to capture the inner social composition of the studied areal units.

Some of the first systematizations in the field of racial or ethnic segregation measures was demonstrated by Duncan and Duncan (1955). They identified some problems common to the measures of segregation. First, all the segregation indices were based on the equivalent of the Lorenz curve that plots the cumulative proportions of majority ethnic group against the minority (see Figure 2.2). As a method to measure unevenness, the Lorenz curve was implemented in economic research as a measure of inequality of income distribution (Huang, 2013), in ecology as a measure of disproportionate spread of species over their habitat (Magurran, 1991). In sociological research, especially as a way to measure the segregation of population, the Lorenz curve plots the cumulative proportions of one population category against another category.

As most of the early measures of segregation were in some way related to this graphical representation, there was an emerging need to find new ways to measure the level of the segregation. Furthermore, as the most of the indices could be derived from the Lorenz curve they had a tendency of being interrelated. Thus, one general mathematical form could be assigned to all of them. Another issue was that the indices did not consider the spatial distribution of the segregation such as a tendency towards a clustered or scattered pattern. The indices were making it unclear how to use them in order to detect the process and the change of segregation patterns. Another common issue was associated with the influence of the size of the areal unit on the analysis results. Finally, the concept of segregation discussed in the earlier literature was termed as somewhat “fuzzy”. Duncan and Duncan (1955) article they advocated the

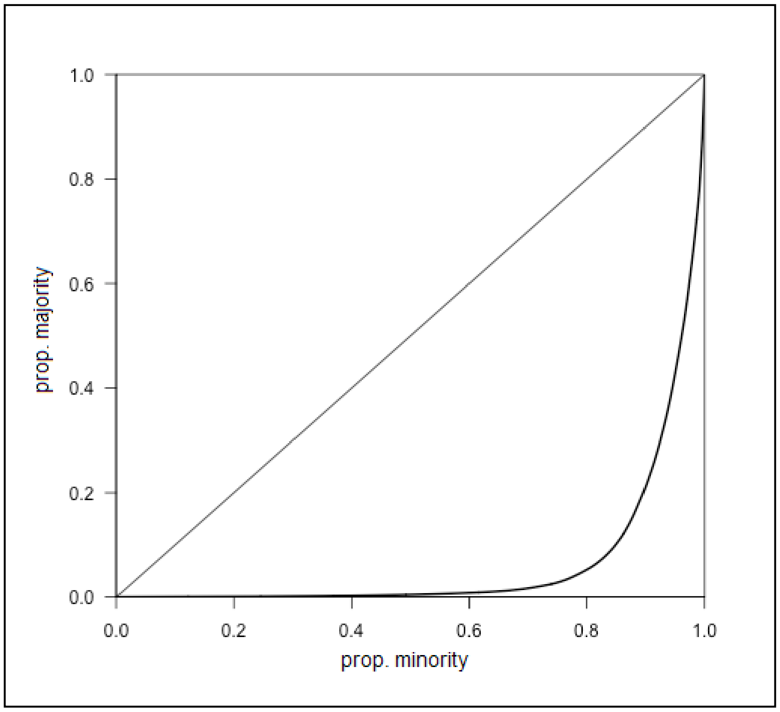


Figure 2.2 A Lorenz Curve Plotting a Hypothetical Minority Population against a Hypothetical Majority Population

usage of the index of dissimilarity that later received a broad implementation in segregation studies. Graphically the index represents the maximum distance between the "segregation curve" (analogue of the Lorenz curve) and the line of equality, which is a straight line at a 45^{o} angle. The line of equality represents the complete geographic integration as each area has the same proportion of each group as the entire region does. The segregation curve represents the deviation of the actual distribution from this norm. The index of dissimilarity is defined as:

$$D = 0.5 \times \sum_i \left| \frac{a_i}{A} - \frac{b_i}{B} \right| \quad ; \qquad (2.1)$$

where,

a_i - majority population living in area i;
b_i – minority population living in area i;
A – total majority population for the city;
B – total minority population for the city;
i = 1,…,n – number of areas composing the city.

This index ranges from 0 (complete geographic integration) to 1 (complete geographic separation). A subsequent period of debate came followed a paper by Cortese *et al.* (1976) that proposed some adjustments to the index of dissimilarity. The use of the index of dissimilarity in its regular form was criticized for not only its properties but also for its incorrect conceptual “vision” of the segregation. Cortese and his colleagues proposed that the computation of the index should rely not on the deviation from the even distribution of population categories in the city, but rather on the difference between the actually observed and their random distribution. Thus the principle of randomness should serve as a basis from which to measure the observed pattern. Furthermore, the interpretation of the index value as “the proportion of the nonwhites who would have to change their tract of residence to make the distribution of the minority even throughout the city” was found inadequate because it defines the proportion of the minority that has to be moved from the tract without replacement of it with the majority population to reach evenness. They stated that a more adequate measure should rather capture the proportion of minority that needs to be exchanged to achieve the evenness, thus leaving population in the areal unit unchanged.

A comprehensive analysis of the segregation that serves as a “benchmark” for the segregation studies was provided by Massey and Denton (1988). They systematized the number of measures of residential segregation. As was noted, the measures utilized all follow different principles which implies that the actual process of segregation can be understood in many ways as opposed to the uni-dimensional way that was preferred at that time. Thus arguing that the segregation can be summarized by five distinct dimensions, Massey and Denton grouped a number of existing indices by identified dimensions. One of the dimensions is evenness. It defines over- and underrepresentation of population groups across the urban area. A minority group is considered to be segregated if it is unevenly distributed across inner urban areal units. It reaches its maximum when all the tracts have the same proportions of majority and minority members as the urban area as a whole, and is minimized when the majority and minority members do not share the same neighborhood.

Another dimension of segregation is the exposure which refers to the amount of the potential interaction between the social groups within an urban environment. The measures attributed to that dimension are usually asymmetric, so that the level of exposure of minority group to majority is different from the exposure of majority members to minority. This dimension measures the likelihood of the interaction between majority and minority groups within the area. The boundaries of interaction can be limited to residential space as the US Census Bureau primarily provides data by the places of residence. When disaggregated data are available, it is proposed to model a so-called activity space for measuring the exposure of one population group to another (Wong and Shaw, 2011). Activity space is formed by aggregation of locations that an individual visits. Such an approach poses several issues for the analysis. First, gathered data on individual travels prescribes generalized assumptions about demographic, socioeconomic patterns and travel behavior of population based on the given subset of people. Also, the problem of formulating an activity space, or a socio-geographic space is open since there are multiple ways that can be implemented to delineate those activity spaces using various principles.

Most of the time the data on population are provided in aggregated form. Various measures were proposed to capture the exposure dimension based on aggregated data (Jakubs, 1981; Morgan, 1983; Wong, 2002). Lieberson (1981) suggested two exposure indices defined as:

$$_{x}P_{y}^{*} = \sum_{i=1}^{n} \frac{x_i}{X} \times \frac{y_i}{t_i} \tag{2.2}$$

and

$$_{x}P_{x}^{*} = \sum_{i=1}^{n} \frac{x_i}{X} \times \frac{x_i}{t_i} \tag{2.3}$$

where,

x_i – population of group X in areal unit *i*;
y_i – population of group Y in areal unit *i*;
t_i – total population in areal unit *i*;
X – population of group X in the study area;
$i = 1, \dots n$ – the number of areal subunits in the study area.

The interaction index (Equation 2.2), measures the extent of exposure, or chance of interaction, of population group X with group Y members. As this measure is asymmetric, the intensity of potential interaction between group Y and X is not necessarily the same as it is between X and Y, therefore the two indices are computed separately. The isolation index (Equaiton 2.3) identifies the exposure of one subgroup to same group members over the area. Both variants of exposure indices are interpreted as the probability that a member of one population subgroup encounters another person of another (Equation 2.2) or same group (Equation 2.3) within the city.

The third dimension of segregation is the dimension of concentration which is defined in terms of the space occupied by the majority or minority members relative to their population size. Following this definition the population group is concentrated if it occupies a smaller area compared to another group. A similar notion is assigned to the fourth dimension – centralization. In this case the tendency of population group to occupy central city areas is the main concern. The fifth dimension is clustering. It is defined as a tendency to form contiguous areas containing minority population groups. Thus segregation is a complicated social process that should be studies using all five defined “axes”.

The proposed dimensions were later reevaluated in the literature in terms of their conceptual basis and matched with particular measures. Some research resulted in merging several dimensions. Reardon and O’Sullivan (2004) reduce the number of dimensions to two – spatial exposure and spatial evenness. For the dimension of spatial exposure, the opposite condition of highly exposed population would be the state of isolation. For the spatial evenness dimension, the clustering of population group members is the opposite state of even distribution. Dawkins (2006) examined two modified spatial Gini indices described by Dawkins (2004) that incorporate spatial proximity function for calculating segregation levels in 237 US Metropolitan areas in 2000. One index measures the average increase in neighborhood minority percentage with respect to proximity to the central business district (CBD). Another index produces the value of the average increase in neighborhood racial composition with respect to proximity to the closest nearby neighborhood. He argued that a spatial Gini and its variations can quantify segregation simultaneously in several dimensions – evenness, centralization and clustering – as they significantly correlate with traditional indices identified by Massey and Denton for these dimensions. Dawkins promotes centralization and clustering to be the only ‘spatial’ dimensions in nature since the measures attributed to them use the relationship among population subgroups of nearest neighborhoods.

Besides computing segregation indices, some graphical approaches within a GIS environment have been used to model the population distribution. For instance, some methods were described by Wong (1999) that included the use of the descriptive statistics such as the spatial mean, standard distance, standard distance circle. Also, measures such as the standard deviational ellipse were proposed to see the dispersion and orientation for each social group (Wong, 1999; Wong, 2003). In that case overlaying two ellipses and defining the proportion of their overlap may also characterize the level of segregation ranging from low level when the overlap area is quite significant to high level when the overlap is too small (see Figure 2.3). Also, the index based on intersection and union of the ellipses may reflect the degree of spatial separation of the ethnic groups within the study area.

An important discussion around the segregation studies centers at the deriving the measures that reflect the local variations in the magnitude of spatial separation of population groups. A comprehensive overview of the problems associated with the measures is provided by Reardon and O’Sullivan (2004). In the evaluation of the existing measures they address two major problems: the Modifiable Areal Unit Problem (MAUP) and checkerboard problems.

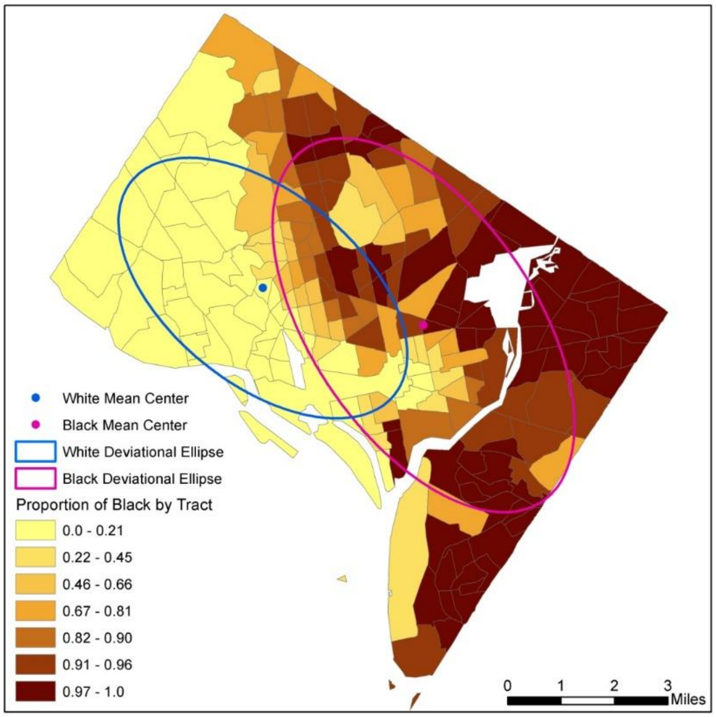


Figure 2.3 Mean Center, Standard Deviational Ellipses for Washington, DC for year of 1990.

MAUP can be defined as a combination of the scale and zoning problems (Openshaw, 1983). Scale problems refer to the situation when the aggregation of smaller areal units into bigger fewer zones has an effect on analysis results. Variations in the results of an analysis due to the presence of alternative ways to construct the units are attributed to the zoning problem. For example, in Figure 2.4 sixteen completely black or completely white squares are aggregated to four larger areas making the distribution even. The value of the index drops drastically from the state of complete segregation to a state of no segregation – even distribution of populations.

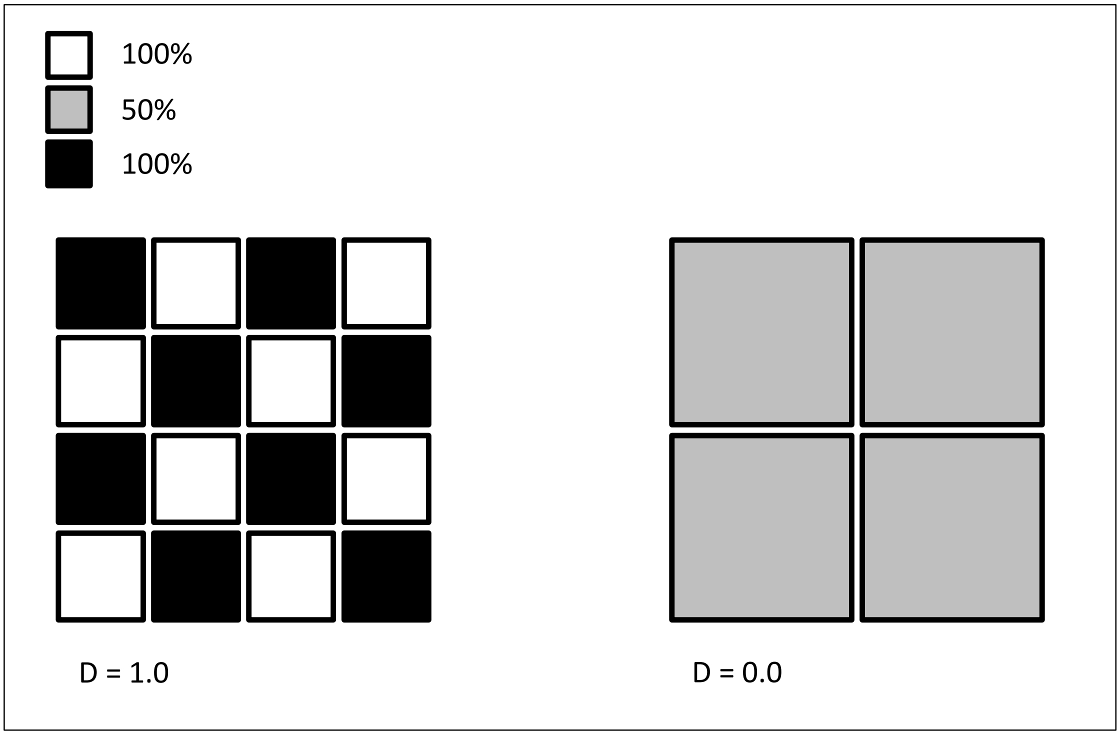


Figure 2.4 The Data Aggregation Problem

The so-called checkerboard problem termed by White (1983), is another issue pertaining to some indices including index of dissimilarity. The issue results from ignoring the spatial relationships among basic units of analysis: their contiguity and arrangement. Essentially, the study area consisting of smaller subunits is treated as a discrete space than a continuous one and each observation unit is independent from the rest in a given spatial pattern. Practically this is demonstrated in insensitivity of the measure’s value to variations in geometric configuration of those populations that are distributed in the city. In Figure 2.5, for instance, it is demonstrated that a spatial rearrangement of black and white squares is not reflected in the value of the index of dissimilarity D, even though the two variants indicate completely different situations in modeled urban area, going from a more dispersed spread of black and white squares to the case with apparent clustering of both population categories.

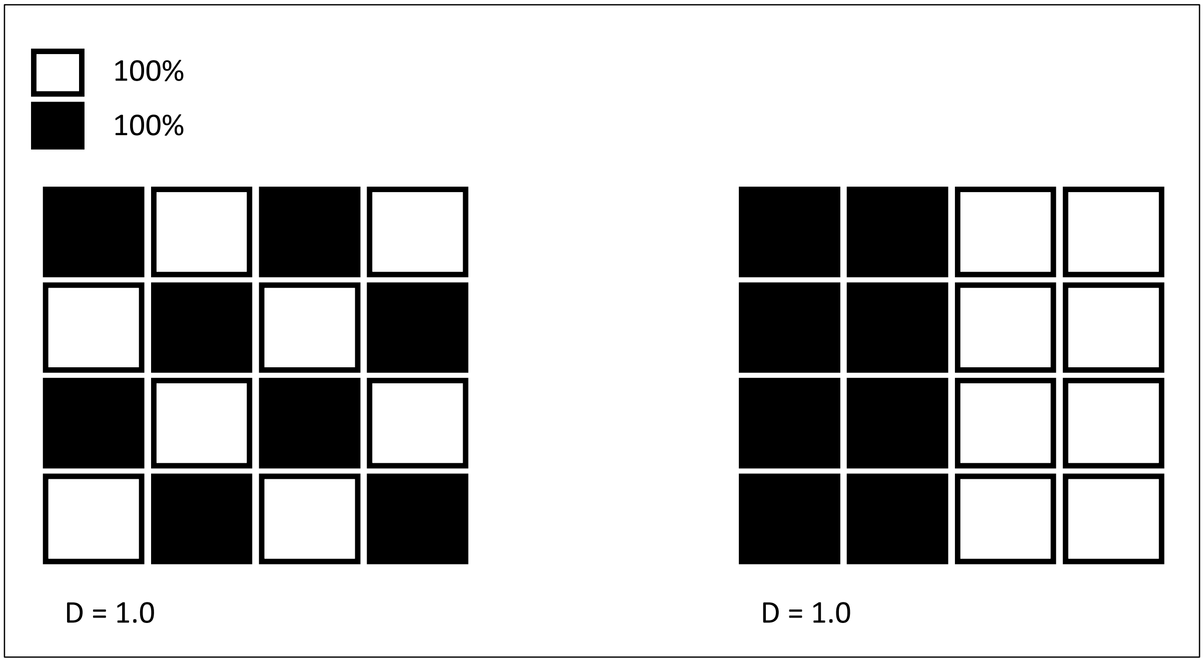


Figure 2.5 The "Checkerboard" Problem

Given the potential existence of methodological issues with developed and new measures the researchers have called for more attention to the properties of segregation indices in order to maintain the consistency of the results with respect to the very definition of segregation that is embedded in a particular formulation. Another important requirement is to avoid the sensitivity of the computation outcomes to variations in data distribution. Various properties of the measures have been considered and discussed (see Duncan and Duncan, 1955; Cortese *et al*., 1976; James and Taeuber, 1985; Reardon and Firebaugh, 2002; Allonso-Villar and del Rio, 2010). Reardon and O'Sullivan (2004) support the need of establishing the set of criteria that would serve as controlling the adequacy of any, as they define it, spatial segregation index. They modified the criteria proposed by Reardon and Firebaugh (2002) so that the criteria could be applied to the spatial evenness dimension of measuring the phenomena. Their notions about the requirements for measurements are primarily based on usage of data on individual residential locations represented as points, but can be extended to the aggregated case. Such criteria include scale interpretability, arbitrary boundary independence, location equivalence, population density invariance, and, as an additional criterion, additive spatial decomposability that can also be used for capturing the spatial exposure dimension as well. Scale interpretability sets the index value to zero if racial proportions do not vary among local environments of every group member (or local environment at a different scale), and to its maximum value when the local environment consists of one race, or if proximity of two people from different groups is zero. Arbitrary boundary independence implies insensitivity of the index value with respect to the manner in which the boundaries are defined. Ideally in order to avoid such an issue segregation, should be examined at the disaggregated level of every individual. Location equivalence states that the aggregation of two local environments with the same population composition should not result in any change of the index value. Population density invariance indicates that with multiplication of population densities of all groups at every point in study area by constant scale factor, the level of segregation remains unchanged. Composition invariance refers to the rule that the index depends on the distribution of population groups across the area regardless of the population composition. The principle of transfers and exchanges is related to particular movements of population around the study area, and how computed segregation levels should change accordingly.

The principle of transfers refers to the decline of the overall level of segregation when a group member moves to a neighborhood where the relative proportion of that group is smaller than that in the original neighborhood. Reardon and O’Sullivan (2004) split he rule of exchanges in two types. Type 1 describes the situation where two individuals belonging to different population subgroups *m* and *n* are exchanged between two places and if the place of origin of person of group m is populated with a higher proportion of group m than the destination, and a higher proportion of group *n* than the proportion of *n* at destination, then the level of segregation declines. Type 2 considers the case where the level of segregation is also reduced when the place of destination for person of subgroup *n* contains a higher proportion of group *m* than that in place of origin, and the proportion of group *n* at the destination is higher than proportion of *m* at the origin. Additive spatial decomposability occurs when the number of areal units is aggregated into a smaller number of units; the measure should be respectively decomposed into a sum of within- and between-area elements. Additive grouping decomposability relates to the aggregation of the number of population groups into a smaller number of groups and the respective decomposition of the segregation measure into independent within- and between-subgroup elements.

Reardon and O'Sullivan (2004) provide several general two- and multi-group measures. The approach for developing indices is based on a spatial proximity function that models the population interaction within neighborhood. When evaluating them against the criteria they conclude that two of the indices respond best to the requirements for the measures and their definition of segregation. As for spatial evenness, the spatial information theory index is found to be the most suitable measure. It is formulated as:

$$\widetilde{H} = 1 - \frac{1}{TE}\int_{p\in R} \tau_p \tilde{E}_p dp \qquad (2.4)$$

where $\tilde{E}_p$ and E are defined respectively as:

$$\tilde{E}_p = -\sum_{m=1}^{M} (\tilde{\pi}_{pm}) \log_M(\tilde{\pi}_{pm}) \qquad (2.5)$$

$$E = -\sum_{m=1}^{M} (\pi_m) \log_M(\pi_m) \qquad (2.6)$$

where,

$\tilde{E}_p$– spatially weighted entropy;
E – overall regional entropy;
T – total population for the set of points R;
τ_p – population density at point p;
$m = 1, \dots, M$ – population subgroups in a region;
$\tilde{\pi}_{pm}$ – proportion of group m in the local environment of point p;
π_m – proportion of group m in total population in the region;
R – set of points containing data on population.

For measuring the degree of spatial exposure, the traditional exposure index is generalized and is formulated in the following manner:

$$ {}_{m}\widetilde{P}_{n} = \int_{q\in R} \frac{\tau_{qm}}{T_m} \tilde{\pi}_{qn} dq \qquad (2.7) $$

${}_{m}\widetilde{P}_{n}$ calculates the mean percentage of group n that are present in the local environments of each person of group m. Similarly, the spatial isolation can be defined as the exposure of the subgroup to itself:

$$ {}_{m}\widetilde{P}_{m} = \int_{q\in R} \frac{\tau_{qm}}{T_m} \tilde{\pi}_{qm} dq \qquad (2.8) $$

where,
τ_{qm} – population density of group m in the local environment of point q;
$\tilde{\pi}_{qm}$ – proportion of group m in the local environment of point q;
$\tilde{\pi}_{qn}$ – proportion of group n in the local environment of point q;
T_m – total population of group m in the set of points R.

Most of the measures are traditionally oriented to measure the degree of spatial separation between two population groups but Reardon and Firebaugh (2002) extend the development of these measures to measure multi-group segregation. For that particular purpose segregation is redefined in four different ways, each one built on a separate conceptual basis. One can be thought of as disproportionality in population group proportions across the study area. This view relates to inequality measures, such as the Gini segregation index (Reardon, 1998; Dawkins, 2004), in order to estimate the unequal distribution of population groups. A second way of viewing segregation is as the degree of association between a nominal variable indexing a group and the organizational unit membership. That relates to traditional measure of association χ^2 and G^2. Normalized values of association measures become measures of segregation. Another type of measure is expressed as diversity ratios. The derived index is based on the ratio of the probability that two people from the same areal unit are members of different groups to the probability that any two people in the study area are members of different population groups. Finally, multi-group segregation can be quantified as the weighted average of two-group segregation indices. For evaluating the multi-group segregation measures seven criteria, partly based on James and Taeuber's ideas (James and Taeuber, 1985), are identified organizational equivalence, size invariance, principle of transfers, principle of exchanges, composition invariance, additive organizational decomposability and additive group decomposability.

In parallel with the discussion of the dimensions of segregation and properties of the measures, the question of using global or local methods has been widely debated. Global measures have been dominant in the study of segregation until recently. In general, global methods were the primary quantitative approach the scientists were using and developing until GIS era began, and the opportunity to process large data sets in a much more easily manageable way was realized. In global models it is assumed that there is no variation of the phenomena over space, and that the calculated, global measure for the area of interest is equally true throughout that area (Lloyd, 2011). While it appears useful to use global methods for comparing the level of geographical segregation between regions, global measures in context of social geography have been criticized as ones that aggregate too much and conceal the variations of the spatial structure of geographic phenomena (Fotheringham *et al.*, 2002; O'Sullivan and Wong, 2007; Lloyd, 2011). Local methods are proposed as an alternative to global methods when the granularity of spatial data allows a measure based on a subset of observations in the data set. Local measures of segregation tend to not only reveal the inner change of racial/ethnic composition over space but also to give the opportunity to visualize that change at different scales, thus demonstrating the spatial structure of segregation that is unique for every region. Overall, local segregation measures increase the informative value of the measure in terms of evaluation of the spatial variability and enlarge the geographic scale of observation of the social phenomena.

Lloyd *et al.* (2004) propose to use the local form of Moran's I index of spatial autocorrelation introduced by Anselin (1995) to measure how similar an area is to its surrounding areas. To detect the evenness dimension geographically weighted index of dissimilarity is introduced to capture the local character of segregation. To model the distance decay effect of the nearby observations a Gaussian kernel function is used to estimate the spatial weight, λ:

$$\lambda_i = \exp[-0.5(d/a)^2] \tag{2.9}$$

where,

d - Euclidean distance between observation *i* and the center of the kernel;

a - the bandwidth of the kernel.

A geographically weighted index of dissimilarity has the following mathematical formulation:

$$D(gw) = 0.5 \times \sum_i \left| \frac{\lambda_i b_i}{\sum_i \lambda_i b_i} - \frac{\lambda_i w_i}{\sum_i \lambda_i w_i} \right| \tag{2.10}$$

where,

w_i – population of category w residing in areal unit *i*;

b_i – population of category b residing in areal unit *i*.

The authors indicate that there are issues associated with scale and the size of the bandwidth. As for the behavior of the index over the study areas, with an increase in distance for the bandwidth, the variation in the local index becomes smoother. For smaller bandwidths, the local characteristics of the observation points are emphasized more.

A similar transition of the index of dissimilarity from its global to local version was attempted by Wong (2008). He uses the concept introduced by Wong (1998) of composite population counts. Composite population for the areal unit is defined by summing its raw population with the population count of the drawn neighborhood. The neighborhood can be defined in many ways, such as based on proximal distance or adjacency, and may include a form of distance decay function for weighting the observations in neighboring units. The generalized form of the index is the following:

$$SD_i = \left| \frac{ca_i}{CA} - \frac{cb_i}{CB} \right| \tag{2.11}$$

where,

ca_i – composite population count for unit *i* for group A;

cb_i – composite population count for unit *i* for group B;
CA – total population count for unit *i* for group A for the urban area;
CB – total population count for unit *i* for group B for the urban area.

Population count for unit i is formally defined as:

$$CP_i = \sum_j^m d(P_j) \qquad (2.12)$$

where,
P_j – total population count in areal unit *j*;
$d(.)$ – function defining the neighborhood of observation *i*;
j = 1,…,*m* – number of areal units in the study area.

Over time other local measures of segregation were introduced. O'Sullivan and Wong, (2007) developed an index using a kernel density estimation function of population groups of interest as an expansion of the measure based on standard deviational ellipses. Their approach favors the analysis by elimination of boundaries between areal units that are usually considered as impenetrable, thus assuming the continuous spread of population across the boundaries of the areal units within the urban area. It also allows one to visualize the population probability density functions for each population and to produce a surface map of difference between maximum and minimum population proportions. In this manner the contribution of the local neighborhoods to the overall segregation level is considered to be more disaggregated.

Borrowing the idea of Wong (2005) about the continuous modeling of a population distribution, Feitosa *et al*. (2007) derived spatially sensitive measures by producing a set of global segregation indices based on the dissimilarity, exposure and isolation dimensions. Each of the global measures is then decomposed into local indices based on a spatial kernel. However, the choice of the bandwidth greatly influences the outcome of the calculation. Scale effect issues have also been noticed concerning the proposed measure.

The current tendency and need in segregation research remains quite similar to those identified by Duncan and Duncan in 1955. However, the research done since then provides a deeper insight into the phenomena and how its measure should be evaluated. Nevertheless, further systematization and coordination of the measures is necessary in order to understand more thoroughly and describe the observed pattern formed by the spatial processes of segregation.

2.4 Summary

This chapter first reviewed the historical aspects of segregation in the United States. The main reasons that residential segregation continues to persist are rooted in the historical events that were happening during the social struggle for the elimination of racial and ethnic discrimination. Economic restructuring then aggravated the conditions of minorities living in urban areas. Thus there are numerous negative outcomes that grow from the limited opportunities of those populations.

The second part of the chapter focused on an overview of the methods that have been developed and used to identify the levels of residential segregation. The indices can be split into two major groups, local and global, based on the scale of investigation they refer to. Another type of classification is based on the concept that underlies the very definition of segregation. Except for addressing the issues of scale and definition of the phenomenon, there are mathematical properties that are preferable for the measures to maintain and that serve as controlling factors for evaluating existing and new measures. The next chapter presents a new method for measuring residential segregation, the co-location quotient, that encapsulates many of the desired criteria associated with these indices.

CHAPTER THREE

Data and Methodology

3.1 Data

The study area for this dissertation consists of twenty-nine Metropolitan Statistical Areas (MSA) and the District of Columbia. The study area was chosen so that results could be compared to an earlier study by Wong (2004) which examined the sensitivity of the index of dissimilarity to geographic scale. In that study, results using census tracts and block groups were compared for the set of MSAs. The computation of segregation measures for these urban areas is performed over the spatial subunits, census tracts and block groups that comprise these MSAs.

Data for census tract and block group levels for the years 1990, 2000 and 2010 were compiled. The US Census Bureau defines the census tract as the area with population between 1,200 and 8,000 people, ideally around 4,000 people (http://www.census.gov/geo/reference/gtc/gtc_ct.html), whereas block groups usually contain between 600 and 3,000 people (http://www.census.gov/geo/reference/gtc/gtc_bg.html). Because of the population dynamics and modifications in the methods to delineate those units, their number and boundaries experienced some changes over time resulting in either the merging, the splitting of old units in newer units, or a total change in the boundaries (see Table 3.1).

The standards for delineation of MSAs have also changed from census to census. The standards for MSAs delineation are issued by the Office of Management and Budget (OMB) (http://www.whitehouse.gov). An MSA is defined as the area covering at least one urbanized territory with the population of at least 50,000 people and may also include additional areas that maintain the high degree of economic and social integration with the core urban area. In 1990 and 2000, MSAs were classified into two major categories: consolidated (CMSA) and primary (PMSA) metropolitan statistical areas, each containing more than one million people. CMSA may consist of two or more PMSAs. In the 2010 census, the Metropolitan and Micropolitan areas were combined into the dataset called Core Based Statistical Areas (CBSAs), consisting of metropolitan and micropolitan statistical areas. Another set of Combined Statistical Areas (CSAs) was issued where every CSA is the area that includes two or more of metro- or micropolitan areas, or any of their combination. Metropolitan Division (MetDiv) dataset includes areas that comprise the biggest metropolitan areas in 2010. Table 3.2 lists the sources of the boundaries of the MSAs used for the analysis in the dissertation.

Decennial censuses have also had significant changes in definitions of the boundaries for MSAs between years considered in the current dissertation. Therefore in order to minimize the influence of geometric configuration of changed metropolitan boundaries on the results of the analysis the segregation trends over time are examined using boundaries for 2010. In that case, the MSA boundaries of 2010 are used to select the census tracts and block groups for the three censuses. (see Table 3.3).

Table 3.1 Summary Table of Observations Used in Study Dataset

MSA Name	State	Census Year					
		1990		2000		2010	
		Number of Tracts	Number of Block Groups	Number of Tracts	Number of Block Groups	Number of Tracts	Number of Block Groups
Atlanta	GA	482	2011	660	1837	946	2588
Baltimore	MD	585	2000	624	1890	676	1936
Birmingham	AL	208	828	196	578	264	807
Boston	MA	631	2616	697	2642	999	3143
Buffalo	NY	236	971	302	1094	297	953
Chicago	IL	1494	5292	1875	5968	1859	5571
Cincinnati	OH	355	1401	405	1015	501	1278
Cleveland	OH	619	1862	714	1861	635	1691
Columbus	OH	349	1291	372	1209	420	1298
Dallas	TX	548	2343	701	2400	1314	4132
Detroit	MI	1192	4590	1275	3947	1297	3693
District Columbia*	-	192	576	188	432	179	449
Gary	IN	117	588	136	448	161	484
Greensboro	NC	238	817	263	804	376	1054
Houston	TX	685	2393	778	2328	1069	3028
Indianapolis	IN	293	1046	340	1104	360	1069
Kansas City	KS	445	1505	503	1450	535	1555
Los Angeles	CA	1641	6004	2052	6348	2922	8239
Memphis	TN	221	941	274	751	312	696
Miami	FL	264	1047	342	1213	1205	3404
Milwaukee	WI	391	1381	416	1271	429	1300
Newark	NJ	453	1703	480	1652	503	1614
New Orleans	LA	367	1255	393	1097	391	1084
New York	NY	2492	6938	2507	6836	2907	8853
Norfolk	VA	318	940	359	1015	409	1137
Philadelphia	PA	1250	4472	1328	4388	1475	3937
Pittsburgh	PA	682	2167	702	1986	711	1919
San Francisco	CA	361	1268	381	1170	973	2890
St. Louis	MO	459	2196	527	1958	620	2009
Tampa	FL	408	1576	536	1572	718	1981

Table 3.2 Definitions of MSAs Used in the Analysis

MSA Name	State	Definition of MSA		
		1990	2000	2010
Atlanta	GA	CMSA	CMSA	CBSA
Baltimore	MD	CMSA	PMSA	CBSA
Birmingham	AL	CMSA	CMSA	CBSA
Boston	MA	PMSA	PMSA	CBSA
Buffalo	NY	PMSA	CMSA	CBSA
Chicago	IL	PMSA	PMSA	MetDiv
Cincinnati	OH	PMSA	PMSA	CBSA
Cleveland	OH	PMSA	PMSA	CBSA
Columbus	OH	CMSA	CMSA	CBSA
Dallas	TX	PMSA	PMSA	CBSA
Detroit	MI	PMSA	PMSA	CBSA
District of Columbia*	-	County	County	County
Gary	IN	PMSA	PMSA	MetDiv
Greensboro	NC	CMSA	CMSA	CSA
Houston	TX	PMSA	PMSA	CBSA
Indianapolis	IN	CMSA	CMSA	CBSA
Kansas City	KS	CMSA	CMSA	CBSA
Los Angeles	CA	PMSA	PMSA	CBSA
Memphis	TN	CMSA	CMSA	CBSA
Miami	FL	PMSA	PMSA	CBSA
Milwaukee	WI	PMSA	PMSA	CBSA
Newark	NJ	PMSA	PMSA	MetDiv
New Orleans	LA	CMSA	CMSA	CBSA
New York	NY	PMSA	PMSA	MetDiv
Norfolk	VA	CMSA	CMSA	cbsa-
Philadelphia	PA	PMSA	PMSA	CBSA
Pittsburgh	PA	PMSA	CMSA	CBSA
San Francisco	CA	PMSA	PMSA	CBSA
St. Louis	MO	CMSA	CMSA	CBSA
Tampa	FL	CMSA	CMSA	CBSA

The data source, National Historical Geographic Information Systems (NHGIS), is a product of Minnesota Population Center (https://www.nhgis.org) that provides aggregate census data, along with GIS boundary files. NHGIS offers modified areal geographic datasets with the coastal water areas removed, which is an improvement for working with population data. The census tracts and block groups have attached information about the racial composition of population.

Table 3.3 Number of Census Tracts and Block Groups
for each MSA Using Boundaries in 1990 and 2010

MSA Name	Number of tracts by MSA boundaries						Number of block groups by MSA boundaries					
	1990			2010			1990			2010		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Atlanta	482	630	883	533	690	946	2011	1744	2387	2184	1923	2588
Baltimore	584	624	677	580	620	676	1995	1890	1940	1988	1883	1936
Birmingham	208	214	251	221	226	264	828	636	762	874	680	807
Boston	624	625	692	890	914	999	2603	2374	2403	3415	3120	3143
Buffalo	236	243	236	290	302	297	971	912	777	1198	1094	953
Chicago	1494	1537	1584	1679	1724	1859	5292	4931	4771	6020	5590	5571
Cincinnati	355	387	393	454	486	501	1121	979	957	1413	1252	1278
Cleveland	618	620	562	691	693	635	1860	1563	1490	2092	1765	1691
Columbus	349	379	414	357	385	420	1291	1235	1275	1317	1259	1298
Dallas	548	670	878	866	1046	1314	2343	2292	2703	3658	3552	4132
Detroit	1192	1327	1335	1153	1289	1297	4587	4062	3815	4459	3937	3693
District of Columbia*	192	188	179	192	188	179	574	432	449	576	432	449
Gary	117	136	149	128	147	161	588	448	446	627	489	484
Greensboro	238	240	297	288	295	376	817	709	813	1064	935	1054
Houston	682	773	940	804	889	1069	2391	2310	2608	2848	2732	3028
Indianapolis	293	304	349	304	315	360	1046	994	1030	1088	1033	1069
Kansas City	445	499	518	462	516	535	1505	1433	1481	1589	1507	1555
Los Angeles	1640	2052	2341	2121	2628	2922	6004	6348	6419	7686	8171	8239
Memphis	221	267	287	239	285	312	842	729	663	865	751	696
Miami	260	342	508	629	884	1205	1040	1213	1577	2072	2506	3404
Milwaukee	391	416	429	391	416	429	1381	1271	1300	1381	1271	1300
New Orleans	366	379	383	373	385	391	1254	1053	1062	1286	1077	1084
New York	2488	2507	2466	2950	2911	2907	6929	6836	7253	8650	8449	8853
Newark	455	457	459	485	491	503	1705	1572	1493	1822	1679	1614
Norfolk	313	347	392	326	361	409	932	978	1092	967	1014	1137
Philadelphia	1248	1304	1300	1408	1472	1475	4470	4339	3827	4599	4444	3937
Pittsburgh	681	604	597	799	721	711	2166	1702	1600	2540	2053	1919
San Francisco	357	381	406	829	870	973	1264	1170	1212	2950	2717	2890
St. Louis	463	522	590	489	551	620	2218	1935	1894	2340	2050	2009
Tampa	395	536	723	399	536	718	1568	1572	1988	1560	1568	1981

Table 3.4 provides information about racial categories for the respective years. These are the classifications defined by US Census Bureau and are based on a 100% count of population. The census provides two versions of race classification – a single race classification and the one based on Hispanic origin. The classification used here is a single race classification. Undoubtedly, variations in geometry and number of basic units affect the results of analysis. But standardization of geographic extent to select those units, especially to compare different time periods, give a chance to minimize the error attributed to pure data re-delineation.

Table 3.4 Racial Categories (One Race) Defined by US Census Bureau for 1990, 2000 and 2010

Census Year	Racial Categories
1990	White Black American Indian, Eskimo, or Aleut Asian or Pacific Islander Other race
2000	White alone Black or African American alone American Indian and Alaska Native alone Asian alone Native Hawaiian and Other Pacific Islander alone Some other race alone
2010	White alone Black or African American alone American Indian and Alaska Native alone Asian alone Native Hawaiian and Other Pacific Islander alone Some Other Race alone Two or More Races

3.2 Defining Co-Location Quotients

The next sections focus on a description of the co-location quotient method for measuring the levels of racial and ethnic segregation and give an empirical example to demonstrate its application using census data. Even though the original formulation of the co-location was not specified for implementation in segregation studies, the idea of co-location has the potential to serve as the basis for a new segregation measure. A co-location quotient (CLQ) is an extension of the concept of location quotients (LQ) that are used in economic geography to identify the specialization of a given region in a particular industry. The notion of a CLQ based on LQ was introduced by Leslie and Kronenfeld (2010) to measure the degree of spatial association between two categorical variables, applying the technique to point data. The original method is based on distance ranks and considers only nearest neighbors. By definition, $CLQ_{A\rightarrow B}$ is the ratio of observed to expected proportions of population size B among category A's nearest neighbors.

The value of the $CLQ_{A\rightarrow B}$ is the degree of spatial attraction of category A to category B. It is the ratio of ratios and is based on probability of interaction of points of type A with nearest neighbor points of type B. The method applies to global and pairwise associations between categorical variables based on nearest neighbor relationships. It is important to note that the nature of the spatial association is taken as *asymmetric*, meaning that the spatial attraction of points of category A to B might not be of the same magnitude as the one of B to A.

A further development of co-location quotients was done by Cromley, Hanink and Bentley (2012) who extended the concept of a CLQ by developing a geographically weighted variant of the measure, thus locally applying the quotient to spatial neighborhoods defined by using spatially fixed or spatially adaptive filters, and assigning the weights within the defined neighborhoods by different types of kernel density functions. The measure was applied to point data represented as housing units of various types (Cromley, Hanink and Bentley, 2014).

In a similar manner the CLQ can be applied to the areal data where each area contains the population of several categories, but assuming that the level of interaction of only two of them, A and B, is of interest. The CLQ has a general form:

$$CLQ(A|B) = P(A|B)/P(B) \tag{3.1}$$

where $P(A|B)$ is the probability of interaction between subgroup A and subgroup B in the area given the total possible interactions of B’s with all the members of population, and P(B) is the probability of finding a person of category B in the urban area.

3.2.1 The Global Co-Location Quotient

First, the global version of co-location quotient is specified below. It is applied to areal data of a meaningful geographical region. The global co-location quotient for measuring the level of residential segregation can be formulated as:

$$CLQ(A|B) = \frac{\sum_{i=1}^{T} a_i(\sum_j w_{ij} b_j) / \sum_{i=1}^{T} a_i(\sum_{j=1}^{T} w_{ij} n_j)}{B/(N-1)} \tag{3.2}$$

where:

$$w_{ij} = \begin{cases} 1, & \text{if } j \epsilon\, neighborhood \text{ of } i \\ 0, & \text{otherwise} \end{cases}$$

$$n_j = \begin{cases} N_j, & if\ j \neq i \\ (N_j - 1), & \text{otherwise} \end{cases}$$

$$a_j = \begin{cases} A_j, & if\ j \neq i \\ (A_j - 1), & \text{otherwise} \end{cases}$$

a_i – population of category A in tract i;
A_j – population of category A in tract j;
b_j – population of category B in tract j;
N_j – total population of tract j;
$i = 1,\dots,T$ – total number of tracts in the city;
A – total city population of category A;
B – total city population of category B;
N – total city population;
w_{ij} – spatial weights defining the neighborhood relationship.

CLQ (A|B) indicates how likely is the co-location with persons of category A given the location of persons of category B, or how likely for persons of category B to co-locate with ones of category A.

Also, the likelihood of co-locating of persons of category A with the same category population can be formulated in global version as:

$$CLQ(A|A) = \frac{\sum_{i=1}^{T} a_i(\sum_j w_{ij} a_j)/\sum_{i=1}^{T} a_i(\sum_{j=1}^{T} w_{ij} n_j)}{(A-1)/(N-1)} \qquad (3.3)$$

Similarly, CLQ (A|A) would indicate how likely for person of category A to co-locate with persons in the same category compared against the region as a whole.

In these formulations, a neighborhood is defined in terms of zero-order, first-order, up to n-order neighbors. In a zero-order neighborhood, w_{ij} equals 1 whenever $i=j$ and zero otherwise; this only bases segregation levels on potential interaction within each areal unit. A zero-order global CLQ is aspatial in the sense that the spatial arrangement of the *ai*, *bi*, and *Ni* values would have no impact on the calculation. The zero-order global CLQ shares this characteristic with the Index of Dissimilarity. In a first-order neighborhood, w_{ij} equals 1 whenever $i=j$ or j is contiguous to i. The next higher order neighborhoods includes all lower order neighbors plus any units that are contiguous to any lower order neighbor. First-order and higher global CLQs are similar in this feature with a spatial weighted Index of Dissimilarity.

3.2.2 Local Co-Location Quotients

The values of the CLQ in the formulae above represent the measure interpreted globally, as they are computed for the overall urban area. CLQ also has the potential to be used locally, thus producing the likelihood of population interactions with respect to each census tract or block group. Such measure has the following form:

$$CLQ^L(A|B) = \frac{a_i(\sum_j w_{ij} b_j)\;/a_i(\sum_{j=1} w_{ij} n_j)}{B/(N-1)} \qquad (3.4)$$

And for same group interaction:

$$CLQ^L(A|A) = \frac{a_i(\sum_j w_{ij} a_j)\;/a_i(\sum_{j=1} w_{ij} n_j)}{(A-1)/(N-1)} \qquad (3.5)$$

where the terms are the same as in equation (3.2) and (3.3), except that i = 1, …, T, where T stands for the number of areal units in the neighborhood of that areal unit. Equation (3.5) can be simplified by cancelling a_i from the numerator ratio. However, if a_i equals zero the numerator ratio is undefined;

Chapter Six discusses a cartographic approach that resolves this conundrum. The simplified CLQ^L(A|B) has the following form:

$$CLQ^L(A|B) = \frac{(\sum_j w_{ij} b_j) / (\sum_{j=1} w_{ij} n_j)}{B/(N-1)} \qquad (3.6)$$

And, for same group interaction the local CLQ is:

$$CLQ^L(A|A) = \frac{(\sum_j w_{ij} a_j) / (\sum_{j=1} w_{ij} n_j)}{(A-1)/(N-1)} \qquad (3.7)$$

The formulation of local CLQ is based on the notion of spatial non-stationarity and the weighting function allows for choosing various size neighborhoods for the analysis. Spatial non-stationarity means that the process would not produce the same values over the spatial domain. The weighting function w_{ij} above can be defined using either kernel density functions or topological relationships among areal units.

3.2.3 The Dimensionality of Co-Location

To address the issue of dimensionality associated with a segregation measure, it can be demonstrated that the CLQ can incorporate at least two of Massey and Denton's dimensions. Primarily the CLQ is a measure of exposure, but its range of values can also be tied to the evenness and concentration dimensions. Those dimensions can be expressed through lower and upper bounds for two-group and same-group CLQs (Fig. 3.1). The global two-group CLQ has a range from 0 to 1, being 0 at where there is perfect concentration in which all members of a group are located in areal units with no members of another group, and 1 where there is a state of evenness in which the same proportion of each group is present across all areal units. The lower bound of zero would only occur for the case in which a zero-order nearest neighborhood is used in the calculation; as the order of the neighborhood increases, the lower bound will become closer and closer to one.

The same-group CLQ lies in values from 1 to any value more than 1, where 1 would refer to even distribution and values more than 1 would be approaching concentration.

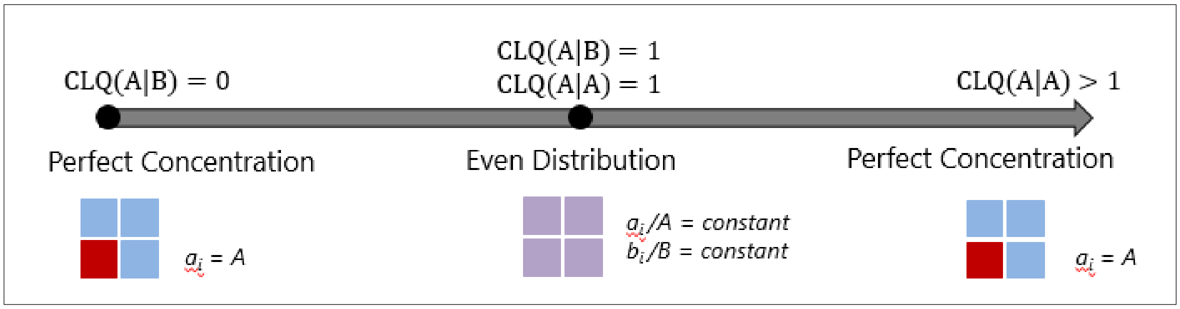


Figure 3.1 Fitting CLQ into Different Dimensions of Segregation

The ranges of the values imply the upper and lower bounds of the global measure. For the even distribution of groups that would indicate the absence of segregation in the urban area, assume that proportions of the A and B populations for the city are r and p respectively, where:

$$r = A/N \;\Rightarrow\; A = rN$$

$$\text{and,}\quad p = B/N \Rightarrow B = pN.$$

When populations are evenly distributed, each areal unit has the same proportion of minority and majority group members as for the city overall. Thus, for every unit i: $a_i = rN_i$, and $b_i = pN_i$. After substitution these values into equation (3.2), we have:

$$CLQ(A|B) = \frac{N\sum_i N_i^2 - \sum_i N_i^2}{N\sum_i [N_i^2 - N_i]} \approx 1 \qquad (3.8)$$

Substituting the same values into equation (3.3), we have the lower bound for co-location with the same group:

$$CLQ(A|A) = \frac{\sum_i (rN_i^2 - N_i)/\sum_i (N_i^2 - N_i)}{(rN-1)/(N-1)} = \frac{(r\sum_i N_i^2 - N)(N-1)}{(\sum_i N_i^2 - N)(rN-1)} \approx 1 \qquad (3.9)$$

The co-location value appears to be close to unity when the proportions of population group of interest are the same across the area and equal the proportion of that group for the city overall. In the two-group case (eq. 3.8), proportions of both groups are assumed to be constant equaling to the city proportions respectfully. The even intensity of the population distribution translates to the even intensity of population interaction or co-location. Assuming that the urban area is perfectly concentrated meaning that all the minority or majority group members reside in one areal unit, CLQ(A|B) will equal zero and CLQ(A|A) will have the following value representing the upper bound:

$$\mathrm{CLQ}(A|A)=\frac{N-1}{N_i-1} \qquad (3.10)$$

As N is assumed to exceed any N_i with number of tracts more than one and $(N-N_i) > 1$, the CLQ(A|A) will have a value more than one. The higher the value the more concentrated the population group is.

The interplay of different dimensions in the measurement reflects the versatility of the co-location in its ability to capture multi-faceted aspects of segregation in the study area. The logic of deriving co-location for two-group and same-group cases is not new to the literature on segregation. At least one segregation measure, the interaction index (Lieberson, 1981) measures levels of segregation for two variants, where same-group measure is referred as isolation index, or the degree of group's concentration in the area. Similar insight is provided here, where CLQ(A|B) can be treated as index of the potential of interaction, and CLQ(A|A) as the index of concentration.

These upper and lower bounds only apply to the global CLQ. An examination of equation (3.6) shows that the $\mathrm{CLQ}^L(A|B)$ measure only depends on the distribution of b_i values. A zero-order local co-location quotient is almost the same as the more familiar location quotient (LQ). A zero-order local CLQ only differs from an LQ in that the denominator ratio for the CLQ is B/(N-1) rather than B/N in the case of an LQ. A first-order or higher local CLQ is very similar to focal location quotients (Cromley and Hanink, 2012). In all of these cases, an index value equal to one indicates the expected value, and values below 1 are less than expected and values above one are greater than expected.

3.3 An Empirical Example

To demonstrate the application of the CLQ, it is tested on three metropolitan statistical areas and Washington, D.C. as defined by the 2010 Census. The set of three MSAs consists of Los Angeles, CA, St. Louis, MO and Tampa, FL. These are the short names of these MSAs. The Los Angeles MSA includes an area outside city of Los Angeles and is identified by the census as Los Angeles-Long Beach-Santa Ana, CA. The Tampa MSA covers areas beyond Tampa's city limits and is listed as Tampa-St. Petersburg-Clearwater, FL. The St. Louis MSA also includes some counties in Illinois.

3.3.1 Global CLQ Example

Figure 3.2 shows distribution of the black population in the chosen areas. Overall, the black population subgroup tends to concentrate within center city areas. A particular pattern is present in Washington, D.C. where the city area is split into two, one predominantly black and one predominantly white area. Also, as can be noted from Table 3.1 the number of census tracts in D.C. is much less than in the three MSAs. Also, due to higher concentrations of population in the center city areas, census tracts are of smaller sizes in the MSA centers than in the outskirts of the metropolitan areas.

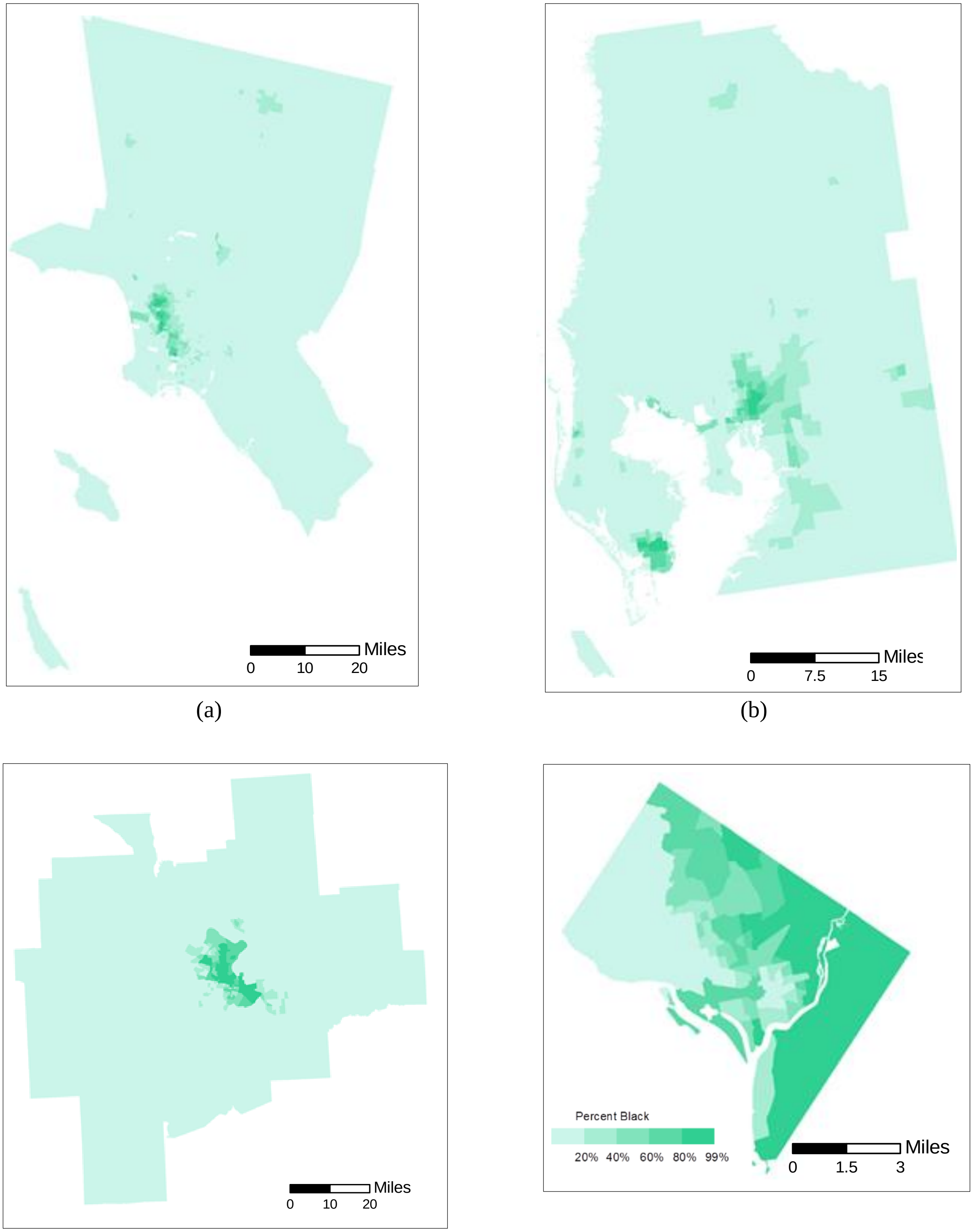
Table 3.5 summarizes the patterns observed for whites and blacks. Washington, D.C. has low values for both co-location with whites given blacks and co-location with blacks given the location of whites. Within Washington D.C., the number of black dominant (meaning blacks are more than 50% of the tract population) tracts is higher than the white dominant ones (103 versus 59 respectively out of 179 in total). Also the percentage of blacks is higher than the proportion of whites (51% versus 38% respectively), resulting in lower values of CLQ(B|W) than CLQ(W|B), where for whites it is more likely to encounter a person who is black than a person of any other race.

The St. Louis MSA has few blacks (18%) and whites are a more dominant group (77%), which produces a imbalance of CLQs between blacks and whites with CLQ(W|B) being slightly higher than CLQ(B|W). The Tampa MSA has somewhat higher values for two-group co-location values. Overall, percentages of whites and blacks are comparable with those for St. Louis. By looking at Figure 3.3 of the cumulative distributions of blacks by census tract it is evident that generally for Tampa there are relatively more census tracts with higher than expected (12%) proportions of blacks than for St. Louis (expected 18% blacks). This situation raises the question of further exploration of CLQ with respect to its sensitivity to various distribution patterns. The Los Angeles population is only 53% white and 7% black. Because the black population is so scarce the expected interaction of between blacks and whites is low, so whenever some blacks are found in census tract in many cases it may provide values close enough to expected, thus resulting in CLQ values being closer to the CLQs for Tampa.

Another set of values is same-group CLQs for these four areas. Whites outnumber the blacks in all areas except for Washington, DC. Thus the concentrations of blacks measured by CLQ(B|B) is higher where they are a minority group and inhabit a relatively smaller number of census tracts as is seen maps for St. Louis, Tampa and Los Angeles in Figure 3.2. Additionally, the concentration of blacks is higher in Los Angeles and St. Louis than in Tampa (3.81, 3.14 and 2.71 respectively) as in Tampa there are two major concentration areas of blacks – in city of Tampa and in the southern peninsula in the area of St. Petersburg, thus overall producing a less concentrated pattern.

Table 3.5 Global Co-Location Quotients Between Whites and Blacks, Based on 2010 Data.

MSA Name	Percent White	Percent Black	CLQ(B|W)	CLQ(W|B)	CLQ(W|W)	CLQ(B|B)
Los Angeles, CA	0.53	0.07	0.67	0.68	1.13	3.81
Tampa, FL	0.79	0.12	0.72	0.73	1.04	2.71
St. Louis, MO	0.77	0.18	0.40	0.49	1.14	3.14
Washington, DC	0.38	0.51	0.34	0.43	1.81	1.47



(a)

(b)

(c)

(d)

Figure 3.2 Distribution of Blacks, 2010: a) Los Angeles, CA; b) Tampa, FL; c) St. Louis, MO; and d) Washington D.C.

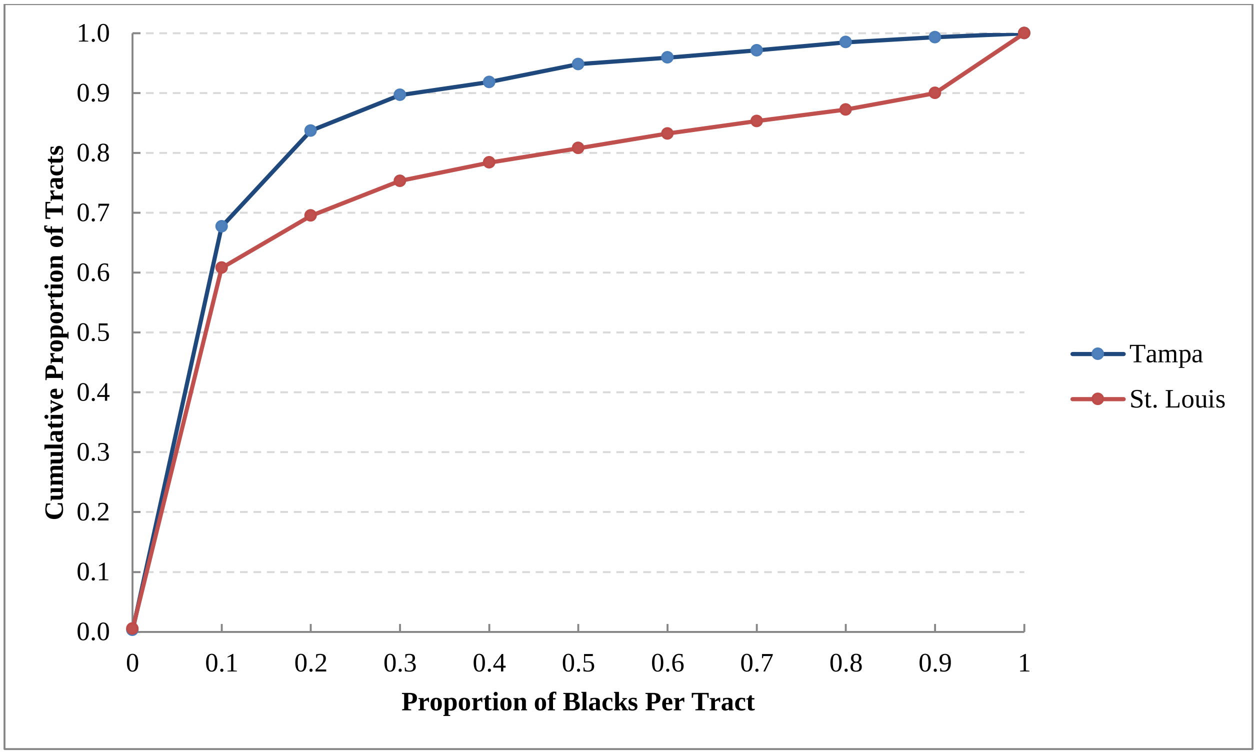


Figure 3.3 Cumulative Distributions of Blacks by Census Tract for Tampa and St. Louis MSAs, 2010.

3.3.2 Local CLQ Example

Focusing solely on global values of co-location may be misleading whenever the aim is to extract an insight about the local pattern of areal units with respect to the co-location of specific population groups. A global value by its nature is best applied to a homogenous space in which any spatial process produces a constant average value (Fotheringham et al., 2002). To see the extent and the amount of spatial variability in parameter values, it is necessary to employ local measures that measure changes in the results over space as well as to visualize those patterns (Lloyd, 2007). In this subsection, examples of using the local version of co-location quotient for investigating the patterns of segregation over each of the four chosen urban areas are demonstrated.

Figures 3.4 – 3.7 show distribution of local values of census tract CLQs across selected areas. In general, the distribution of local CLQs visually follows the distribution of blacks in the regions in Figure 3.2. For example, Figure 3.4 for Washington, D.C. shows that the co-location of whites with blacks is higher where relative proportions of blacks are high and proportions of whites are low. The opposite is true for blacks co-locating with whites. The black-white quotient is higher in the areas with a larger proportion whites. In this case it means that for any black it is more likely to find a white person than anyone else because the raw count of whites in the locality (or neighborhood) overcomes the count of blacks and the sum of other groups present in the area. In terms of same-group values of CLQs a subgroup's concentration tends to be higher where their proportions are bigger. If the area is black dominant, then for any black it is very likely to encounter another black person, and for any white in this area it is less likely to meet another white than any other group's representative including black population member.

Usage of the local CLQ is beneficial to highlight the areas of unusually high and low CLQ values in order to examine the area in details rather than to give a generalized value such as a global quotient. However the visual and quantitative description will depend on the scale of data used. Later chapters will examine the pattern of local CLQs at two different scales: block group and census tracts.

Figure 3.4 Local CLQs for Washington, D.C. Census Tracts, 2010

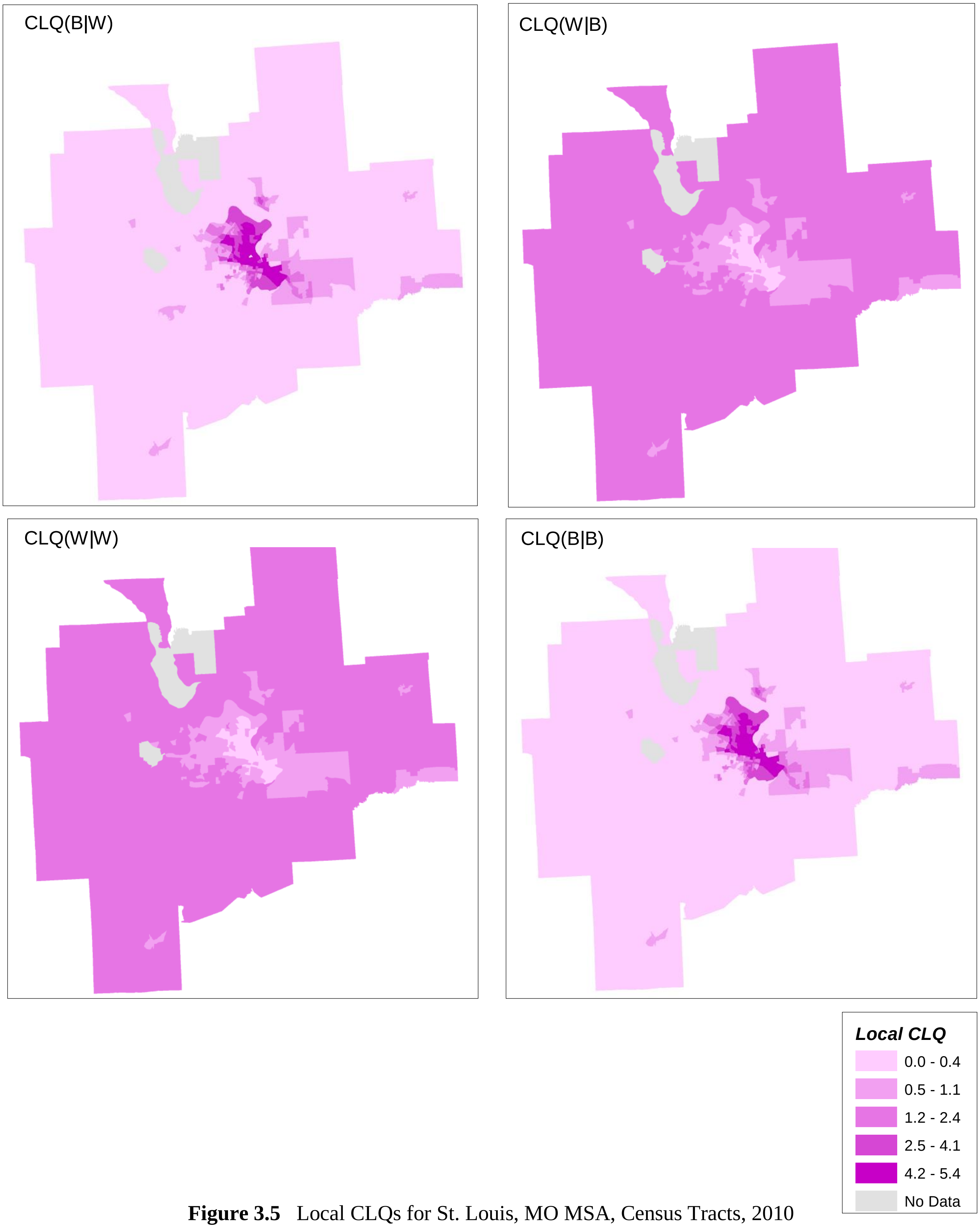


Figure 3.5 Local CLQs for St. Louis, MO MSA, Census Tracts, 2010

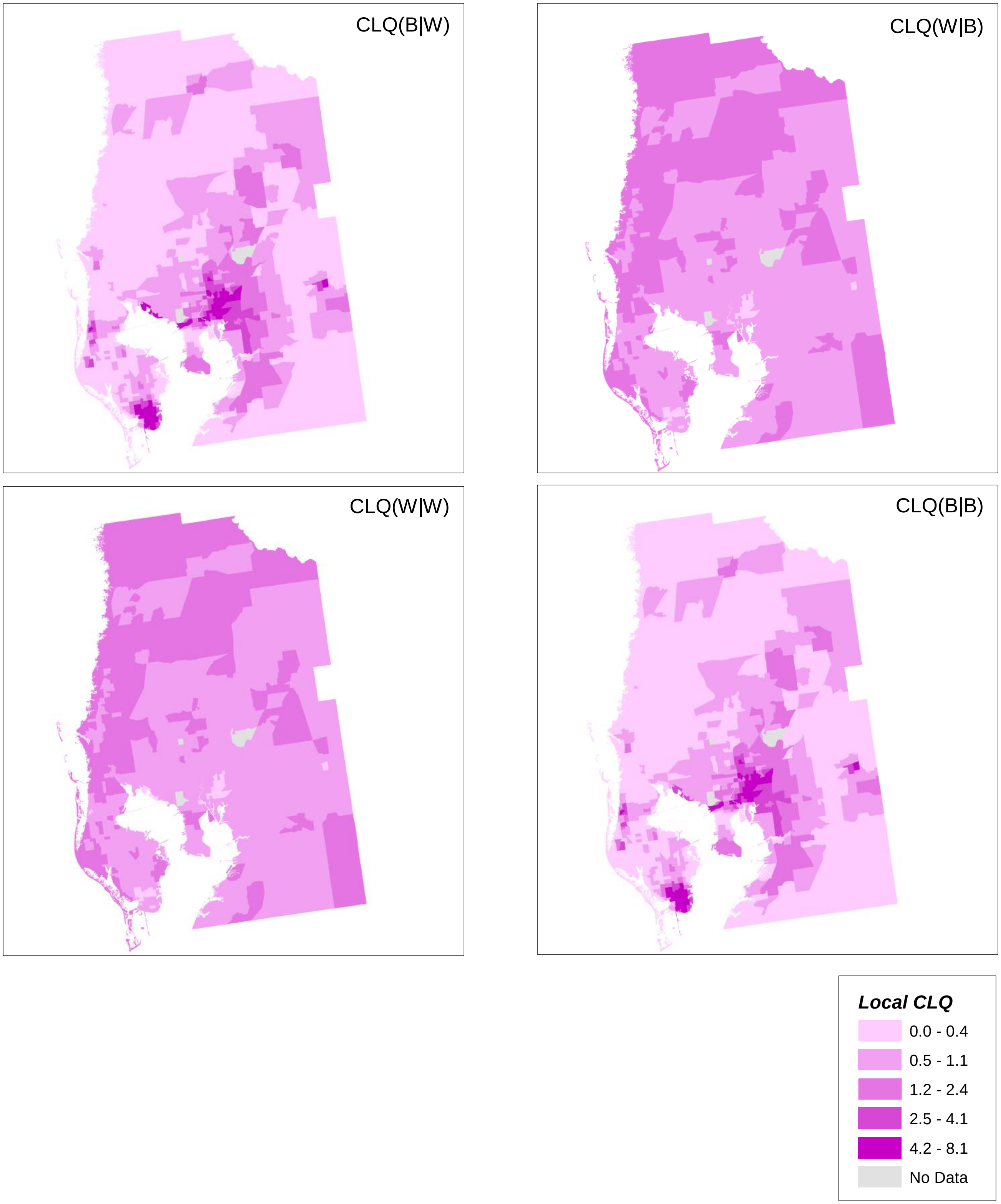


Figure 3.6 Local CLQs for Tampa, FL MSA, Census Tracts, 2010

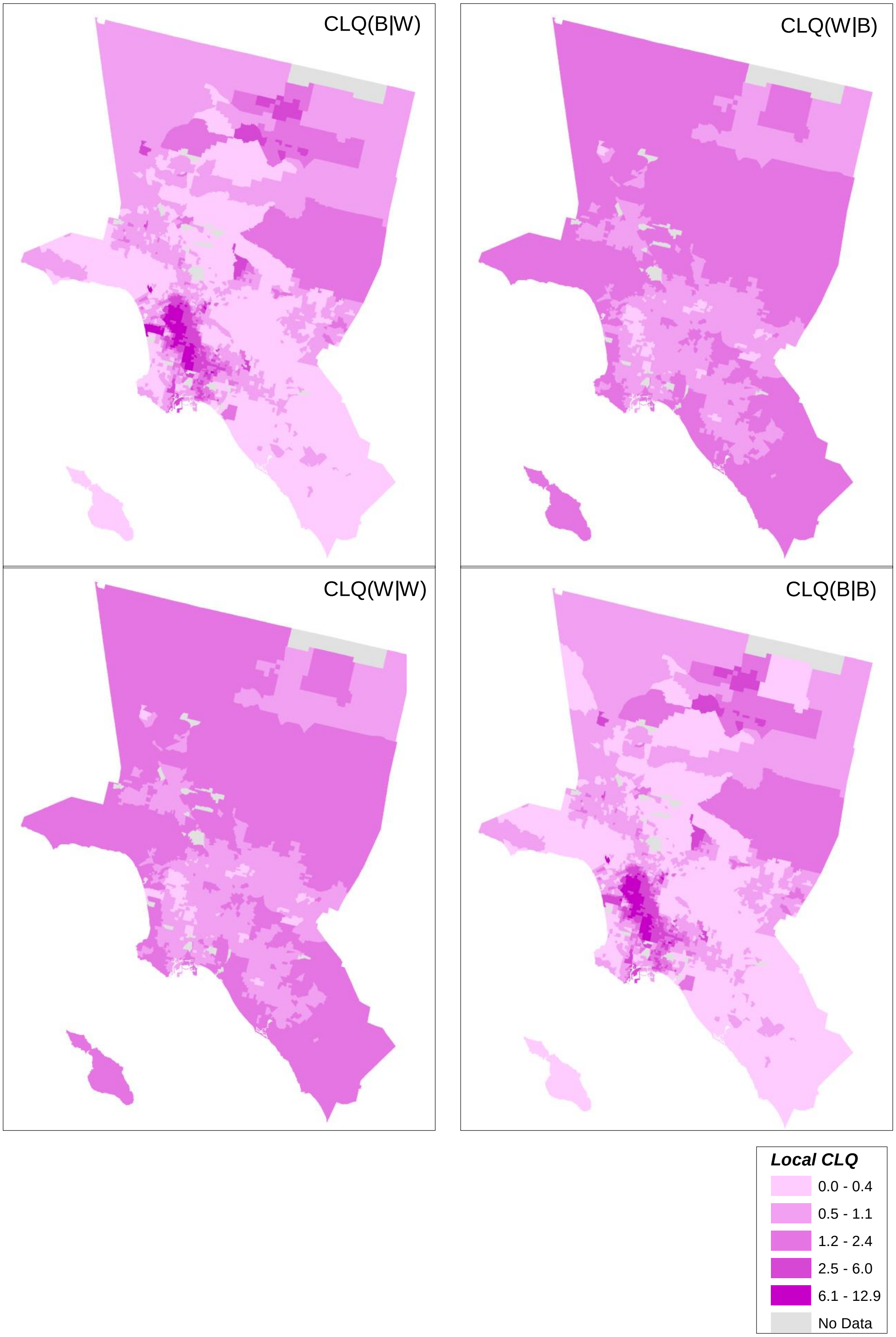


Figure 3.7 Local CLQs for Los Angeles, CA MSA, Census Tracts, 2010

3.4 Summary

This chapter introduces the co-location quotient in a formulation that can be applied to measure the levels of residential segregation using areal data. There are two formulations, capturing both global and local scales of segregation. Data that will be used further for comprehensive testing of the measures and analysis of the results are also described. Four urban areas were used as an example to demonstrate how both types of CLQs could be used.

However, it is not intended to present insights about the national or statewide trends of segregation of black population, but to provide a tangible example of using and interpreting results of computing the CLQs. Some of these preliminary results do raise questions about how sensitive the CLQ might be with respect to different statistical and spatial aspects of data distribution. As with any other quantitative analysis in geography, any analysis using the CLQ would be scale dependent. The pattern of residential segregation can change at different geographic scales. The next two chapters now investigate how results differ for two geographic scales for the global CLQ over a national sample of metropolitan areas (Chapter 4) and for the local CLQ within each of these metropolitan areas (Chapter 5).

CHAPTER FOUR

A Global Co-Location Quotient Analysis of Residential Segregation Change

4.1 Introduction

The purpose of this chapter is to examine the changes and trends in black-white residential segregation among selected metropolitan areas in the United States, and to compare results from the global co-location quotient with other measures such as the widely applied Theil's entropy index of diversity (Wright et al., 2011), Lieberson's interaction indices (Lieberson, 1981) and index of dissimilarity (Wong, 2004). It needs mentioning that the task here is not to explore the causal processes and particular contextual conditions that establish and maintain segregated black and white communities in certain metropolitan areas, but rather to reveal the usefulness of CLQ as a measure to track the existing racial disparities and its ability to provide a complete or partial image of the racial relationships across the space and over time.

It was mentioned in the previous chapter that the analysis would be conducted at two different spatial scales – census tract and block group levels. Kaplan and Holloway (2001) note that there might be different levels of segregation existing at different scales depending on the level of data detail. Therefore, the data scale reflects the context within which segregation persists and the methods suitable to measure it. This is especially true when dealing with drastically different levels of data, such as going from a household to a regional or national scale. Census tracts and block groups are defined similarly and do not represent the shift large enough to use different methodologies. Instead, examining out these two levels of data aggregation helps register the sensitivity of the CLQ to scale and its overall susceptibility to the level of detail. Also, when using two scales it is interesting to see whether the usage of these two different areal units may affect any insight into the dynamic of segregation over time, by matching 1990, 2000 and 2010 census years for each scale.

Finally, this chapter will explore how the selection of neighborhood size changes the value of CLQ. Is there an increase or decrease in CLQ values with increase of the neighborhood size, or it is dictated by particular urban area and its structure?

4.2 Co-Location Results at the Census Tract Level

Tables 4.1 and 4.6 list the global co-location quotients at census tract level computed for the three selected census years. Figures 4.1 - 4.4 visualize the trends and differences among the census years for each respective pairwise combination, where the MSAs are ranked according to their co-location values in 1990.

4.2.1 Two-group Co-Location

Over the two decades, there was an overall increase of the chance of interaction between two groups in both directions as can be seen in Tables 4.1 and 4.2. In that sense residential segregation has declined over twenty years as the co-location quotients of the most of the urban areas have increased. To confirm that trend based on co-location values, Table 4.3 provides summary of descriptive statistical measures for each year and each two-group measure. While the mean, median and minimum CLQ values have increased since 1990, their range of indices has declined. A positive indication of the decline in segregation is also an increase in the minimum co-location values. For co-location with whites given the location of blacks the maximum values and standard deviations have increased through time, but for co-location with blacks given the location with whites these statistics have decreased. Overall there is a higher likelihood of co-locating with whites than with blacks resulting from a higher exposure of blacks to whites than that of whites to blacks population group.

The change in black-white segregation is not even across the MSAs. The ranking of MSAs in 1990 for any of the CLQs does not retain the same order when shifting from 1990 to 2000 to 2010 (Figures 4.1 - 4.2, Tables 4.4 - 4.5). As the census year changes some MSAs take higher positions each time and some drop in their position relative to previous census year, and other metropolitan areas do not exhibit an only-increasing or only-decreasing trend in the change of their CLQ values. This is true for both the CLQ(W|B) and CLQ(B|W) indices. Figures 4.1 and 4.2 are useful for observing the range and unevenness of change in co-location for particular metro areas. Figure 4.1 shows the urban areas that have experienced the largest and smallest transformation over the years. The most changed MSAs in terms of co-location with whites given the location of blacks are Kansas City, Miami, Tampa, Los Angeles, San Francisco and Dallas, while the least changes occurred in Milwaukee, the District of Columbia, Cincinnati, New Orleans and Norfolk. In terms of co-location with blacks given the location of whites (Figure 4.2), the most changed areas are Detroit, Gary, Cleveland, Indianapolis, Kansas City and San Francisco, while the least changed are Milwaukee, St. Louis, Boston, Miami, Greensboro and Norfolk.

Table 4.4 represents the rankings of CLQ(W|B) in non-decreasing order. Leading positions among the most lacking interactions between whites and blacks, thus the most segregated, take Gary, Detroit, Cleveland, Chicago and Milwaukee in 1990 and 2000 with Chicago dropping from the group of five lowest in CLQ value in 2010 (Table 4.4). The first four mentioned MSAs and Chicago are still experiencing racial composition changes that are echoing the economic restructuring in 1960s and white flight processes.

From perspective of blacks least exposed to whites, the set of urban areas is less constant (Table 4.5). Detroit and Chicago stay in the top five lowest CLQ rankings for the three census years. The downside of ranking is that it reflects the relative positions of urban areas among themselves, but ignores the absolute numeric values. Thus over two decades the Milwaukee MSA climbed from position six in 1990 and the same position in 2000 to the lowest CLQ in 2010 even though there was an increase from 0.373 to 0.391 between 1990 and 2000, and in 2010 when it was the lowest in terms of the co-location of blacks with whites its value had only slightly decreased to 0.390. In fact, the difference of 0.001 is negligible compared to, for example, with difference of over 0.1 for Boston MSA between the same two census years (Table 4.1). This is due to the overall average increase in co-location with blacks given the location of whites that occurred at the national scale, and sole change in ranking without insight about the actual variation in absolute values (as reflected in Figure 4.2) should be taken with distrust, unless the way to rank the MSAs in designed to account for relative changes in CLQ values across the census years.

Table 4.1 Global Co-Location Quotients for Between Groups Computed at the Census Tract Level Using a Zero Order Neighborhood for the Years 1990, 2000 and 2010*

MSA	CLQ(W|B)			CLQ(B|W)		
	1990	2000	2010	1990	2000	2010
Atlanta	0.458	0.454	0.595	0.511	0.567	0.601
Baltimore	0.417	0.439	0.485	0.461	0.512	0.525
Birmingham	0.415	0.385	0.466	0.427	0.481	0.585
Boston	0.453	0.499	0.558	0.568	0.572	0.616
Buffalo	0.340	0.350	0.377	0.407	0.429	0.484
Chicago	0.234	0.277	0.349	0.274	0.349	0.439
Cincinnati	0.413	0.428	0.451	0.500	0.547	0.615
Cleveland	0.231	0.273	0.319	0.297	0.379	0.490
Columbus	0.455	0.530	0.591	0.598	0.668	0.686
Dallas	0.516	0.602	0.705	0.614	0.689	0.720
Detroit	0.197	0.226	0.331	0.234	0.255	0.425
District Of Columbia	0.323	0.290	0.340	0.376	0.370	0.434
Gary	0.153	0.227	0.339	0.292	0.323	0.480
Greensboro	0.545	0.564	0.631	0.660	0.708	0.668
Houston	0.545	0.580	0.690	0.616	0.619	0.726
Indianapolis	0.406	0.401	0.487	0.501	0.569	0.655
KansasCity	0.364	0.404	0.517	0.547	0.589	0.706
Los Angeles	0.504	0.626	0.668	0.518	0.612	0.683
Memphis	0.442	0.474	0.520	0.511	0.528	0.599
Miami	0.436	0.528	0.609	0.600	0.552	0.593
Milwaukee	0.261	0.265	0.290	0.373	0.391	0.390
Newark	0.281	0.324	0.372	0.373	0.396	0.452
New Orleans	0.446	0.419	0.487	0.504	0.473	0.603
New York	0.376	0.385	0.440	0.392	0.411	0.471
Norfolk	0.646	0.692	0.689	0.778	0.770	0.748
Philadelphia	0.362	0.423	0.470	0.358	0.432	0.495
Pittsburg	0.414	0.447	0.498	0.594	0.620	0.691
San Francisco	0.511	0.590	0.700	0.557	0.642	0.719
St. Louis	0.328	0.389	0.403	0.457	0.466	0.490
Tampa	0.447	0.604	0.724	0.651	0.654	0.726

Table 4.2 Changes in Co-Location Values for MSAs Between 1990 and 2010

MSA	W|B	B|W
Atlanta	↓↑	↑↑
Baltimore	↑↑	↑↑
Birmingham	↓↑	↑↑
Boston	↑↑	↑↑
Buffalo	↑↑	↑↑
Chicago	↑↑	↑↑
Cincinnati	↑↑	↑↑
Cleveland	↑↑	↑↑
Columbus	↑↑	↑↑
Dallas	↑↑	↑↑
Detroit	↑↑	↑↑
District Of Columbia	↓↑	↓↑
Gary	↑↑	↑↑
Greensboro	↑↑	↑↓
Houston	↑↑	↑↑
Indianapolis	↓↑	↑↑
KansasCity	↑↑	↑↑
Los Angeles	↑↑	↑↑
Memphis	↑↑	↑↑
Miami	↑↑	↓↑
Milwaukee	↑↑	↑↓
Newark	↑↑	↑↑
New Orleans	↓↑	↓↑
New York	↑↑	↑↑
Norfolk	↑↓	↓↓
Philadelphia	↑↑	↑↑
Pittsburg	↑↑	↑↑
San Francisco	↑↑	↑↑
St. Louis	↑↑	↑↑
Tampa	↑↑	↑↑

* Up-looking arrow indicates increase in CLQ value, down-looking arrow indicates the respective decrease in values. The first arrow displays the change that occurred between 1990 and 2000, the second – between 2000 and 2010

Table 4.3 Descriptive Statistics for Co-Location with Whites Given the Location of Blacks (W|B) and with Blacks Given the Location of Whites (B|W) for 1990, 2000 and 2010

	CLQ	1990	2000	2010
Mean	W|B	0.397	0.437	0.503
	B|W	0.485	0.519	0.584
Median	W|B	0.414	0.425	0.487
	B|W	0.503	0.537	0.600
Range	W|B	0.493	0.466	0.434
	B|W	0.544	0.515	0.358
Minimum	W|B	0.153	0.226	0.290
	B|W	0.234	0.255	0.390
Maximum	W|B	0.646	0.692	0.724
	B|W	0.778	0.770	0.748
Standard Deviation	W|B	0.112	0.126	0.133
	B|W	0.130	0.127	0.110

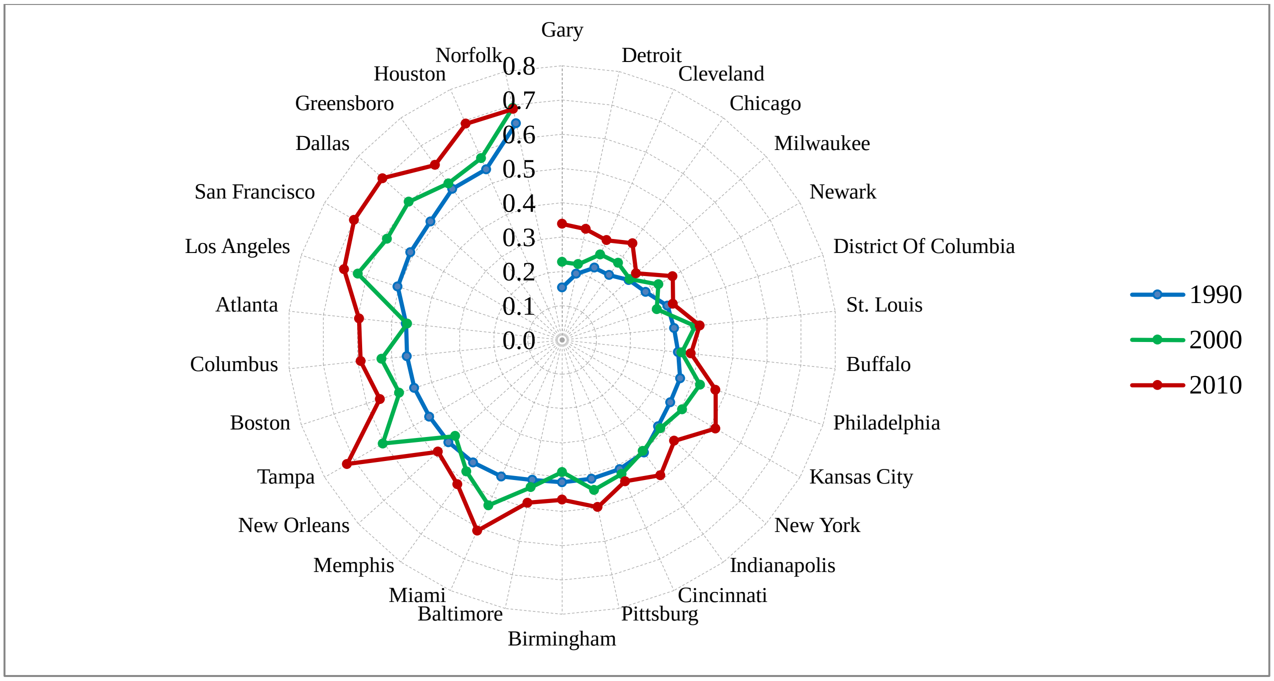


Figure 4.1 Diagram of the Urban Area Rankings for Co-Location with Whites Given the Location of Blacks (W|B) at the Census Tract Level

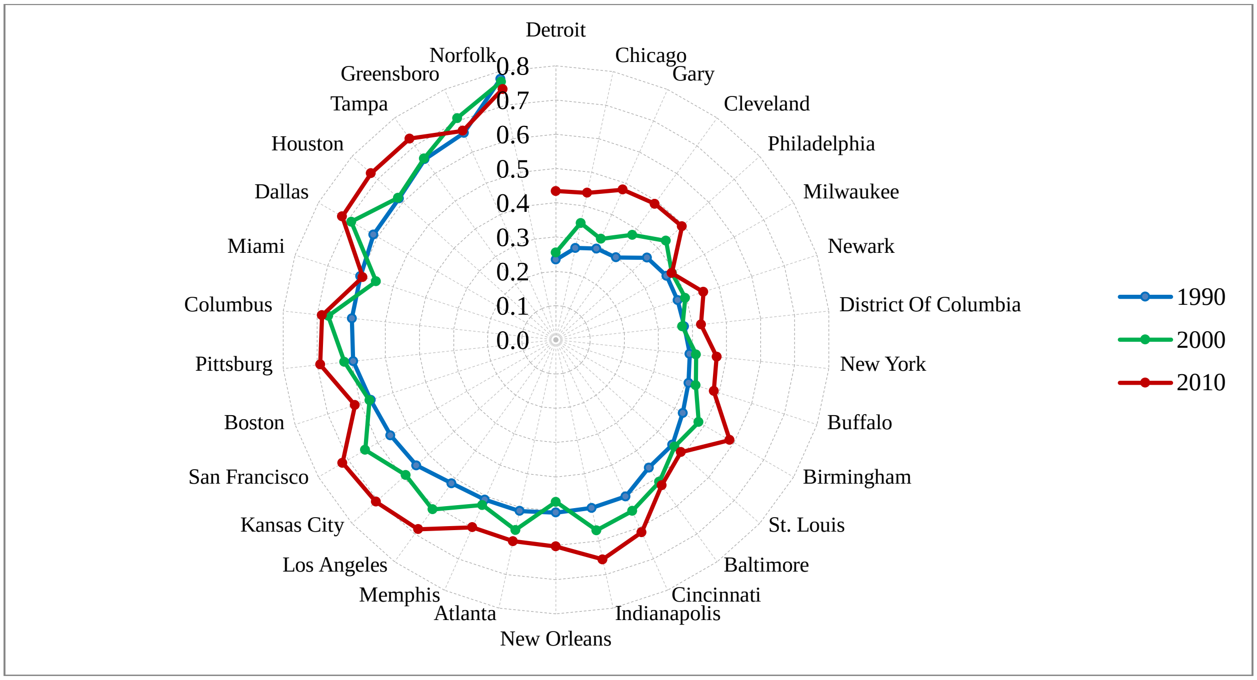


Figure 4.2 Diagram of the Urban Area Rankings for Co-Location with Blacks Given the Location of Whites (B|W) at the Census Tract Level

Table 4.4 Ranking of Co-Location with Whites Given the Location of Blacks (W|B) in Ascending Order.

	1990		2000		2010
1	Gary		Detroit		Milwaukee
2	Detroit		Gary		Cleveland
3	Cleveland		Milwaukee		Detroit
4	Chicago		Cleveland		Gary
5	Milwaukee		Chicago		District Of Columbia
6	Newark		District Of Columbia		Chicago
7	District Of Columbia		Newark		Newark
8	St. Louis		Buffalo		Buffalo
9	Buffalo		New York		St. Louis
10	Philadelphia		Birmingham		New York
11	Kansas City		St. Louis		Cincinnati
12	New York		Indianapolis		Birmingham
13	Indianapolis		Kansas City		Philadelphia
14	Cincinnati		New Orleans		Baltimore
15	Pittsburg		Philadelphia		New Orleans
16	Birmingham		Cincinnati		Indianapolis
17	Baltimore		Baltimore		Pittsburg
18	Miami		Pittsburg		Kansas City
19	Memphis		Atlanta		Memphis
20	New Orleans		Memphis		Boston
21	Tampa		Boston		Columbus
22	Boston		Miami		Atlanta
23	Columbus		Columbus		Miami
24	Atlanta		Greensboro		Greensboro
25	Los Angeles		Houston		Los Angeles
26	San Francisco		San Francisco		Norfolk
27	Dallas		Dallas		Houston
28	Greensboro		Tampa		San Francisco
29	Houston		Los Angeles		Dallas
30	Norfolk		Norfolk		Tampa

Table 4.5 Ranking of Co-Location with Blacks given the Location of Whites (B|W) in Ascending Order

	1990		2000		2010
1	Detroit		Detroit		Milwaukee
2	Chicago		Gary		District Of Columbia
3	Gary		Chicago		Detroit
4	Cleveland		District Of Columbia		Chicago
5	Philadelphia		Cleveland		Newark
6	Milwaukee		Milwaukee		New York
7	Newark		Newark		Gary
8	District Of Columbia		New York		Buffalo
9	New York		Buffalo		St. Louis
10	Buffalo		Philadelphia		Cleveland
11	Birmingham		St. Louis		Philadelphia
12	St. Louis		New Orleans		Baltimore
13	Baltimore		Birmingham		Birmingham
14	Cincinnati		Baltimore		Miami
15	Indianapolis		Memphis		Memphis
16	New Orleans		Cincinnati		Atlanta
17	Atlanta		Miami		New Orleans
18	Memphis		Atlanta		Cincinnati
19	Los Angeles		Indianapolis		Boston
20	Kansas City		Boston		Indianapolis
21	San Francisco		Kansas City		Greensboro
22	Boston		Los Angeles		Los Angeles
23	Pittsburg		Houston		Columbus
24	Columbus		Pittsburg		Pittsburg
25	Miami		San Francisco		Kansas City
26	Dallas		Tampa		San Francisco
27	Houston		Columbus		Dallas
28	Tampa		Dallas		Tampa
29	Greensboro		Greensboro		Houston
30	Norfolk		Norfolk		Norfolk

4.2.2 Same-group Co-Location

Although the two-group measures differ to a modest degree overall, the differences between same-group CLQs uncover unequal experiences for blacks and whites in the metropolitan areas around the U.S. even though there was an overall decrease of isolation of blacks between 1990 and 2010. Overall, the black population is much more isolated than the white population.

In examining the concentration of blacks and whites (Figures 4.3 and 4.4), the trend for whites differed from that of blacks. Overall, the white population has experienced little change in concentration according to global values. The most noticeable change occurred for District of Columbia where concentration of whites has decreased over time from 2.41 in 1990 to 1.81 in 2010. The other slight fluctuations occurred in New Orleans (decreased by 2010) and Atlanta (increased by 2010) (see Figure 4.3).

The concentration trend for blacks was a much different pattern. In general, the concentration of blacks is much higher than that of whites across MSAs with the exception of the District of Columbia. The values of the same-group co-location for whites ranged between 1.0 and 1.5 (except for District of Columbia) at the tract level, but the CLQs for all urban areas was greater than 2.0 with respect to co-location of blacks given the location of blacks. Also, the metropolitan areas experienced greater changes in terms of concentration of black population. Only several metropolitan areas (the District of Columbia, Norfolk, Memphis, New York and Los Angeles) experienced very little change. The largest transformations occurred in the Boston, Pittsburg, Buffalo, Tampa and Indianapolis MSAs.

Table 4.6 Global Co-Location Quotients for Within Groups Computed at the Census Tract Level Using a Zero Order Neighborhood for the Years 1990, 2000 and 2010*

MSA	CLQ(W|W)			CLQ(B|B)		
	1990	2000	2010	1990	2000	2010
Atlanta	1.188	1.249	1.251	2.412	1.976	1.745
Baltimore	1.204	1.225	1.245	2.500	2.199	1.996
Birmingham	1.211	1.241	1.226	2.589	2.333	2.003
Boston	1.051	1.067	1.077	6.952	5.584	4.218
Buffalo	1.083	1.101	1.108	5.965	4.885	4.273
Chicago	1.241	1.239	1.206	3.763	3.489	3.302
Cincinnati	1.074	1.078	1.081	4.956	4.292	3.550
Cleveland	1.176	1.191	1.194	4.172	3.486	2.889
Columbus	1.071	1.077	1.084	3.932	3.022	2.549
Dallas	1.115	1.113	1.099	3.091	2.559	2.213
Detroit	1.234	1.244	1.217	3.649	3.394	2.821
District Of Columbia	2.421	2.282	1.806	1.298	1.352	1.466
Gary	1.215	1.201	1.183	3.986	3.763	2.989
Greensboro	1.107	1.123	1.129	2.463	2.079	2.013
Houston	1.143	1.143	1.123	2.496	2.388	1.905
Indianapolis	1.094	1.108	1.113	4.172	3.373	2.582
Kansas City	1.096	1.103	1.095	4.136	3.653	2.769
Los Angeles	1.141	1.154	1.127	4.091	3.957	3.813
Memphis	1.393	1.428	1.447	1.696	1.585	1.433
Miami	1.118	1.123	1.116	2.819	2.646	2.334
Milwaukee	1.136	1.176	1.187	4.773	3.993	3.655
Newark	1.228	1.240	1.232	3.058	2.811	2.596
New Orleans	1.304	1.380	1.307	1.876	1.802	1.672
New York	1.306	1.354	1.333	2.551	2.526	2.446
Norfolk	1.137	1.151	1.162	1.528	1.453	1.476
Philadelphia	1.162	1.172	1.181	3.600	2.992	2.572
Pittsburg	1.047	1.051	1.051	6.065	5.200	4.096
San Francisco	1.125	1.164	1.165	3.322	2.955	2.548
St. Louis	1.134	1.139	1.145	3.721	3.384	3.144
Tampa	1.059	1.054	1.041	4.323	3.605	2.710

Table 4.7 Descriptive Statistics for Within Group Co-Location at the Census Tract Level for 1990, 2000 and 2010

	CLQ	1990	2000	2010
Mean	W|W	1.201	1.212	1.191
	B|B	3.532	3.091	2.659
Median	W|W	1.139	1.159	1.163
	B|B	3.624	3.007	2.577
Range	W|W	1.374	1.231	0.765
	B|B	5.654	4.232	2.840
Minimum	W|W	1.047	1.051	1.041
	B|B	1.298	1.352	1.433
Maximum	W|W	2.421	2.282	1.806
	B|B	6.952	5.584	4.273
Standard Deviation	W|W	0.245	0.223	0.146
	B|B	1.348	1.070	0.819

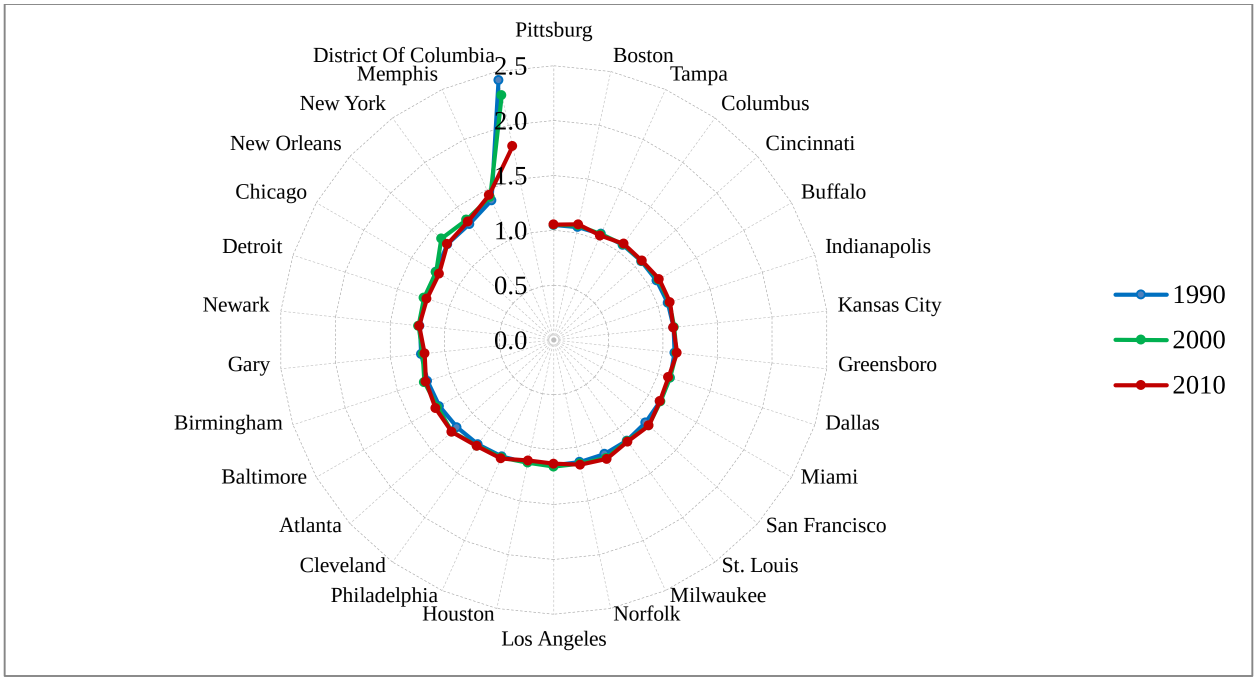


Figure 4.3 Diagram of the Urban Area Rankings for Co-Location with Whites Given the Location of Whites (W|W) at the Census Tract Level.

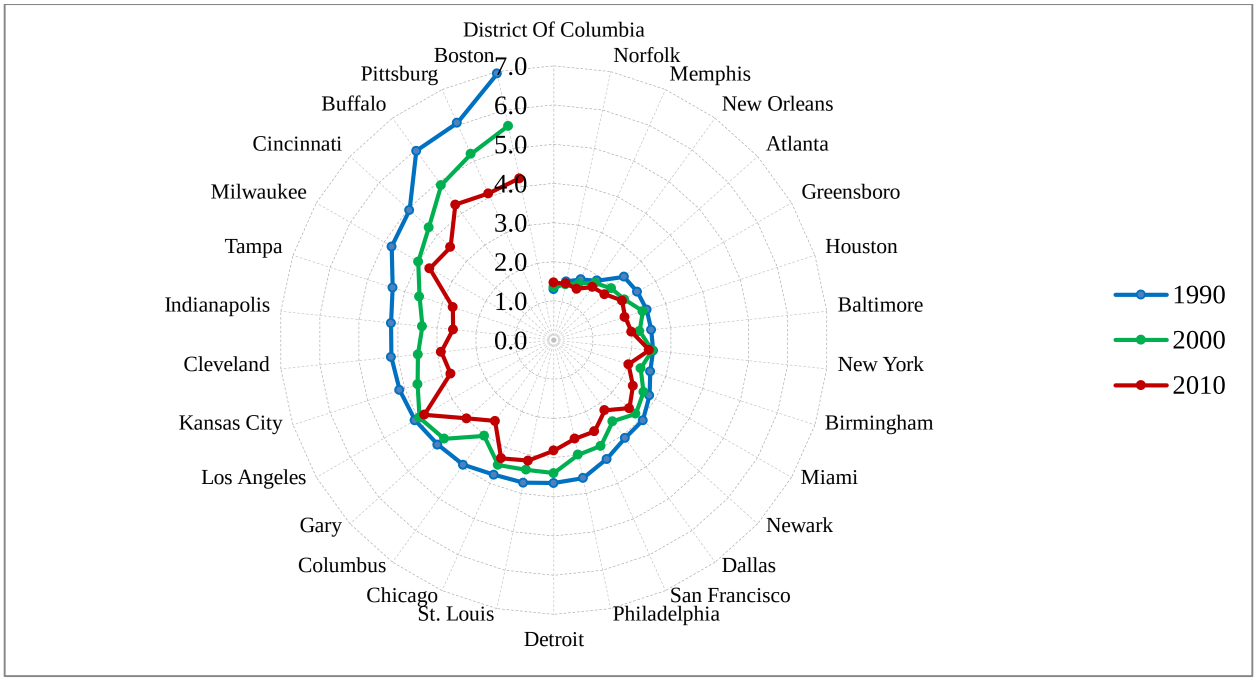


Figure 4.4 Diagram of the Urban Area Ranking for Co-Location with Blacks Given the Location of Blacks (B|B) at the Census Tract Level.

Table 4.8 Ranking for Co-Location with Whites Given the Location of Whites (W|W) in Ascending Order.

	1990		2000		2010
1	Pittsburg		Pittsburg		Tampa
2	Boston		Tampa		Pittsburg
3	Tampa		Boston		Boston
4	Columbus		Columbus		Cincinnati
5	Cincinnati		Cincinnati		Columbus
6	Buffalo		Buffalo		Kansas City
7	Indianapolis		Kansas City		Dallas
8	Kansas City		Indianapolis		Buffalo
9	Greensboro		Dallas		Indianapolis
10	Dallas		Miami		Miami
11	Miami		Greensboro		Houston
12	San Francisco		St. Louis		Los Angeles
13	St. Louis		Houston		Greensboro
14	Milwaukee		Norfolk		St. Louis
15	Norfolk		Los Angeles		Norfolk
16	Los Angeles		San Francisco		San Francisco
17	Houston		Philadelphia		Philadelphia
18	Philadelphia		Milwaukee		Gary
19	Cleveland		Cleveland		Milwaukee
20	Atlanta		Gary		Cleveland
21	Baltimore		Baltimore		Chicago
22	Birmingham		Chicago		Detroit
23	Gary		Newark		Birmingham
24	Newark		Birmingham		Newark
25	Detroit		Detroit		Baltimore
26	Chicago		Atlanta		Atlanta
27	New Orleans		New York		New Orleans
28	New York		New Orleans		New York
29	Memphis		Memphis		Memphis
30	District Of Columbia		District Of Columbia		District Of Columbia

Table 4.9 Ranking of Co-Location Values with Blacks Given the Location of Blacks (B|B) in Ascending Order

	1990		2000		2010
1	District Of Columbia		District Of Columbia		Memphis
2	Norfolk		Norfolk		District Of Columbia
3	Memphis		Memphis		Norfolk
4	New Orleans		New Orleans		New Orleans
5	Atlanta		Atlanta		Atlanta
6	Greensboro		Greensboro		Houston
7	Houston		Baltimore		Baltimore
8	Baltimore		Birmingham		Birmingham
9	New York		Houston		Greensboro
10	Birmingham		New York		Dallas
11	Miami		Dallas		Miami
12	Newark		Miami		New York
13	Dallas		Newark		San Francisco
14	San Francisco		San Francisco		Columbus
15	Philadelphia		Philadelphia		Philadelphia
16	Detroit		Columbus		Indianapolis
17	St. Louis		Indianapolis		Newark
18	Chicago		St. Louis		Tampa
19	Columbus		Detroit		Kansas City
20	Gary		Cleveland		Detroit
21	Los Angeles		Chicago		Cleveland
22	Kansas City		Tampa		Gary
23	Cleveland		Kansas City		St. Louis
24	Indianapolis		Gary		Chicago
25	Tampa		Los Angeles		Cincinnati
26	Milwaukee		Milwaukee		Milwaukee
27	Cincinnati		Cincinnati		Los Angeles
28	Buffalo		Buffalo		Pittsburg
29	Pittsburg		Pittsburg		Boston
30	Boston		Boston		Buffalo

4.3 Co-Location Results at the Block Group Level

Generally, the finer data scale produced a similar result as at the census tract level, although there were different changes over time with respect to certain metropolitan areas. For example, at the census tract level the Houston MSA (Table 4.7 and Figure 4.5) had a slight change in co-location with whites given the location of blacks between 1990 and 2000 (0.545 versus 0.580) and then this increased to 0.690 in 2010. At the block group level, a similar slight change occurred between 1990 and 2000 (0.529 and 0.553), but increased substantially in 2010 to 0.812, This means that at the block group level, the Houston MSA distribution of whites and blacks more closely approaches evenness than at census tract level.

Also, this change in scale affected the rankings of MSAs because of an increase or decrease in the respective co-location values from before. Comparing Figures 4.1 and 4.5 where CLQs are ranked by the year 1990, the most and the least segregated MSAs remained unchanged. Gary, Detroit and Cleveland have the least chances of whites encountering blacks, while Dallas Houston, Greensboro and Norfolk had the distributions with the highest potential of interaction for these groups albeit with slight change in relative positions. A similar situation is true for the co-location of blacks with whites where Detroit, Chicago and Gary stay in the top most lacking interaction between two groups, but in the other tail of the list Miami makes a progress from the sixth highest at census tract to the second highest at block group level. As for the same-group co-location quotients for whites, block groups level of data demonstrates the trend close to one observed at census tract (figures 4.3 and 4.7) with quite similar ranking of MSAs in 1990 and absolute values if compare two scales. Except for the District of Columbia that experiences the most significant change in CLQ values across census years at both scales, at block group level area of Houston appears to have a noticeable drop in concentration of whites by 2010 (from 1.155 in 2000 to CLQ of 1.017 by 2010). Co-location with blacks given the location of blacks at block group level, similarly with three previous quotient categories replicates the trend provided by tract level with minor shifts in relative ranking positions of metro areas. All MSAs follow the pattern of decreasing black concentrations except for District of Columbia. But the absolute numbers of that decline vary if comparing with census tract level of analysis. For instance, Pittsburg in 1990 had CLQ of 6.065 and dropped to 5.200 in 2000, whereas at block group scale the same MSA had CLQ of almost seven (6.969) and in 2000 decreased to 6.092. For comparison, Buffalo MSA maintained a more stable dynamic at both scales. Its 1990 CLQs at tract and block group levels were 5.965 and 6.127 respectively. By 2000 they both decreased to 4.885 and 4.635 respectively. That observation provides a key that the fluctuations in CLQ values with change in spatial unit size are not due to the pure disaggregation of data, but in fact demonstrate the scale effect in its property to conceal variations in population distribution that are important in order to grasp a proper impression about the level of racial or ethnic geographic disparities.

Disaggregating areas populated by different racial groups uncovers naturally occurring balances or imbalances in the distribution of their proportions. Consequently, as a result of the uneven distribution information derived from the analysis conducted at one scale may or may not be tantamount to the information produced by the analysis at another scale. This issue delves into not only the area aggregation problem and thus inaccurate results of analysis, but also into a conceptual perception of scale in its absolute sense as a static baseline upon which inferences are made. Scale can be seen at a continuous axis where every marking point is valid if it fits the contextual character of the analysis.

Table 4.10 Global Co-Location Quotients for Between Groups Computed at the Block Group Level Using a Zero Order Neighborhood for the Years 1990, 2000 and 2010

MSA	CLQ(B|W)			CLQ(W|B)		
	1990	2000	2010	1990	2000	2010
Atlanta	0.457	0.541	0.573	0.423	0.422	0.586
Baltimore	0.471	0.510	0.526	0.389	0.425	0.464
Birmingham	0.437	0.528	0.570	0.267	0.313	0.438
Boston	0.525	0.554	0.602	0.465	0.475	0.533
Buffalo	0.388	0.464	0.490	0.259	0.268	0.345
Chicago	0.282	0.387	0.439	0.268	0.287	0.345
Cincinnati	0.409	0.482	0.551	0.428	0.432	0.445
Cleveland	0.297	0.383	0.447	0.205	0.248	0.314
Columbus	0.610	0.667	0.646	0.477	0.542	0.599
Dallas	0.546	0.673	0.670	0.520	0.598	0.712
Detroit	0.255	0.299	0.437	0.183	0.213	0.306
District Of Columbia	0.381	0.366	0.393	0.357	0.313	0.370
Gary	0.254	0.339	0.464	0.116	0.202	0.311
Greensboro	0.588	0.648	0.620	0.530	0.578	0.614
Houston	0.523	0.579	0.567	0.529	0.553	0.812
Indianapolis	0.542	0.587	0.653	0.432	0.467	0.513
Kansas City	0.546	0.565	0.672	0.343	0.402	0.526
Los Angeles	0.549	0.630	0.700	0.509	0.655	0.689
Memphis	0.431	0.572	0.644	0.370	0.372	0.495
Miami	0.621	0.580	0.569	0.369	0.488	0.588
Milwaukee	0.411	0.371	0.3728	0.330	0.272	0.2952
Newark	0.285	0.340	0.404	0.294	0.304	0.348
New Orleans	0.425	0.419	0.550	0.393	0.381	0.450
New York	0.346	0.378	0.426	0.440	0.461	0.446
Norfolk	0.782	0.725	0.720	0.654	0.715	0.667
Philadelphia	0.483	0.511	0.528	0.311	0.368	0.433
Pittsburg	0.521	0.540	0.648	0.433	0.463	0.490
San Francisco	0.575	0.660	0.701	0.489	0.603	0.705
St. Louis	0.474	0.499	0.495	0.284	0.313	0.357
Tampa	0.615	0.656	0.733	0.363	0.485	0.727

Table 4.11 Global Co-Location Quotients for Within Groups Computed at the Block Group Level Using a Zero Order Neighborhood for the Years 1990, 2000 and 2010

MSA	CLQ(W|W)			CLQ(B|B)		
	1990	2000	2010	1990	2000	2010
Atlanta	1.199	1.265	1.256	2.554	2.024	1.796
Baltimore	1.213	1.226	1.245	2.464	2.191	2.020
Birmingham	1.263	1.266	1.239	2.561	2.202	2.030
Boston	1.049	1.071	1.082	7.385	5.590	4.212
Buffalo	1.094	1.118	1.112	6.127	4.635	4.230
Chicago	1.224	1.244	1.212	3.709	3.315	3.307
Cincinnati	1.069	1.076	1.082	5.681	4.772	3.983
Cleveland	1.182	1.198	1.194	4.165	3.460	3.051
Columbus	1.067	1.073	1.082	3.822	3.016	2.762
Dallas	1.119	1.126	1.116	3.494	2.655	2.394
Detroit	1.235	1.242	1.224	3.572	3.233	2.773
District Of Columbia	2.320	2.214	1.767	1.284	1.344	1.509
Gary	1.226	1.212	1.195	4.162	3.700	3.062
Greensboro	1.109	1.116	1.136	2.768	2.291	2.185
Houston	1.143	1.155	1.017	2.870	2.567	2.161
Indianapolis	1.086	1.092	1.100	3.880	3.215	2.571
Kansas City	1.099	1.102	1.092	4.127	3.815	2.976
Los Angeles	1.149	1.138	1.114	3.890	3.760	3.542
Memphis	1.444	1.513	1.473	1.805	1.526	1.379
Miami	1.131	1.132	1.121	2.722	2.529	2.404
Milwaukee	1.123	1.173	1.184	4.526	4.078	3.724
Newark	1.214	1.240	1.238	3.368	2.989	2.768
New Orleans	1.332	1.404	1.331	2.017	1.879	1.762
New York	1.277	1.325	1.324	2.727	2.687	2.602
Norfolk	1.124	1.134	1.175	1.486	1.531	1.511
Philadelphia	1.178	1.195	1.198	3.091	2.715	2.475
Pittsburg	1.044	1.047	1.052	6.969	6.092	4.531
San Francisco	1.138	1.168	1.159	3.286	2.966	2.674
St. Louis	1.141	1.156	1.155	3.625	3.225	3.116
Tampa	1.069	1.073	1.039	4.676	3.555	2.578

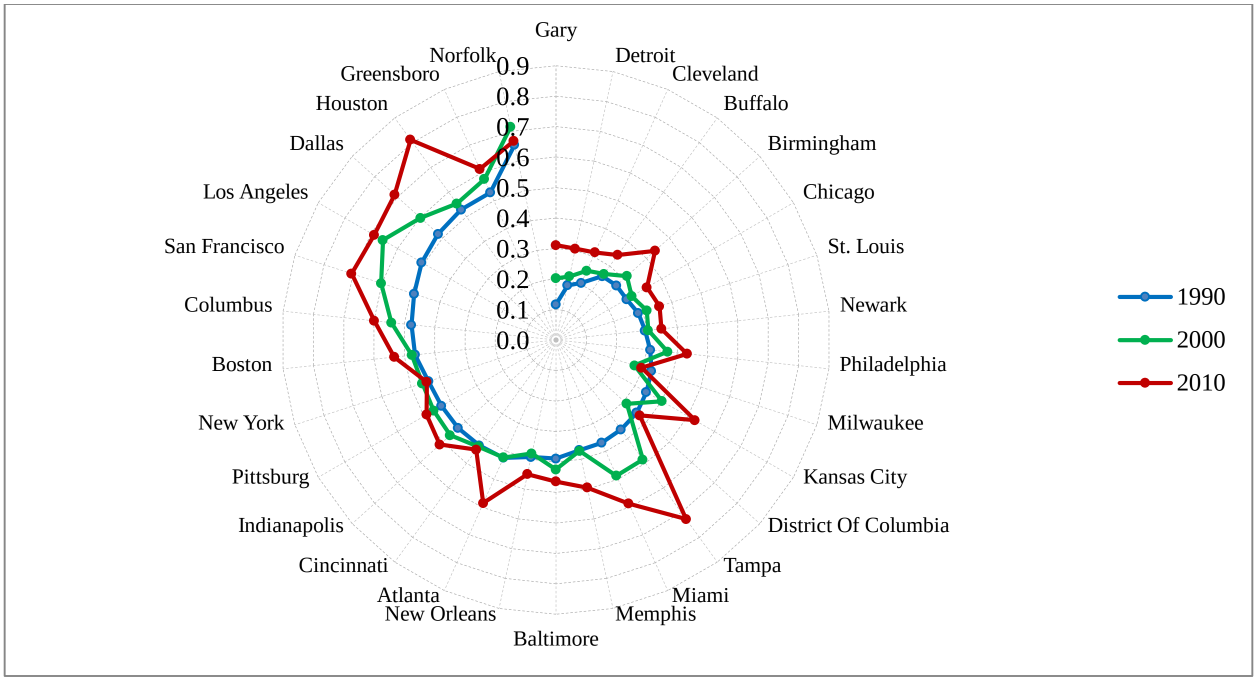


Figure 4.5 Diagram of the Urban Area Rankings for Co-Location with Whites Given the Location of Blacks (W|B) at the Block Group Level

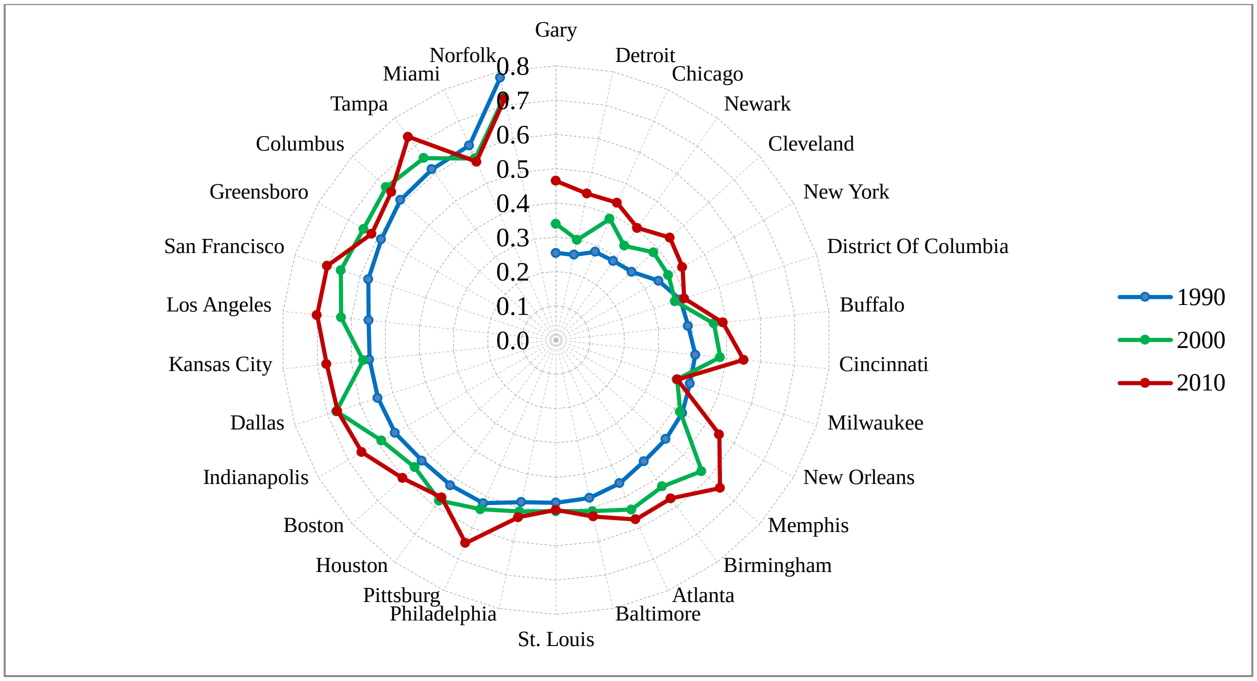


Figure 4.6 Diagram of the Urban Area Rankings for Co-Location with Blacks Given the Location of Whites (B|W) at the Block Group Level

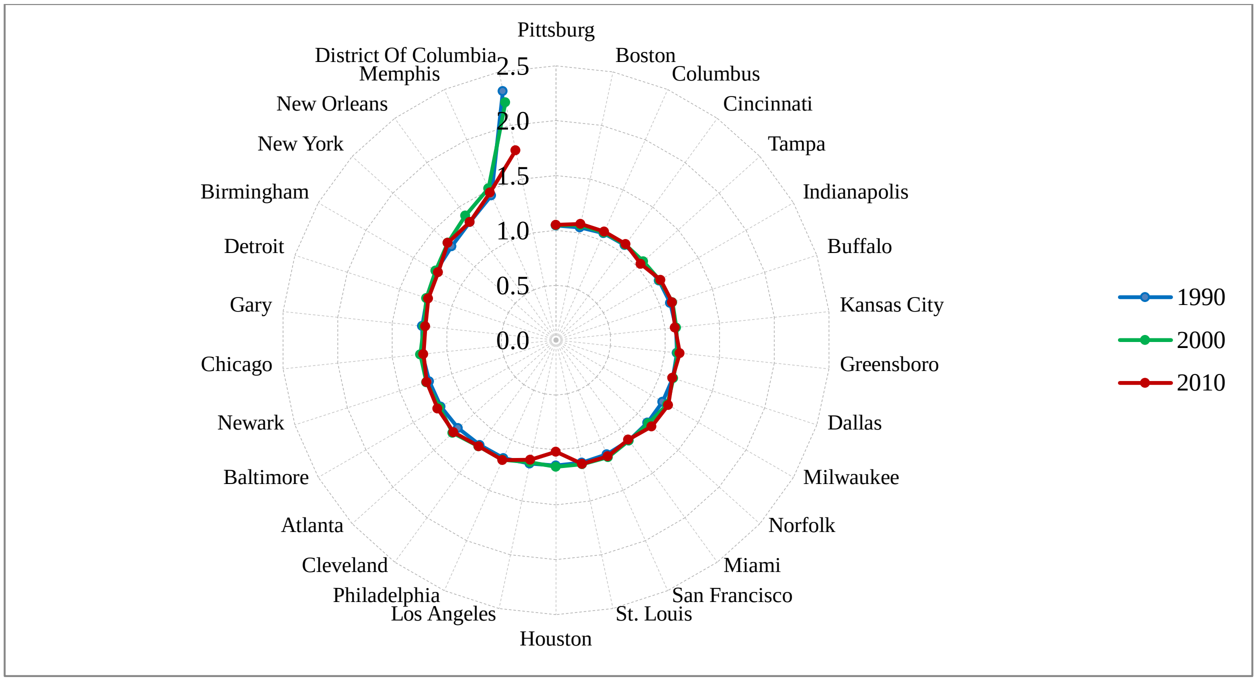


Figure 4.7 Diagram of the Urban Area Rankings for Co-Location with Whites Given the Location of Whites (W|W) at the Block Group Level

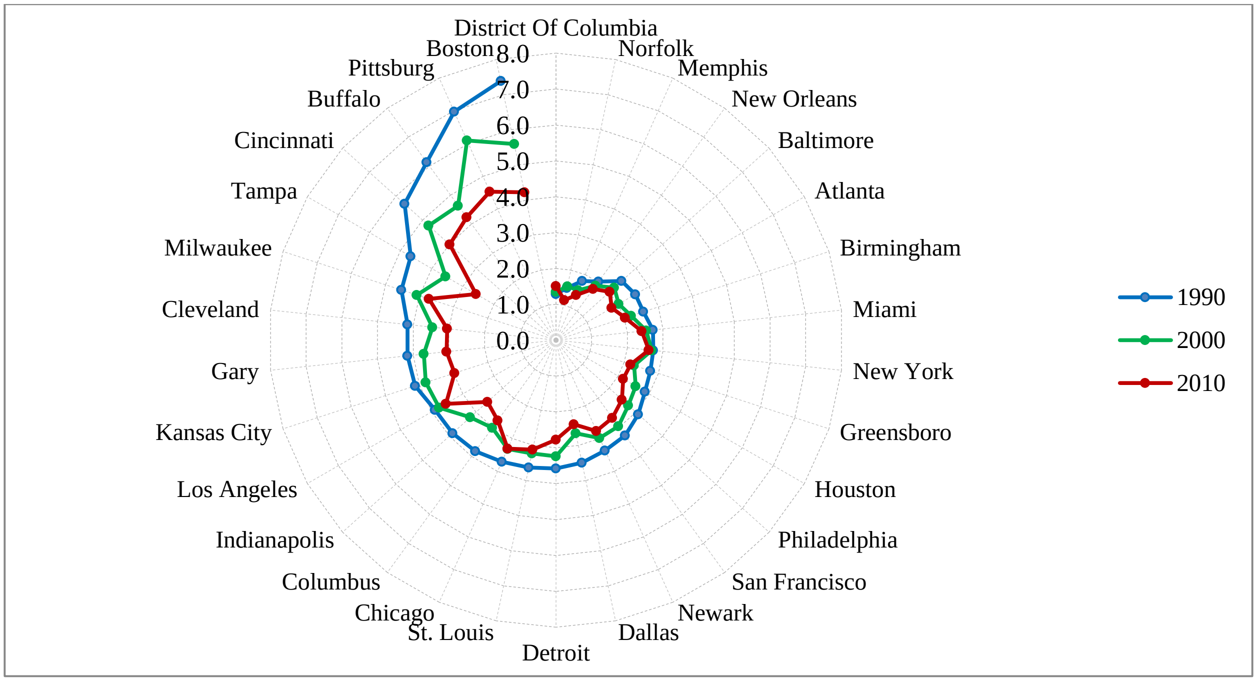


Figure 4.8 Diagram of the Urban Area Rankings for Co-Location with Blacks Given the Location of Blacks (B|B) at the Block Group Level

4.4 Sensitivity of the CLQ to Neighborhood Size

The previous analyses at the tract and block group levels were conducted for a zero order neighborhood. As the neighborhood size increases, the local environment of the focal spatial unit begins to change making the overall level of segregation either more or less. Figure 4.9 displays how the co-location quotients with blacks given the location of whites change with an increase in neighborhood size. In general, the indices increase as more white population on average is included in each neighborhood because this resulted in higher chances of blacks to encounter whites in their extended residential space.

At the same time the ranking of metropolitan areas does not maintain the same order and relative "jumps" in values are evident with an increase of the number of spatial units considered to be in a neighborhood. Some areas have greater increases in their CLQs than others. It is particularly noticeable for Gary, Memphis, New Orleans, Greensboro and Kansas City. Uneven growth of co-location values across MSAs reflects the differences in geographic distributions of black and white populations in these areas. Overall increase of the exposure for blacks in one urban area may not be repeated by another area due to local differences in their inner-metropolitan population distribution.

Several parameters have primary influence on the co-location of two groups in the central tract. One, is the size of the focal spatial unit and relative sizes of those units included in the neighborhood. When the central area is relatively small compared to outer larger areas it is surrounded by, the potential of interaction will be different than when smaller units surround a not very large census unit. Essentially the absolute areas (and as a result the distances between target populations) of influence may significantly differ at different parts of the city when using the same neighborhood order. Another parameter that affects the co-location value is the absolute population size of the units included in the neighborhood. Together with variable size of the tracts, it presents challenging problems of correspondence of two neighborhoods within the area. One, that may be concise and densely populated, and the other that is significantly larger and has low population density. The accuracy of comparing of such areas is questionable.

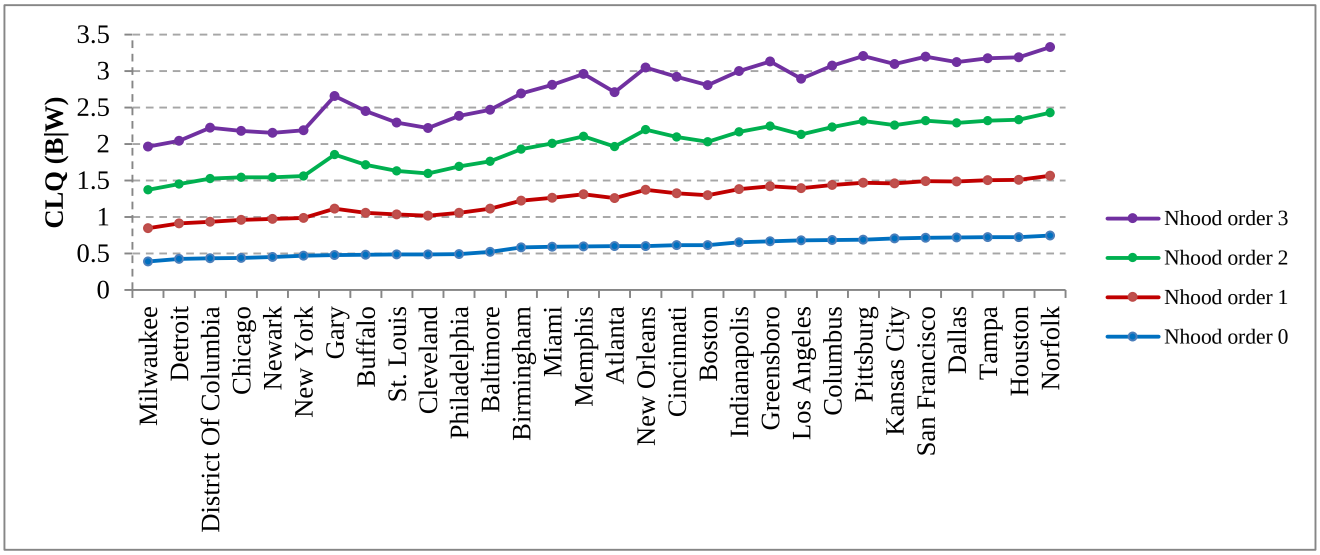


Figure 4.9 Global Co-Location Quotients with Blacks Given the Location of Whites (B|W) Computed at the Census Tract Level for 2010 data (using MSA boundaries of 2010) for Different Neighborhood Orders from 0 to 3. (MSAs are sorted by the neighborhood order of zero)

4.5 Comparison of the CLQ Against Other Measures

There is a strong negative correlation (over 0.89 at absolute scale, see Table 4.12) between two-group co-location quotients and index of dissimilarity values. This is expected as two-group co-location quotient encompasses the evenness dimension and also considers two population groups. Metro areas as Milwaukee, Detroit, Chicago and Gary maintain high segregation values thus somewhat aligning with co-location quotient results for the most segregated areas. Also, the decrease in dissimilarity index values between 1990 and 2010 is confirmed by the trend using CLQs. But because index of dissimilarity is a symmetric measure it provides an averaged insight about the numeric (and not geographic) disparities among blacks and whites. It does not take into account other population present in the area. In contrast, co-location is based on illuminating interaction of white with blacks and blacks with whites considering other groups. Figures 4.1 and 4.2 demonstrate that there are clear differences in how likely one group interacts with another in the presence of other populations.

Table 4.12 Pearson Correlation Coefficent between the Index of Dissimilarity Values (Whites versus Blacks) and the Co-Location Values for Respective Years

CLQ	1990	2000	2010
B|W	-0.904	-0.930	-0.897
W|B	-0.964	-0.947	-0.958
W|W	0.159	0.253	0.267
B|B	0.353	0.366	0.427

Table 4.13 Index of Dissimilarity Computed at the Census Tract Level

MSA	1990	2000	2010
Atlanta	0.661	0.630	0.567
Baltimore	0.712	0.679	0.649
Birmingham	0.703	0.689	0.654
Boston	0.675	0.663	0.621
Buffalo	0.797	0.774	0.722
Chicago	0.833	0.799	0.745
Cincinnati	0.758	0.736	0.690
Cleveland	0.825	0.776	0.732
Columbus	0.675	0.631	0.617
Dallas	0.614	0.565	0.510
Detroit	0.874	0.854	0.748
District Of Columbia	0.767	0.776	0.708
Gary	0.888	0.833	0.749
Greensboro	0.565	0.551	0.545
Houston	0.632	0.605	0.526
Indianapolis	0.743	0.717	0.654
Kansas City	0.725	0.700	0.597
Los Angeles	0.693	0.631	0.585
Memphis	0.654	0.654	0.618
Miami	0.713	0.658	0.601
Milwaukee	0.825	0.824	0.797
Newark	0.801	0.771	0.731
New Orleans	0.680	0.688	0.627
New York	0.764	0.751	0.715
Norfolk	0.493	0.461	0.471
Philadelphia	0.747	0.700	0.666
Pittsburg	0.707	0.688	0.656
San Francisco	0.653	0.622	0.569
St. Louis	0.771	0.739	0.720
Tampa	0.684	0.620	0.521

Table 4.14 (a,b,c) presents correlation coefficients measured between CLQs and Lieberson's indices for the years 1990, 2000 and 2010 respectively. There is no consistent correspondence between same direction measures (such as between isolation of blacks Pbb and CLQ(B|B)). Both two-group CLQs are strongly positively correlated with a single two-group interaction of blacks with whites, but not with interaction of whites with blacks. Also both two-group CLQs are negatively correlated with the same-group co-location with blacks given the location blacks. Same-group CLQs with whites given whites are positively correlated with interaction index of whites with blacks and negatively correlated with interaction of blacks with whites. Same-group co-location of blacks is positively correlated with isolation index of whites and negatively correlated with interaction of whites with blacks and isolation of whites.

Table 4.14 Pearson Correlation Coefficients Between Interaction/Isolation Indices and Co-Location Quotient Values for: a) 1990, b) 2000, and c) 2010

a)

	CLQ			
	W|B	B|W	W|W	B|B
Pwb	**0.352**	0.217	0.680	-0.824
Pbw	0.708	**0.853**	-0.604	0.318
Pww	-0.440	-0.193	**-0.544**	0.676
Pbb	-0.763	-0.789	0.559	**-0.306**

b)

	CLQ			
	W|B	B|W	W|W	B|B
Pwb	**0.228**	0.188	0.574	-0.858
Pbw	0.710	**0.851**	-0.662	0.290
Pww	-0.445	-0.232	**-0.436**	0.572
Pbb	-0.821	-0.814	0.565	**-0.296**

c)

	CLQ			
	W|B	B|W	W|W	B|B
Pwb	**0.174**	0.096	0.623	-0.866
Pbw	0.650	**0.805**	-0.756	0.260
Pww	-0.474	-0.246	**-0.439**	0.533
Pbb	-0.794	-0.802	0.633	**-0.267**

Table 4.15 Indices of Interaction and Isolation in 2010

MSA	Pwb	Pbw	Pww	Pbb
Atlanta	0.187	0.319	0.699	0.580
Baltimore	0.142	0.292	0.766	0.631
Birmingham	0.139	0.330	0.810	0.627
Boston	0.043	0.466	0.843	0.321
Buffalo	0.055	0.369	0.893	0.550
Chicago	0.067	0.231	0.760	0.669
Cincinnati	0.066	0.456	0.887	0.484
Cleveland	0.080	0.297	0.864	0.649
Columbus	0.092	0.478	0.838	0.435
Dallas	0.105	0.454	0.717	0.349
Detroit	0.081	0.248	0.850	0.699
District Of Columbia	0.203	0.154	0.668	0.765
Gary	0.072	0.277	0.849	0.641
Greensboro	0.131	0.447	0.788	0.434
Houston	0.116	0.405	0.678	0.373
Indianapolis	0.086	0.441	0.844	0.453
Kansas City	0.074	0.463	0.844	0.435
Los Angeles	0.048	0.356	0.600	0.276
Memphis	0.244	0.256	0.689	0.689
Miami	0.121	0.404	0.796	0.508
Milwaukee	0.056	0.248	0.862	0.655
Newark	0.085	0.251	0.787	0.611
New Orleans	0.174	0.298	0.752	0.629
New York	0.092	0.221	0.674	0.552
Norfolk	0.215	0.410	0.696	0.503
Philadelphia	0.099	0.321	0.807	0.561
Pittsburg	0.051	0.540	0.913	0.409
San Francisco	0.060	0.366	0.610	0.228
St. Louis	0.079	0.331	0.870	0.623
Tampa	0.083	0.550	0.828	0.348

4.6 Summary

This chapter examines changes in residential segregation patterns within and between different metropolitan areas using the global co-location quotient for 1990, 2000 and 2010. The major findings are that there is an overall, but uneven, increase in the potential of interaction between whites and blacks and blacks and whites. Patterns of concentration for whites remained stable over the time span. But the concentration of black population as measured by CLQ(B|B) shows a substantial decrease indicating an increasing exposure of blacks in the global sense. The two-group measures differ to a modest degree. Conversely, same-group co-location quotients for whites and for blacks expose unequal experiences for these two population groups in American urban areas.

The effect of scale was explored using two different census levels - census tracts and block groups. The results suggest that finer disaggregation of areal data does not manifest any new pattern, but rather reflects the same behavior consistent with the trend inferred using the tract level. However, this observation is not stated as the law that the scale does not affect the results, but rather indicates that the extent of disaggregation at block group level compared to census tracts is not significant enough to reflect the changes in co-location that inevitably occur at finer dataset. Also, relating to the spatial unit aggregation problem, the neighborhood size affects the results of computation. As all areal units substantially differ by territorial size and population size within a metro area, there is a potential for high discrepancy among neighborhoods and their real effects on the co-location.

CHAPTER FIVE

Analyzing Segregation Patterns Within Urban Areas Using the Local Co-Location Quotient

5.1 Introduction

While estimation of residential segregation trends at a global scale focuses on the nationwide pattern of racial and ethnic relations, local evaluation examines the uniqueness and variation within each metropolitan area that contributes to the national indicators. This chapter will use the local form of co-location quotient to analyze three selected metropolitan areas. These MSAs are located in different geographic regions of the United States and have different historical contexts that formed the current patterns of black-white residential segregation. The chosen urban areas are the Boston, Detroit, and

Houston metropolitan areas. The choice of the areas is based on their relatively high degree of change in one or all of the global CLQ values over the period of 1990-2010 as described in Chapter Four.

Similar to the analysis using the global CLQ, two different census levels will be used – census tract and block group. The enumeration unit again defines the extent of disaggregation in the metropolitan setting. In order to examine spatial differences between using census tracts and block groups, the co-location at census tract level will be computed ignoring the influence of the neighboring units on co-location whereas at the block group level, local CLQs will be derived using the first-order neighbors of the areal units. A census block group and its first order neighbors covers a similar size area as a census tract.

The global co-location quotient is different from its local form not only by averaging local neighborhood variations across the urban area, but also by the range of values it can have. In Chapter Three, Figure 3.1 demonstrates that the values of co-location are restricted for one group with respect to another group ranging from perfect concentration (a value of 1) to an even distribution (a value of 0). That is the case because the summed observed potentials for interactions are scaled with respect to the total possible interactions in the region; therefore we can establish limits for the values regardless of the particular pattern of population distribution. For the local CLQ, the formula considers the summed local potential of interaction, ignoring the rest of the region, but still scaled to the total possible interactions in the entire region; thus there is no upper limit on the local co-location quotient for between group measures. A local CLQ can have a value from zero to any value over one whether it is same-group or two-group measure.

Table 5.1 contains the percentages of black and white population and their change across the census years for selected metropolitan areas. Of the three urban areas, Boston, the northernmost large MSA, contains the smallest share of blacks residing in its neighborhoods. For all three MSAs, the percentage of whites declines over the two decades, while percentages of blacks does not change much. In Boston the percentage of Blacks increases slightly over time. In Detroit the share of blacks slightly increased in 2000 but then stayed the same in 2010. As for Houston the percentage of blacks first dropped by 1% in 2000, but in 2010 it slightly increase although it was still lower than in 1990.

Table 5.1 Percent of Whites and Blacks in the Selected MSAs, 1990-2010.

MSA Name	1990		2000		2010	
	Percent White	Percent Black	Percent White	Percent Black	Percent White	Percent Black
Boston	88.8%	5.7%	83.2%	6.1%	78.8%	7.3%
Detroit	75.4%	22.2%	71.4%	22.8%	70.1%	22.8%
Houston	67.7%	17.9%	62.7%	16.9%	60.2%	17.2%

The global co-location coefficients for these two population groups given in Table 5.2 at the census tract level changes over time in a pattern consistent with the change in the percentages of blacks and whites. Co-location with whites given the location of blacks and with blacks given the location of whites increased for all three metropolitan areas over time as the percentage of blacks increased and white decreased. Same group co-location for the white population, CLQ(W|W), decreased in Detroit and Houston, but increased in Boston. On the other hand, same group co-location quotients for the black population, CLQ(B|B), decreased in all three metropolitan areas by 2010 indicating an overall relative reduction in the extent of black residential isolation.

Table 5.2 Global Co-Location Quotients for the Selected MSAs at the Census Tract Level, 1990-2010.

MSA	CLQ(W|B)			CLQ(B|W)			CLQ(W|W)			CLQ(B|B)		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Boston	0.453	0.499	0.558	0.568	0.572	0.616	1.051	1.067	1.077	6.952	5.584	4.218
Detroit	0.197	0.226	0.331	0.234	0.255	0.425	1.234	1.244	1.217	3.649	3.394	2.821
Houston	0.545	0.58	0.690	0.616	0.619	0.726	1.143	1.143	1.123	2.496	2.388	1.905

However, the global statistics do not match the percentage changes as one compares the different MSA with one another. For example, Boston in 1990 had a higher percentage of whites than Detroit yet the CLQ(B|W) and CLQ(W|B) values much higher for Detroit than in Boston indicating a very different internal structure of the distribution of blacks and whites in the two cities.

5.2 Local CLQs for the Boston Metropolitan Area

The territory of Boston metropolitan area also includes counties within Massachusetts and southern New Hampshire. As mentioned above, the Boston metropolitan area has a relatively low percentage of blacks but their percentage increased from 5.7% in 1990 to 7.3% in 2010. Meanwhile the percentage of whites decreased by ten percent from 88.8% in 1990 to 78.8% in 2010, thus increasing the overall global chances for whites to encounter blacks in their residential neighborhood given all other factors being equal.

To provide insight into the distribution of the co-location values with respect to the shares of blacks and whites in the census tracts for Boston MSA, Figure 5.1 displays summary scatter plots of percentages of blacks and whites colored by their corresponding co-location values. It is clear that for CLQ(B|W) and CLQ(B|B) the index value is high where the percentage of blacks is high. Also it is noticeable that the majority of tracts exhibit low co-location values. CLQ(W|B) and CLQ(W|W) have low values and appear to cluster where the percentage of blacks is low.

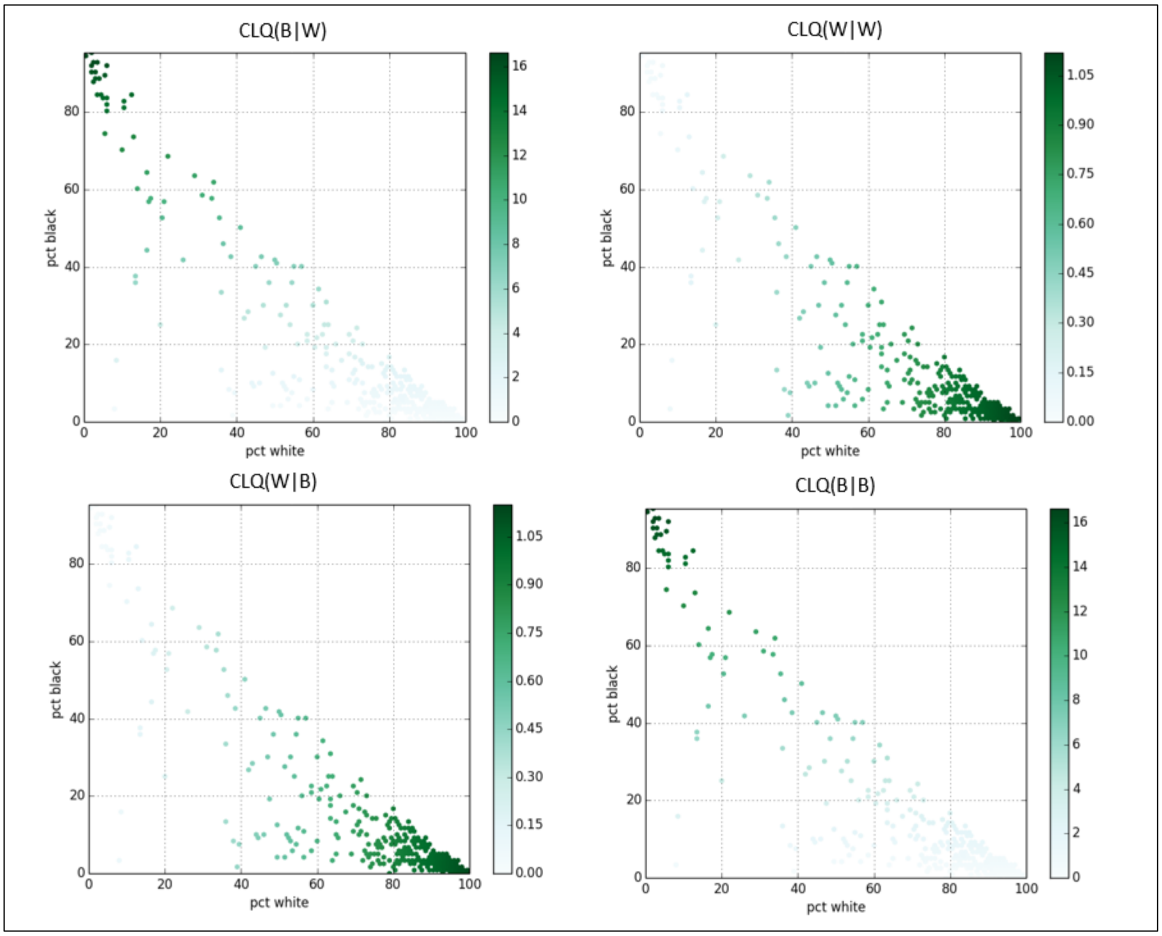


Figure 5.1 Scatter Plots of Relationships Between Percent Black and Percent White and Local Co-Location Coefficients Symbolized By Color Intensity: Boston Metropolitan Area, 1990, at the Census Tract Level.

Figures 5.2 and 5.3 present local CLQ(B|W) for Boston at the tract and block group level respectively. Using block groups reveals a more detailed pattern of the values than the one consisting of census tracts. In terms of temporal change the area of the highest co-location with blacks given the location of whites remains in southern part of Boston area, but it is apparent that the surrounding areas of eastern Norfolk and western Plymouth counties increased co-location values by 2010, while the nothern part of the metropolitan area only slightly changed. It appears more likely to have a contact with blacks in the southern portion of the Boston core area, south of Suffolk County, lowering the values with distance from this metropolitan segment. The northern part of the metropolitan area remains barely changed over 20 years - being a white dominant region.

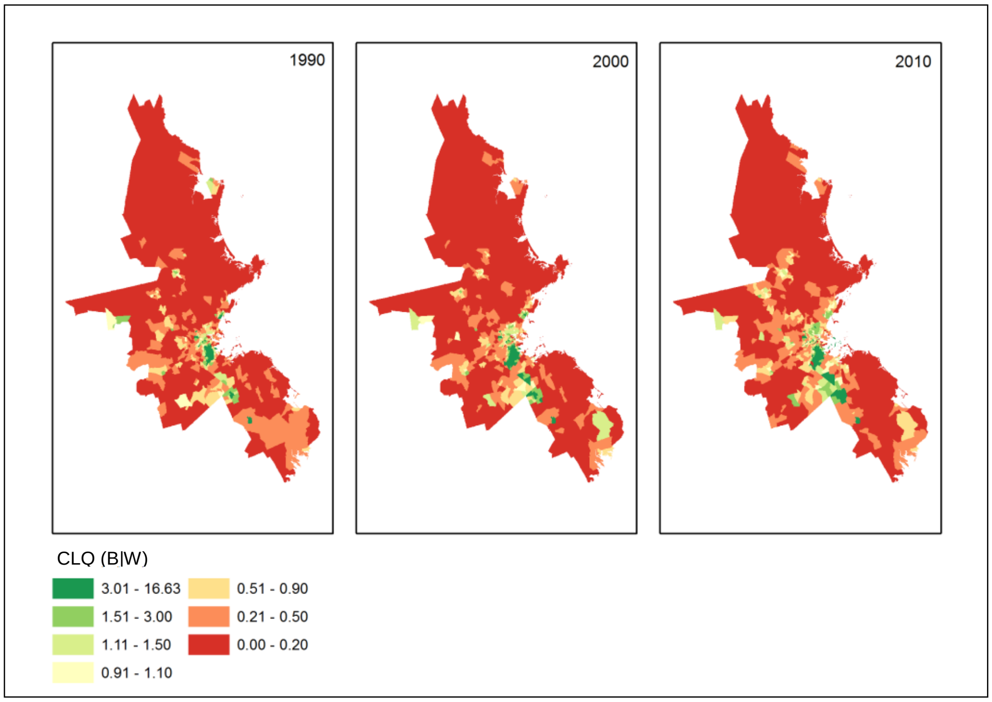


Figure 5.2 Local Co-Location with Blacks Given the Location of Whites:
Boston Metropolitan Area, 1990-2010 Census Tract Level.

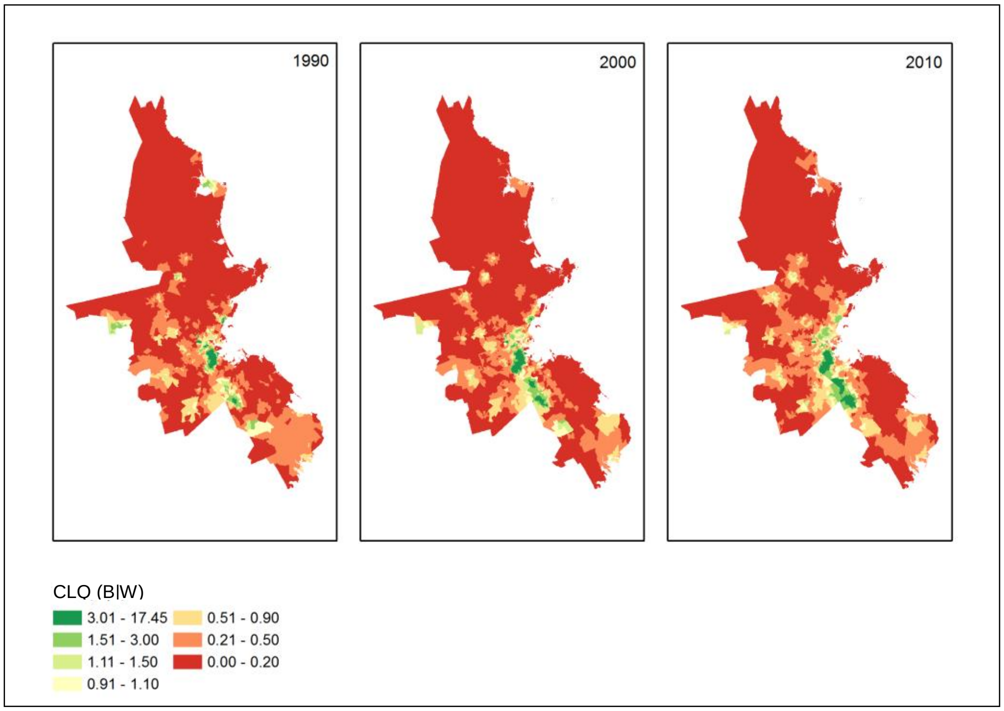


Figure 5.3 Local Co-Location with Blacks Given the Location of Whites (W|B):
Boston Metropolitan Area, 1990-2010 Block Group Level.

Over the span of 20 years the northern part of the Boston MSA displays the high chance of co-location with whites given the location of blacks. Even though the pattern created by choropleth mapping can be misleading as the displayed image essentially depends on the method of the categorical grouping of values, in Figure 5.4 it is evident that many tracts have increased their local CLQs compared to the census of 1990 and 2000. Such pattern indicates that most of suburban Boston metropolitan has been moving towards a more segregated pattern rather than scenario of integration of black population. Examining the change at block group level (Figure 5.5) indicates overall higher proportion of the metropolitan area where the co-location is as expected compared to census tract maps. But similarly with the temporal change at tract level, census block groups data show that over time the areas with excepted levels of co-location (or areas of no segregation) have decreased transforming to areas of high level of co-location with whites given the location of blacks.

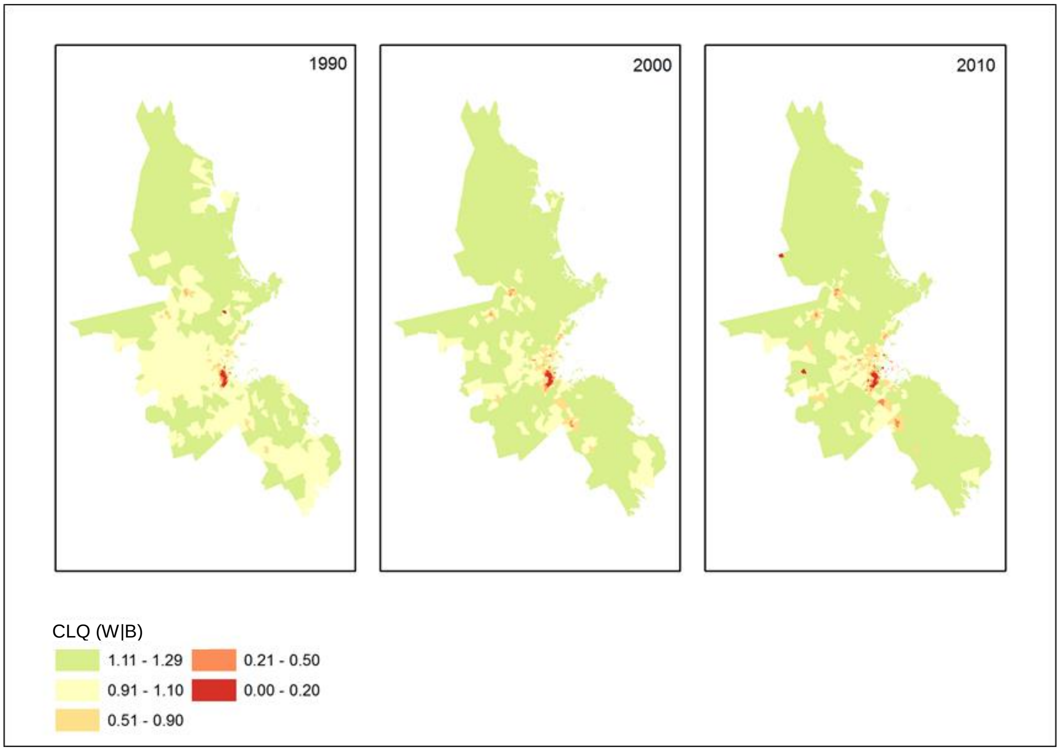


Figure 5.4 Local Co-Location with Whites Given the Location of Blacks:
Boston Metropolitan Area, 1990-2010 Census Tract Level.

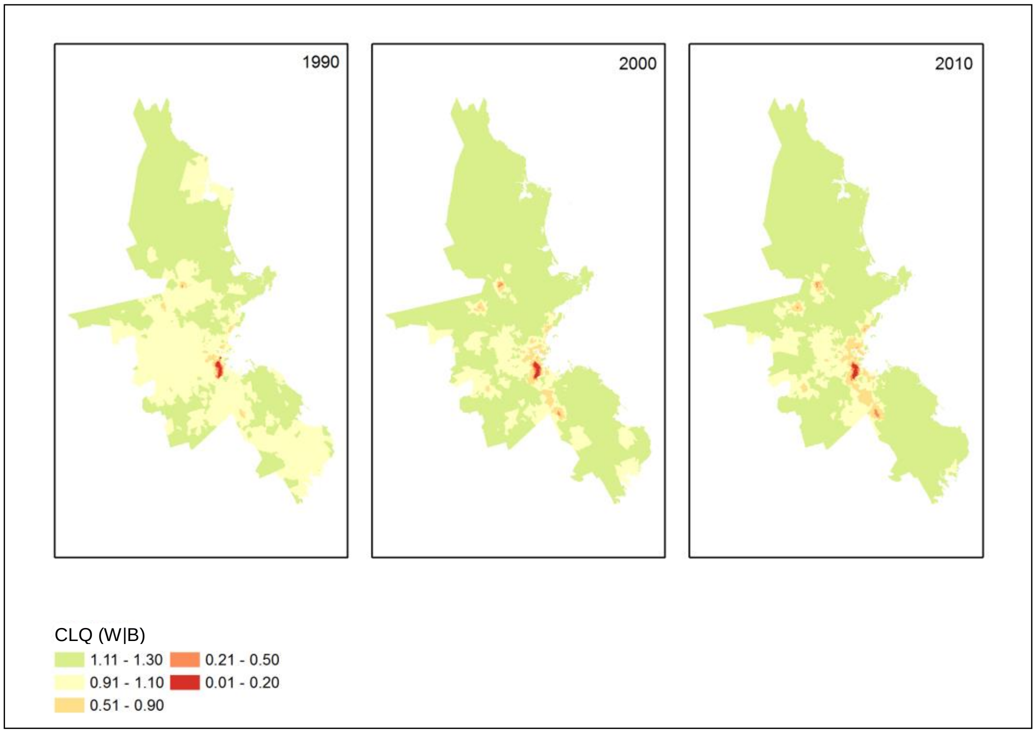


Figure 5.5 Local Co-Location with Whites Given the Location of Blacks: Boston Metropolitan Area, 1990-2010 Block Group Level.

Maps of co-location with whites given the location of whites demonstrate that the areas with expected values of same-group co-location have decreased (Figures 5.6 and 5.7) by the year of 2010 thus leaving these tracts and block groups with increased levels of concentration of whites. Such trend is observed in all north, south and central parts of the metropolitan area. Because blacks and whites in Boston metropolitan area are not two mutually exclusive groups the pattern of concentration of whites, or co-location with whites given the location of whites does not mirror the pattern of co-location with blacks given the location of blacks (Figures 5.8 and 5.9). For most of the Boston metropolitan area there is a high chance to co-locate with whites.

Some studies report that the Boston metropolitan area has been moving towards higher levels of segregation by observing the dynamics of the home-buying trends and home-ownership in the area (Lee, 2004). From 1993 to 1998 Randolph town that is located in south-easter corner of Norfolk county, is listed as the second popular destination for purchases by African-Americans after Boston city. The map for co-location with blacks given the location of blacks easily highlights the area around that town, south of the city of Boston downlown. By 2010 there is a new vivid epicenter for concentration of black population around town of Brockton (Figures 5.8, 5.9). At both spatial unit types, block groups and census tracts, the areas of high concentration of blacks have increased by 2010.

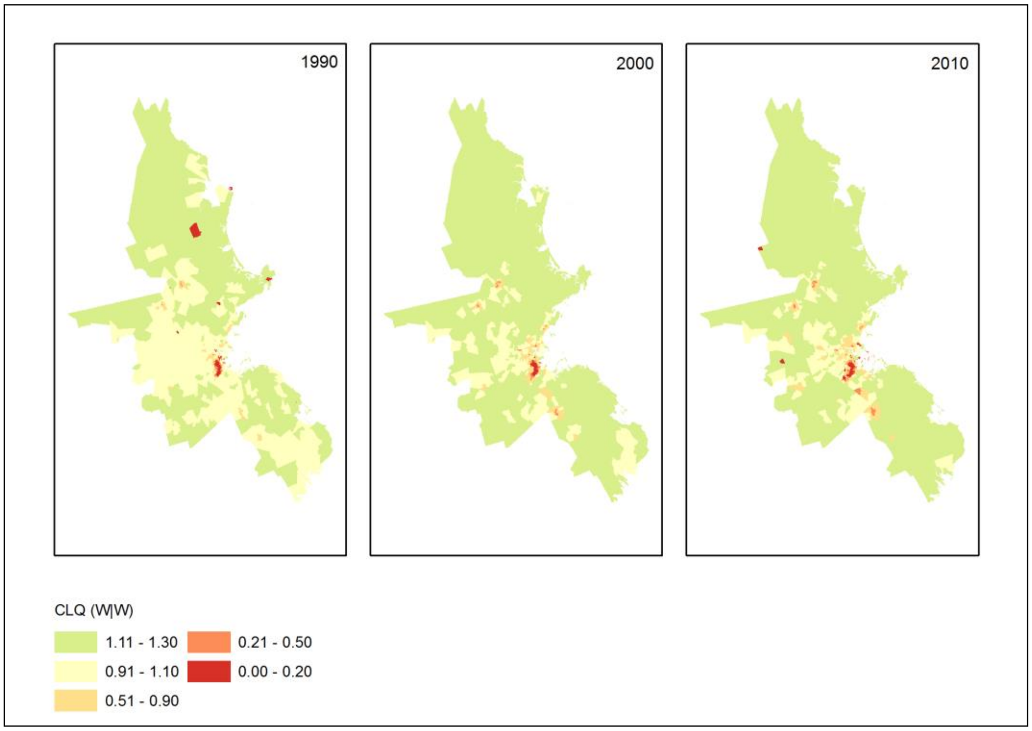


Figure 5.6 Local Co-Location with Whites Given the Location of Whites: Boston Metropolitan Area, 1990-2010 Census Tract Level.

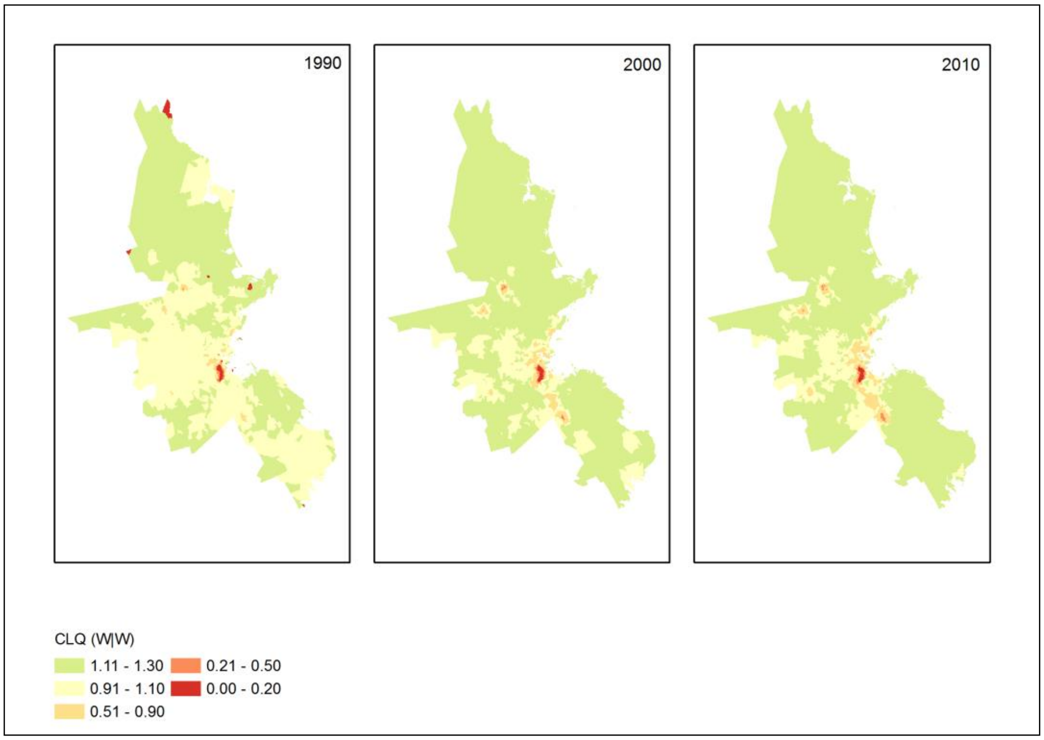


Figure 5.7 Local Co-Location with Whites Given the Location of Whites: Boston Metropolitan Area, 1990-2010 Block Group Level.

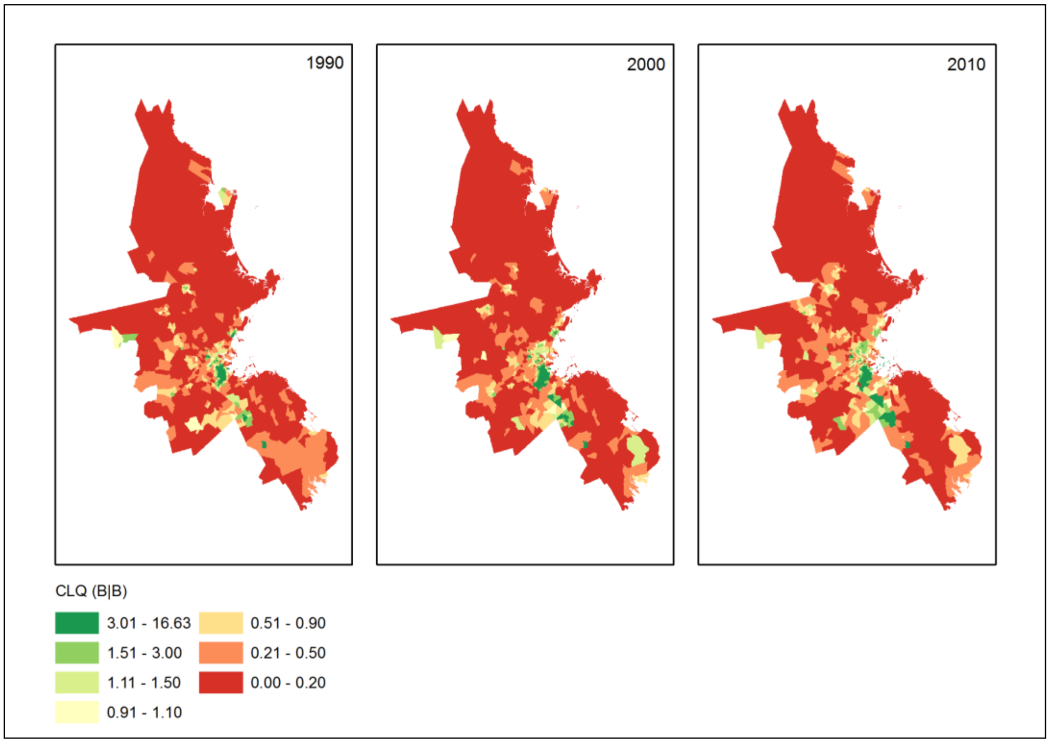


Figure 5.8 Local Co-Location with Blacks Given the Location of Blacks: Boston Metropolitan Area, 1990-2010 Census Tract Level.

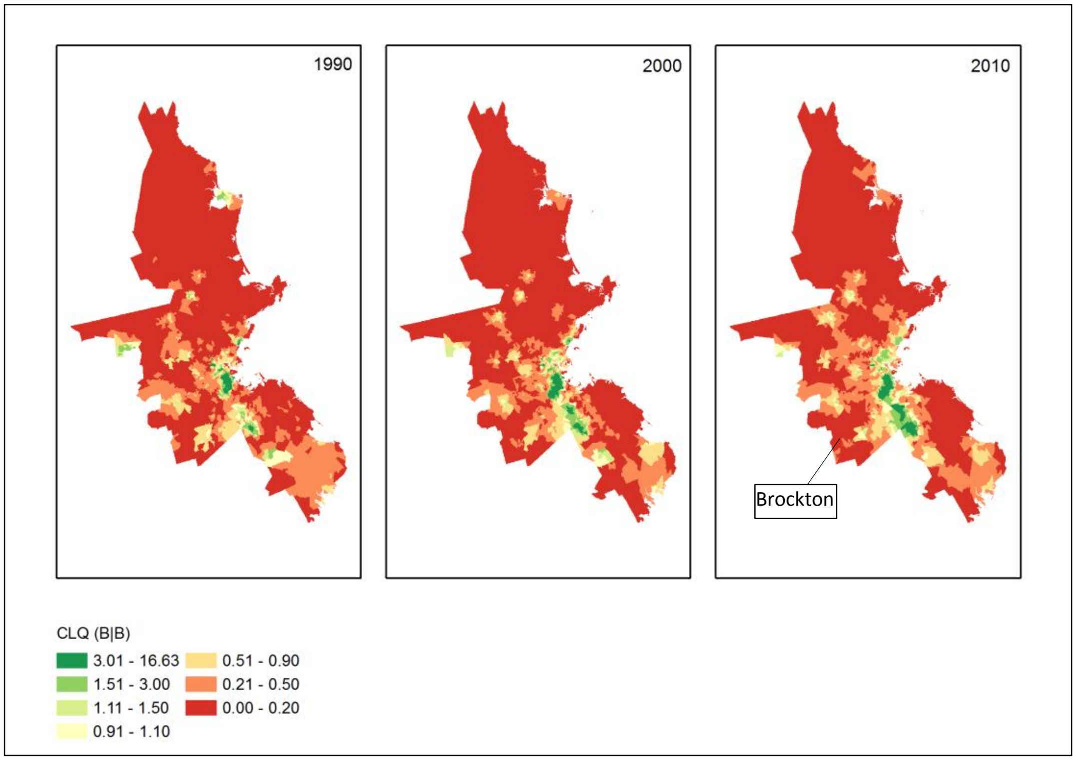


Figure 5.9 Local Co-Location with Blacks Given the Location of Blacks: Boston Metropolitan Area, 1990-2010 Block Group Level.

5.3 Local CLQ Values for the Detroit Metropolitan Area

The Detroit metropolitan area has been undergoing substantial economic and demographic changes since the economic restructuring that took place in American industrial cities in 1960s and 1970s. At the same time the Detroit metropolitan area has been one of the most racially segregated areas in the country. Since the collapse of industrial sectors in manufacturing cities, Detroit started losing its population, the economic sitiation deteriorated and affected the majority of blacks in the region. According to Census 2010, the city of Detroit is 84% African Americans.

Even though the core of the Detroit metropolitan area, the city of Detroit, has a majority black population, recent studies report eventual, but slow declines in black-white residential segregation in Detroit metropolitan by 2010 compared to its persistence and increase in previous censuses (Logan and

Stults, 2011). This is due not only to the greater integration of blacks in mainstream society, but mainly to the overall growth of diversity, a more substantial presence of other groups in American residential neighborhoods.

The most segregated areas in the Detroit metropolitan are Detroit city, the towns of Southfield and Highland Park adjoining Detroit, Inskter south-west from Detroit and Pontiac north-west from Detroit. These are the major areas of concentration of blacks in the region. On the opposite side pof the spectrum, the town of Livonia just west of the city of Detroit is one of the whitest areas in the country containing over 90% whites.

By looking at the map of co-location with whites given the location of blacks (Figures 5.10 and 5.11) the areas of black-dominated towns are marked out by green shades while the majority of suburban Detroit metropolitan maintains low chances for whites to meet blacks. This pattern slightly changes over time with more areas of increasing likelyhood, but the main core areas of segregated blacks remain. While the majority of the metropolitan area remains unchanged with very low values of CLQ(B|W), the territory surrounding the city of Detroit experience changes to rising co-location values. The maps of co-location at block group level (Figure 5.11) of aggregation exhibit smoother boundaries for the zones of low and high CLQ.

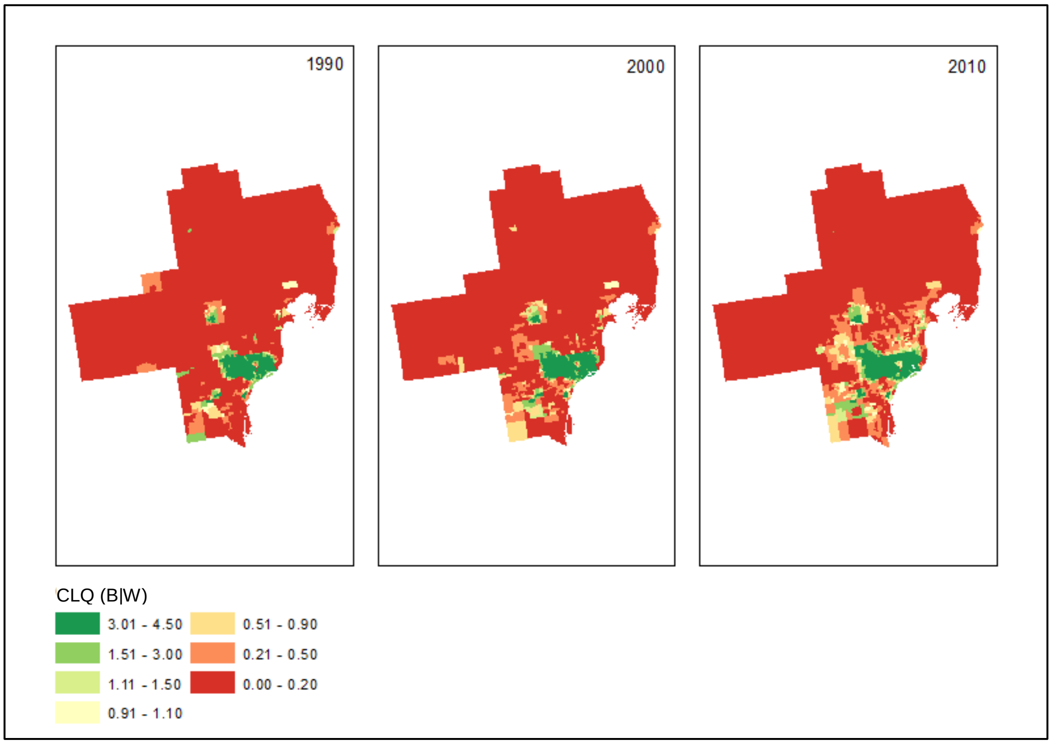


Figure 5.10 Local Co-Location with Blacks Given the Location of Whites: Detroit Metropolitan Area, 1990-2010 Census Tract Level.

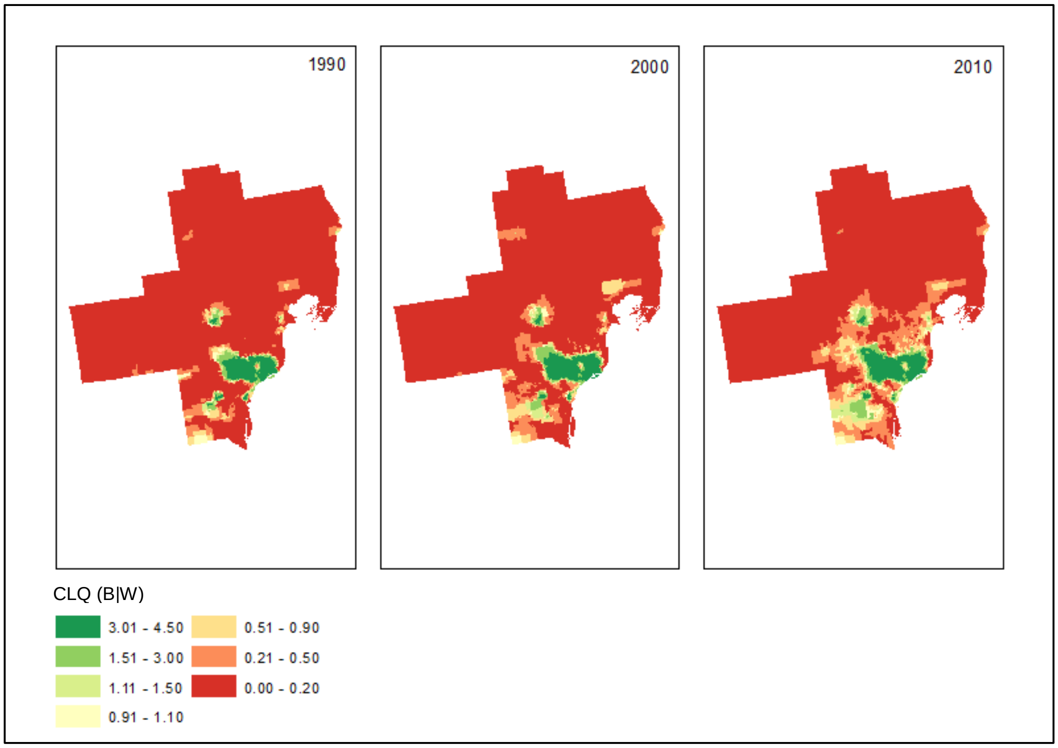


Figure 5.11 Local Co-Location with Blacks Given the Location of Whites: Detroit Metropolitan Area, 1990-2010 Block Group Level.

As for co-locating with whites biven the location of blacks in the region (Figures 5.12 and 5.13) the pattern highlights consistently lowest likelihood for the black person to meet a white person withing the core Detroit city area and its neighboring towns and within town of Pontiac nort-west from Detroit. Some changes occur west from Detroit in the area of Farmington Hills where over time neighborhoods appeared with slightly lower co-location values by 2010. The towns of Inkster and Wayne southwest from the city of Detroit also show expanding neighborhoods with decreasing co-location values over time.

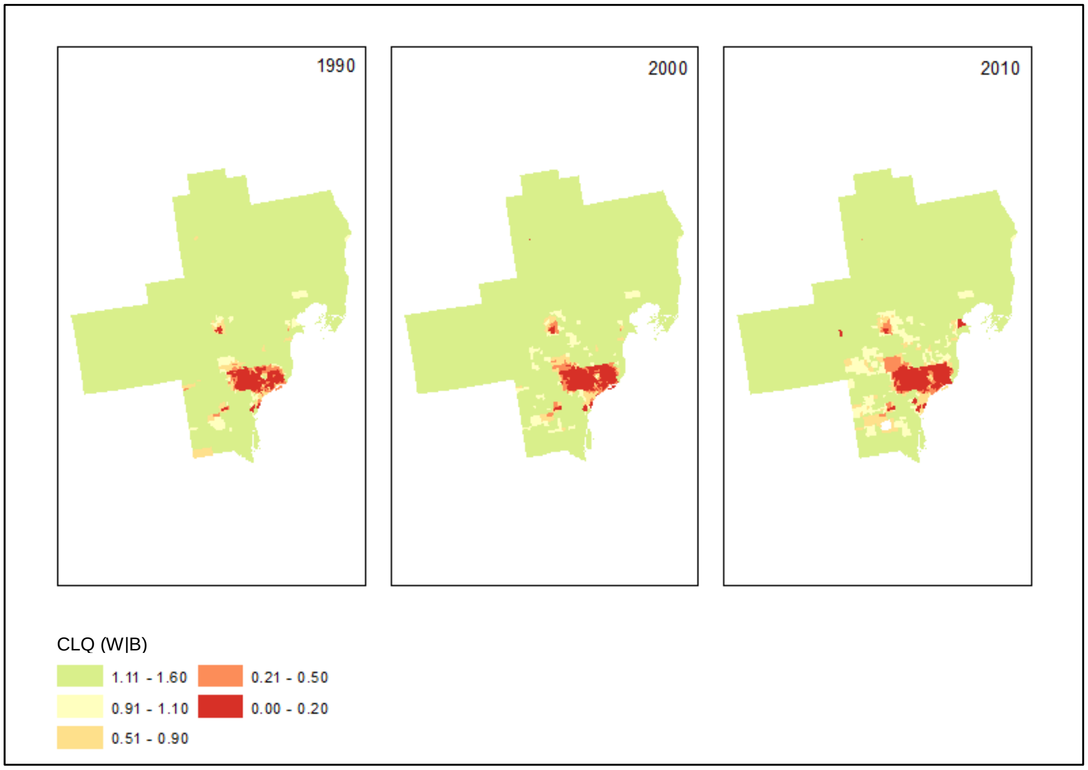


Figure 5.12 Local Co-Location with Whites Given the Location of Blacks: Detroit Metropolitan Area, 1990-2010 Census Tract Level.

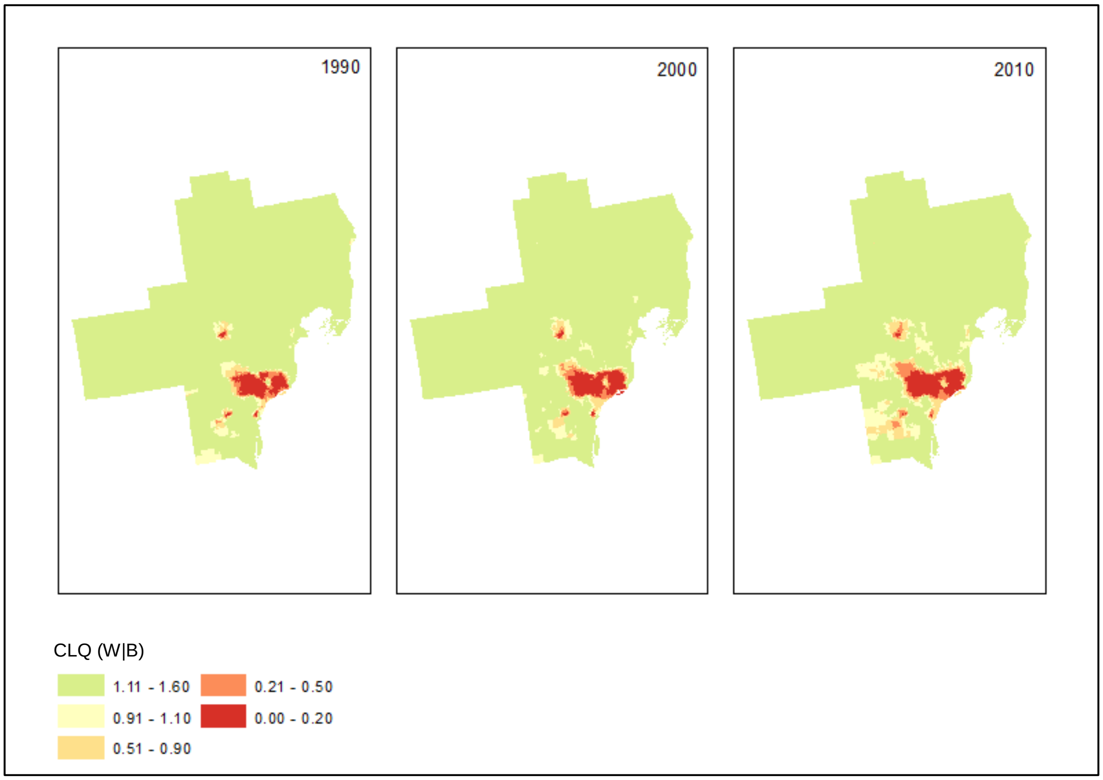


Figure 5.13 Local Co-Location with Whites Given the Location of Blacks: Detroit Metropolitan Area, 1990-2010 Block Group Level.

Whites are least exposed to other whites where the black population is concentrated the most (Figures 5.14 and 5.15). When whites are less concentrated than blacks, the upper CLQ values do no exceed 1.5 while the most black concentrated neighborhoods exhibit CLQ values of over 3.0 (Figures 5.17 and 5.18). Therefore, as white population is highly concentrated in some parts of the metropolitan area, their level of concentration is low compared to that of blacks. The Detroit metropolitan area at the block group level appears to have a less homogenous pattern than that of census tracts. Overall, by 2010 CLQ values for concetration of whites increase throughout the region. The areas of core of Detroit metropolitan area that did not have any whites reported at block group have reduced in number by 2010.

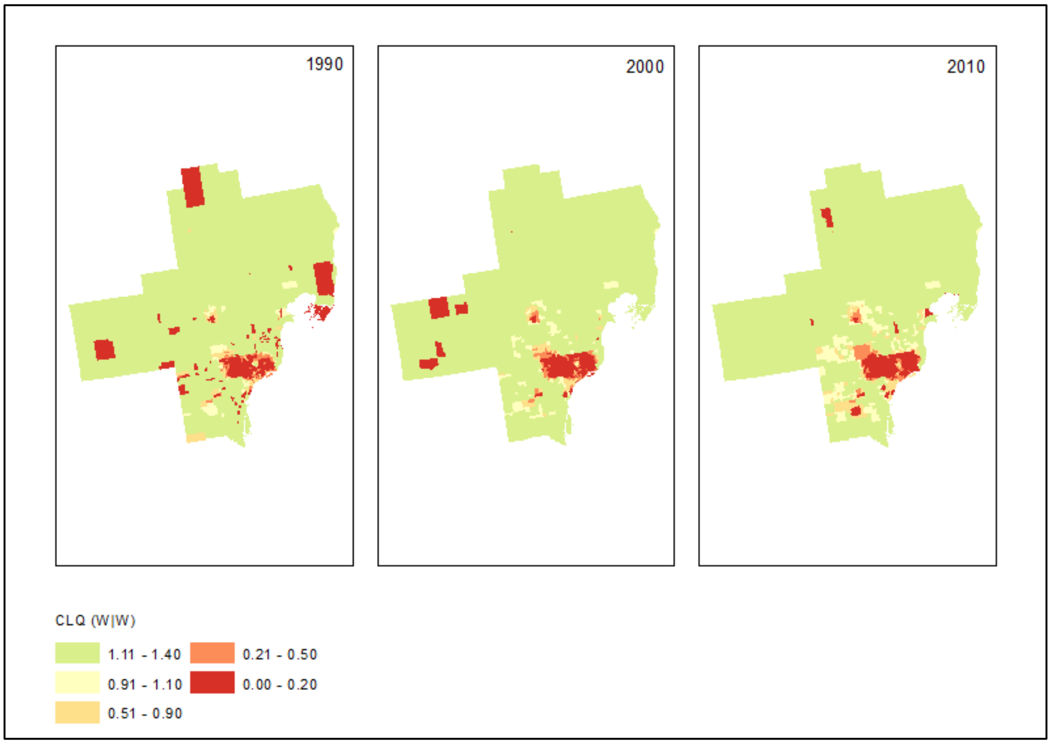


Figure 5.14 Local Co-Location with Whites Given the Location of Whites: Detroit Metropolitan Area, 1990-2010 Census Tract Level.

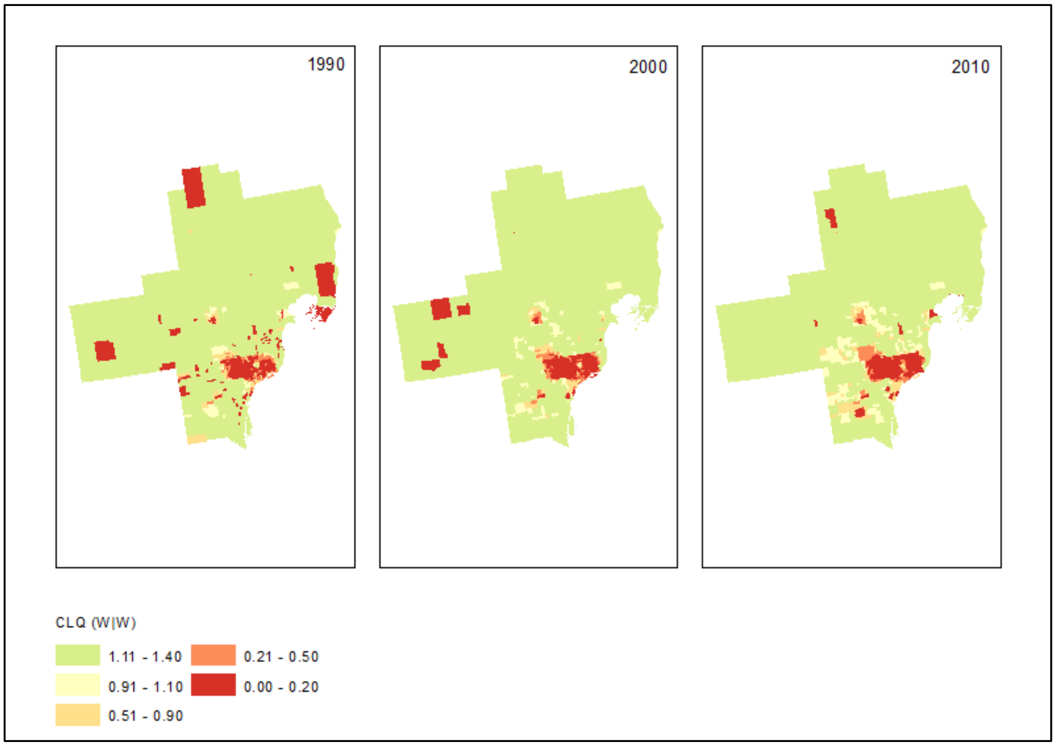


Figure 5.15 Local Co-Location with Whites Given the Location of Whites: Detroit Metropolitan Area, 1990-2010 Block Group Level

The Detroit metropolitan area is highly segregated with an increased concentration of blacks in Pontiac, Detroit and neighboring towns (Figures 5.17 and 5.18) . In accordance with census tract level map of co-location with blacks given the location of blacks at the block group level indicates that blacks are highly exposed to whites in areas other than the areas of their historical concentration mentioned above. Over the years these areas maintained similar values with some expansion towards increasing values of concentration.

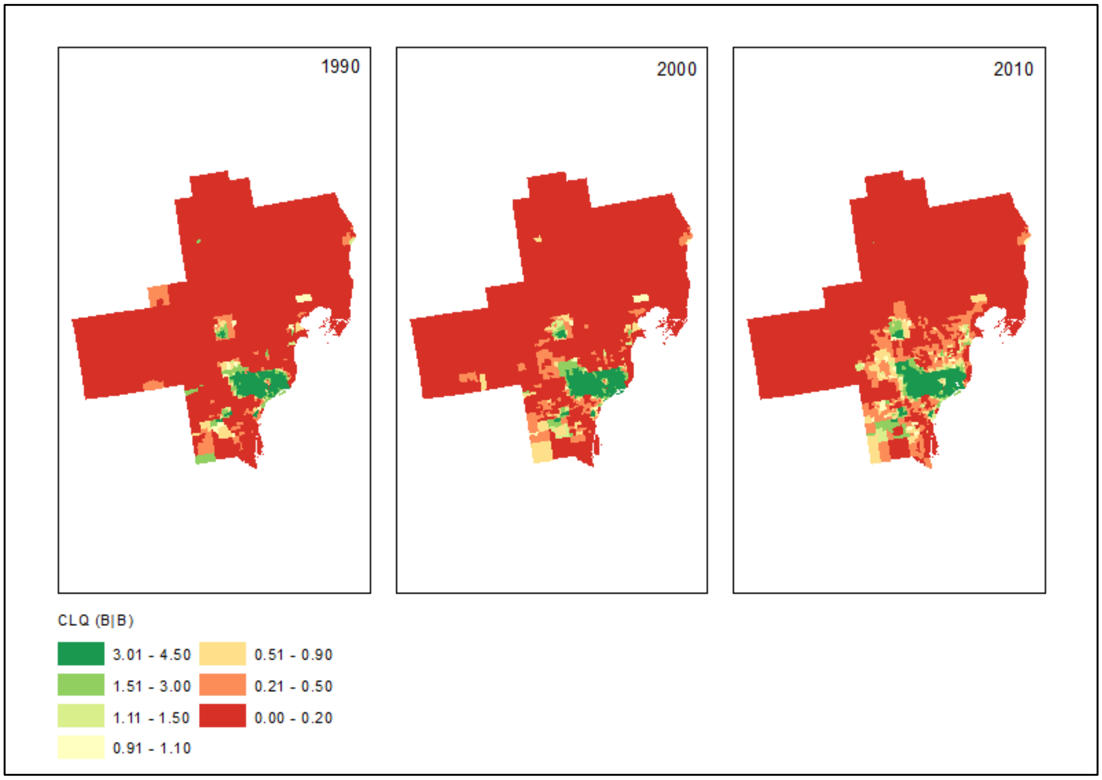


Figure 5.16 Local Co-Location with Blacks Given the Location of Blacks: Detroit Metropolitan Area, 1990-2010 Census Tract Level.

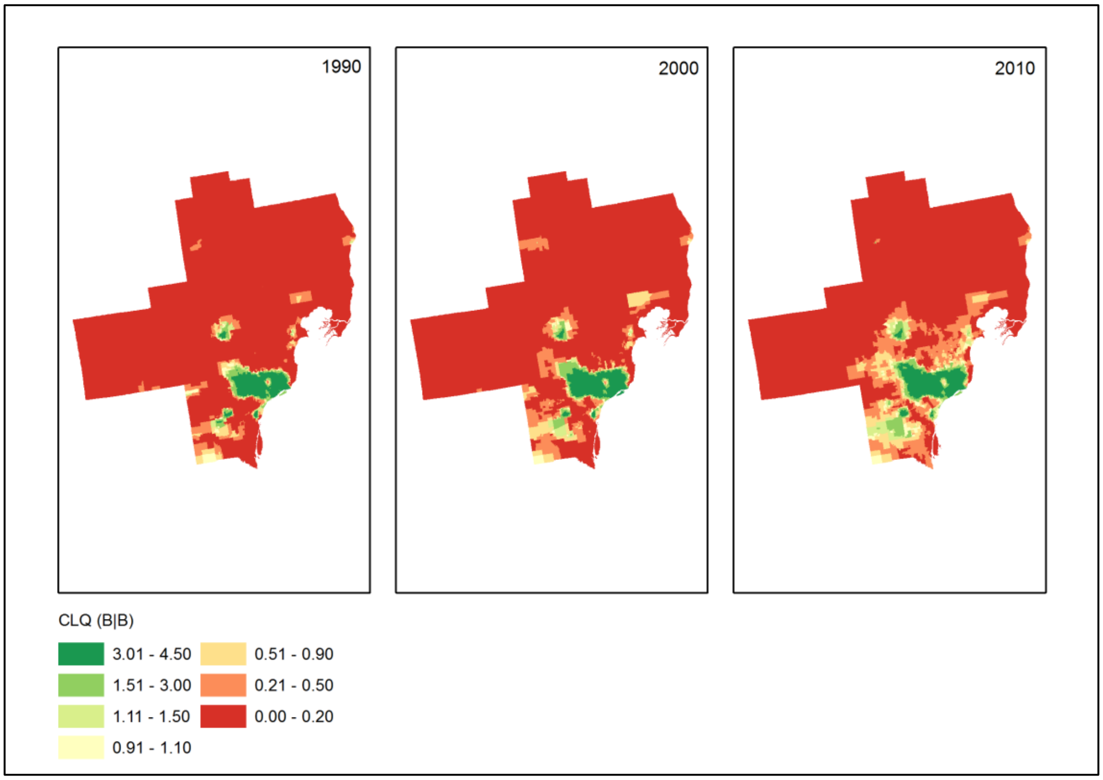


Figure 5.17 Local Co-Location with Blacks Given the Location of Blacks: Detroit Metropolitan Area, 1990-2010 Block Group Level.

5.4 Local CLQ values for the Houston metropolitan area

Houston is one of the largest metropolitan areas in the American South and historically has had high concentrations of African Americans. Even though the 20th century has seen a large migration of blacks to the North in search of job opportunities, southern states still have large black communities living in urban areas. It is reported that over twenty years from 1990 to 2010, Houston metropolitan area has grown more diverse due to the faster increase of minority populations rather than white majority (Emerson et al., 2012). The total population of Houston MSA grew from 3.8 million in 1990 to 5.9 million in 2010 while the percentage of black has slightly decreased from 17.9% in 1990 to 17.2% in 2010. In addition being a slightly smaller propotion of the population, African Americans are residentially more segregated than other minority groups.

As in other large metropolitan areas, the Houston MSA has high concentrations of blacks in the core city of Houston. The suburban ring is more populated with whites, it has a highly fragmented pattern iin terms of the settlement of whites and blacks. The areas that are most populated by blacks are the Waller county towns of Rocharon and Bonney.   Even though the region's population is considered to be the most racially diverse in the top ten metropolitan areas in the country (Emerson et al. 2012) the imbalance in the black-white dynamic is apparent on the co-location maps below. Over the twenty years,there has been a decrease in the extreme values of co-location with blacks given the location of whites (Figures 5.18 and 5.19). Many areas where these values are high in 1990 and 2000 display smaller levels of co-location in by 2010, along with a slight increase of the values in the areas where CLQ was the lowest in 1990 and 2000. This pattern points towards a gradual integration of blacks in the region. The city of Houston remains the place with the highest likelihood for whites to be exposed to blacks than anywhere else in the region.

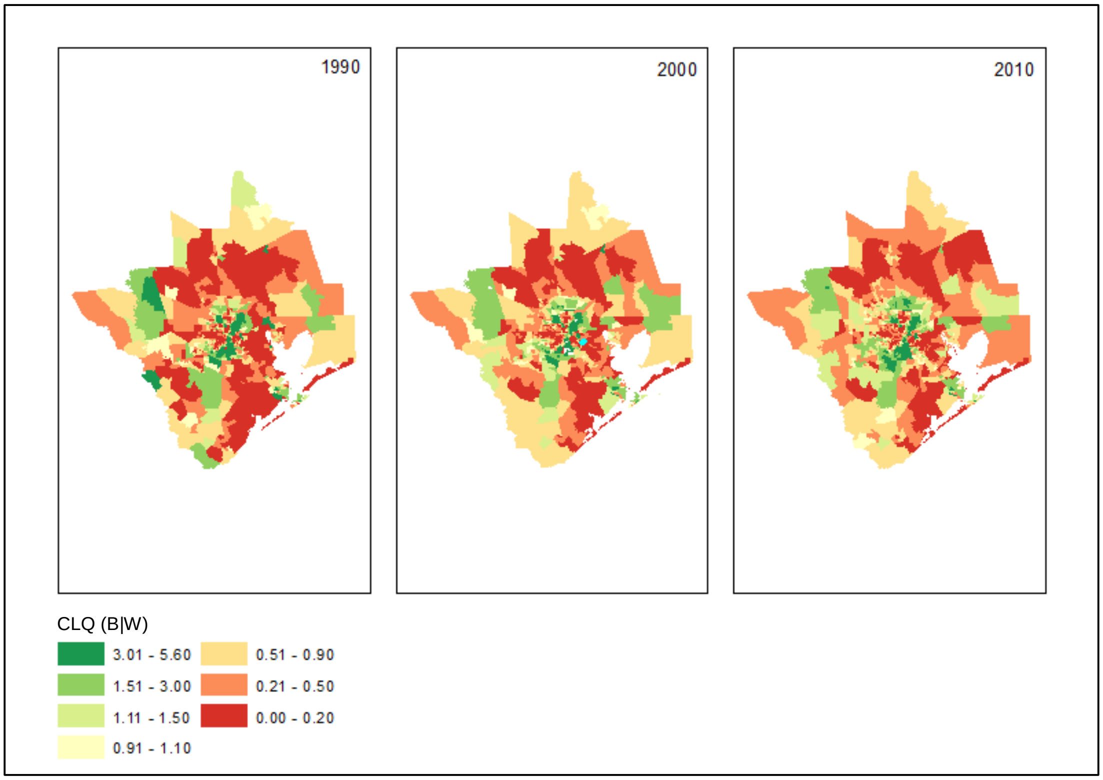


Figure 5.18 Local Co-Location with Blacks Given the Location of Whites: Houston Metropolitan Area, 1990-2010 Census Tract Level.

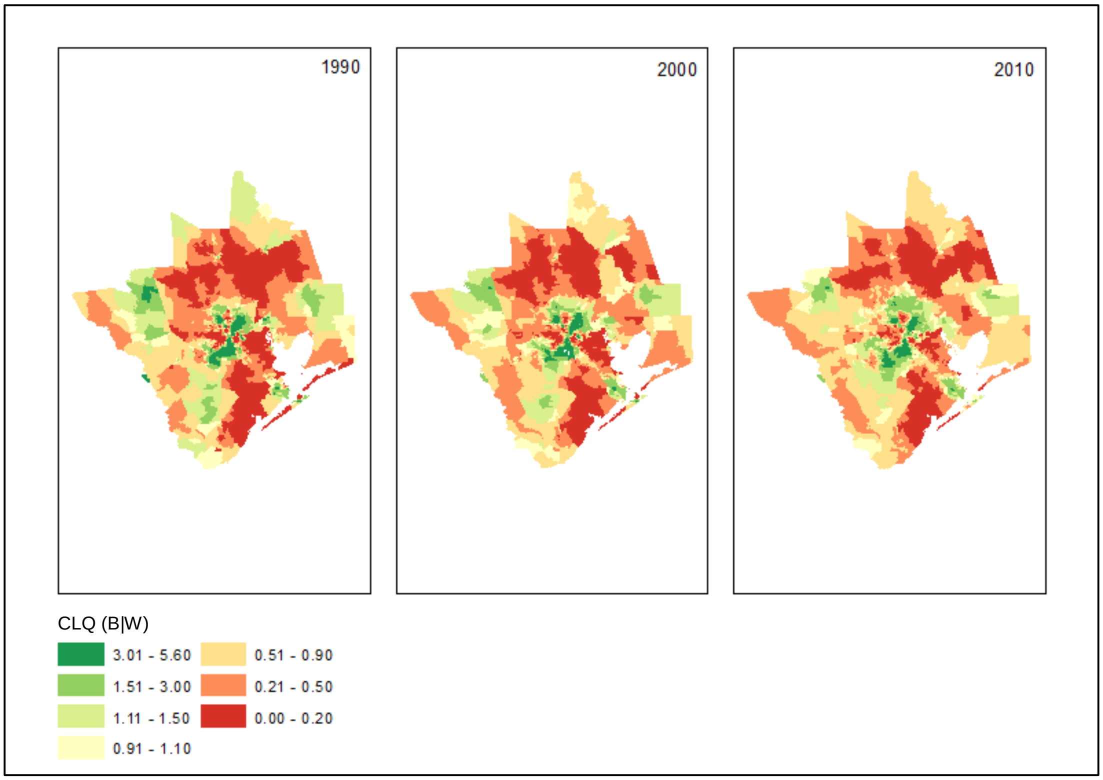


Figure 5.19 Local Co-Location with Blacks Given the Location of Whites: Houston Metropolitan Area, 1990-2010 Block Group Level.

In Figures 5.20 and 5.21 the core of the metropolitan area shows a slight increase in the areas of rising co-location with whites given the location of blacks by 2010, with an increased area where the observed and expected likelihood of interaction is balanced. This includes San Jacinto county in the northern corner of the region where by 2010 the pattern has is also highlighting increased likelihood for blacks to meet whites.

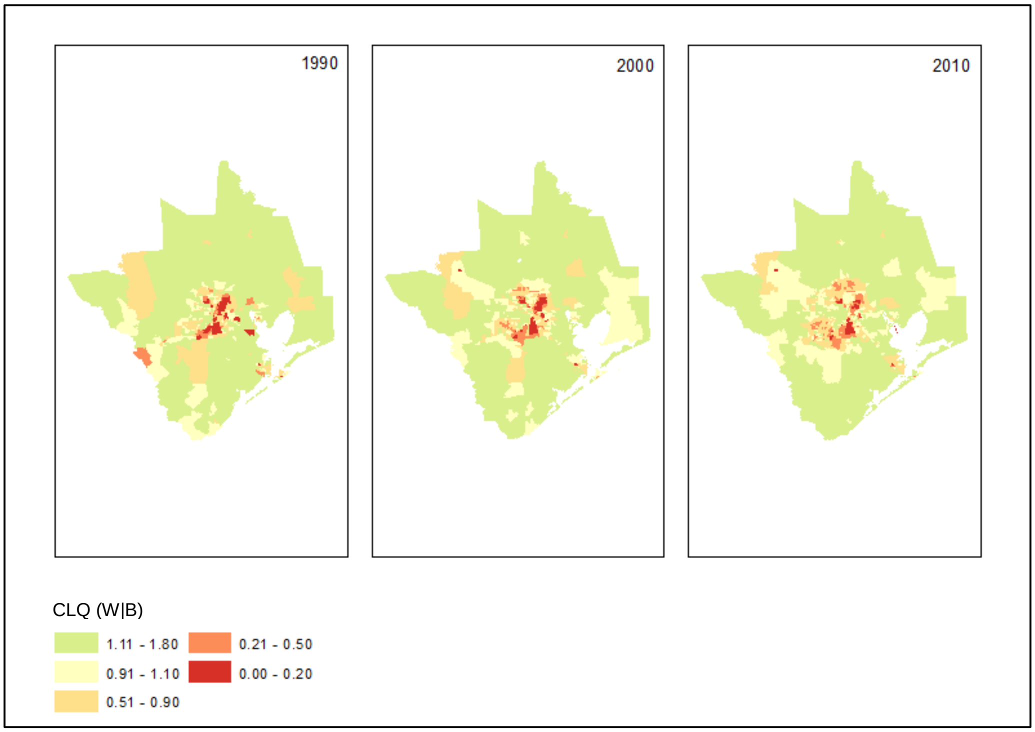


Figure 5.20 Local Co-Location with Whites Given the Location of Blacks: Houston Metropolitan Area, 1990-2010 Census Tract Level.

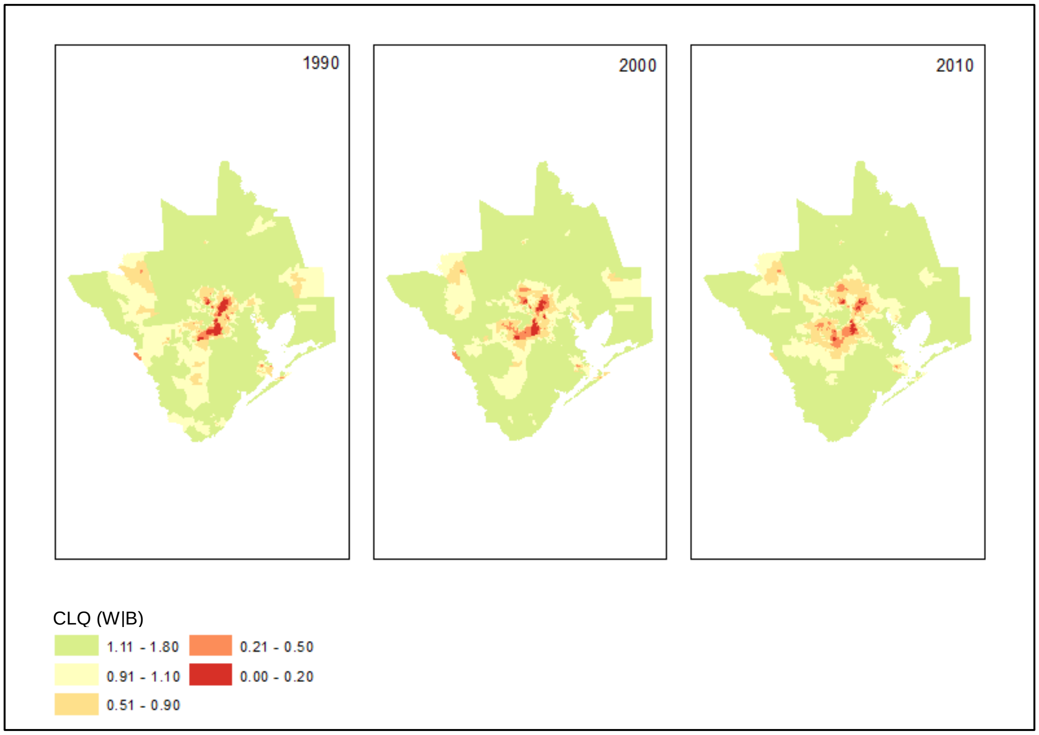


Figure 5.21 Local Co-Location with Whites Given the Location of Blacks: Houston Metropolitan Area, 1990-2010 Block Group Level.

Concentration of whites in the Houston metropolitan area increased in San Jacinto county in the north and adjoining Montgomery county. There are no noticeable areas of a large reduction in the concentration of whites over twenty years. The maps of local CLQ for self-exposure of whites produced using block group data repeats the pattern observed at census tract level. The north of the region has been experiencing greater concentration of whites by 2010. The pattern in the south of the metropolitan also produces slightly higher CLQ values by 2010 compared to the ones in 1990.

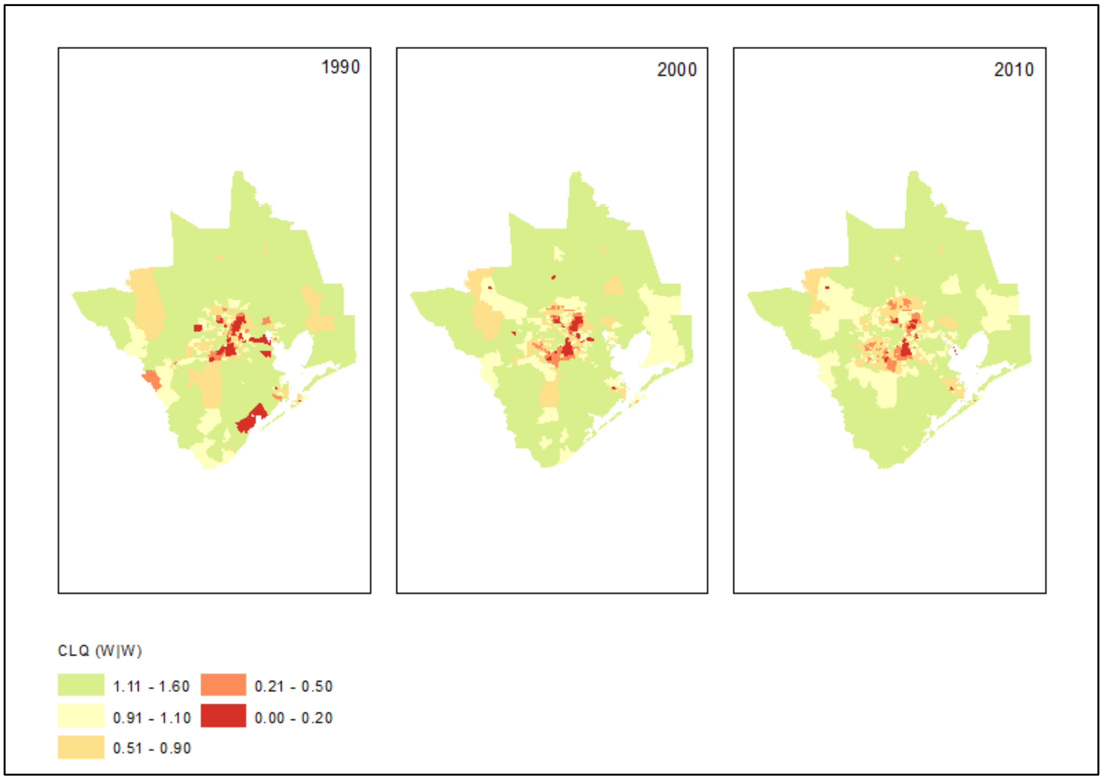


Figure 5.22 Local Co-Location with Whites Given the Location of Whites: Houston Metropolitan Area, 1990-2010 Census Tract Level.

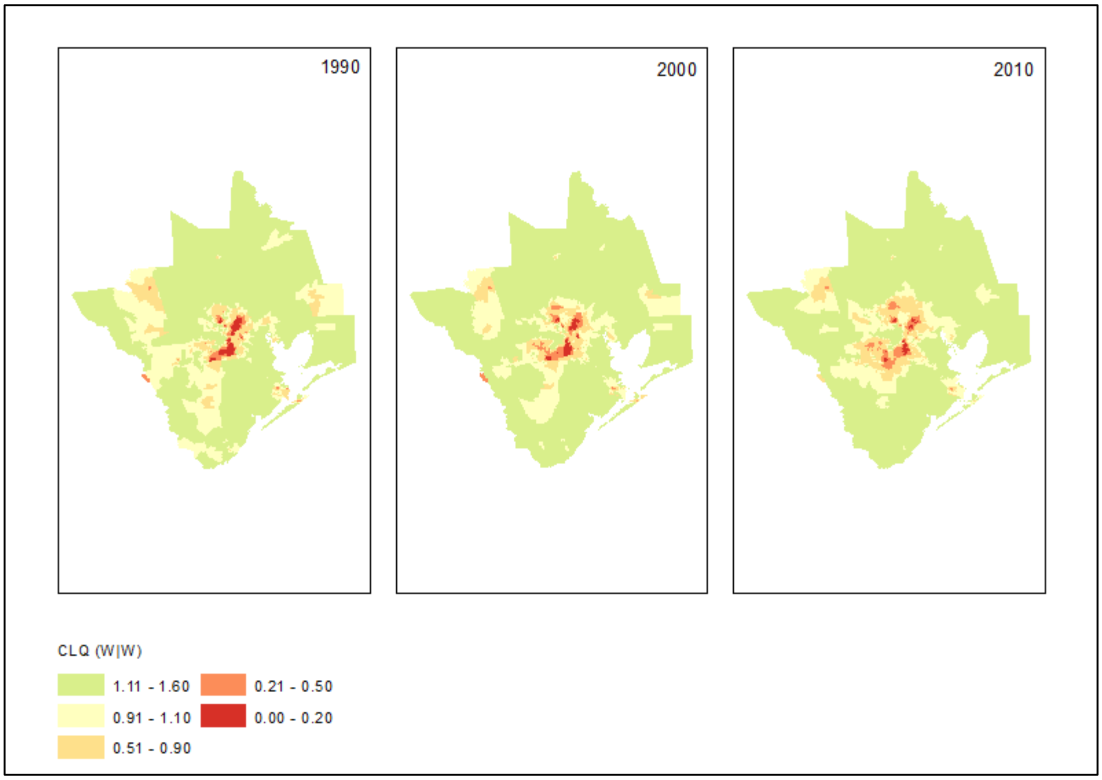


Figure 5.23 Local Co-Location with Whites Given the Location of Whites: Houston Metropolitan Area, 1990-2010 Block Group Level.

African Americans are most exposed to themselves in the city of Houston, and Waller county in the north-west part of the region (Figures 5.24 and 5.25). The areas with highest values of self-expoure of blacks have slightly decreased by 2010 in the region, along with the areas that had under-exposure in 1990. It is noticeable that in contrast with maps of co-location with whites given the location of whites and co-location with blacks given the location of whites (Figures 5.18 and 5.19) for other metropolitan areas the pattern observed for Houston demonstrates a quite different distribution of co-location values. Similarly with other metropolitan areas Houston has a high concentration of blacks in the city core, but their high percentages are not limited by the metropolitan center. Counties south, west and east from city of Houson have diverse racial compositions. Still these compositions are not balanced in most of the tracts and block groups, thus producing a quite patchy pattern.

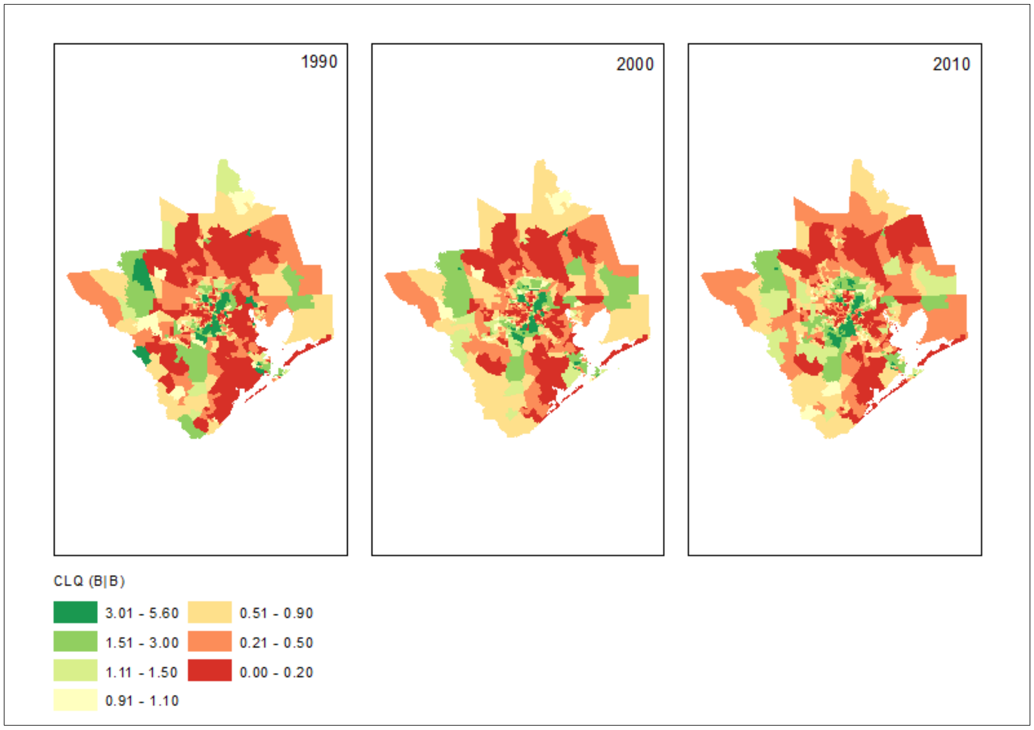


Figure 5.24 Local Co-Location with Blacks Given the Location of Blacks: Houston Metropolitan Area, 1990-2010 Census Tract Level.

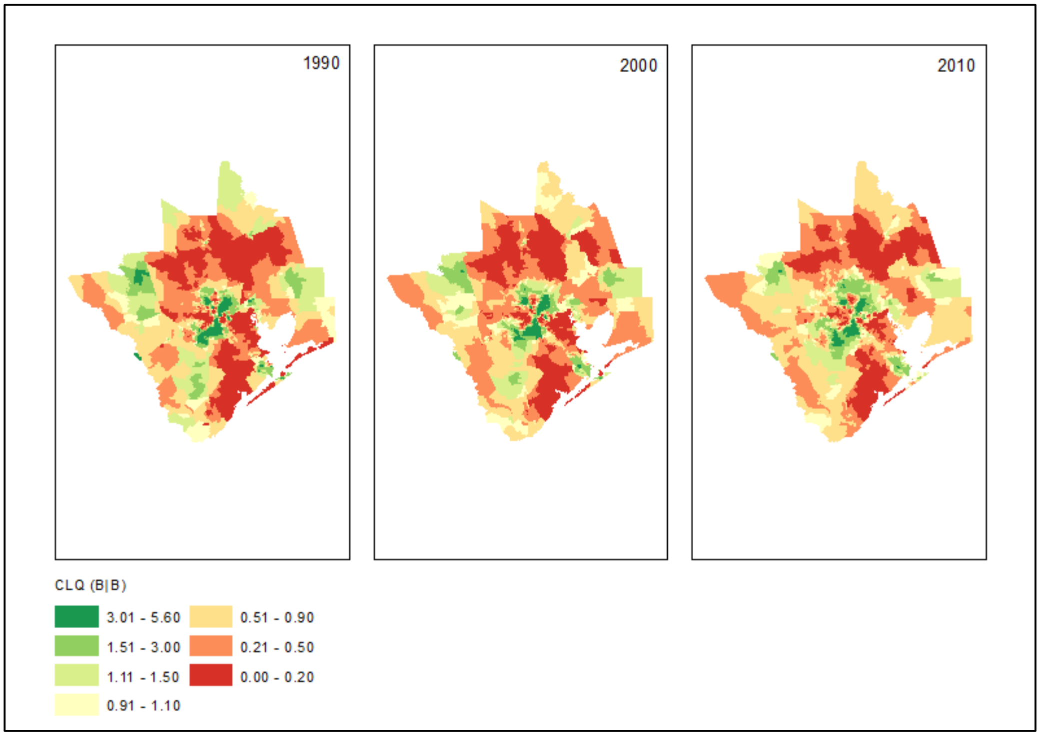


Figure 5.25 Local Co-Location with Blacks Given the Location of Blacks: Houston Metropolitan Area, 1990-2010 Block Group Level.

5.5 Summary

This chapter has provided application of the local co-location quotient to the metropolitan areas of Boston, Detroit and Houston. For temporal comparison, data for census years 1990, 2000 and 2010 were used. To demonstrate the sensitivity of the measure to scale two levels of spatial unit aggregation were used, census tracts and block groups.

A series of choropleth maps reveals regional variations in the black-white distribution dynamic and their change. Core metropolitan areas maintain high concentrations of blacks while whites tend to occupy the outskirts and suburban areas. This is not the case with Houston metropolitan area which exhibits a quite fragmented pattern of black concentration and white-black co-location. The area of Detroit appears to expand its black concentrated neighborhoods, occupying a larger area over time. For Boston metropolitan area the territories of high black-black co-location also dilate, while areas of balanced white-white co-location values transition to areas of high co-location. In terms of the two levels of aggregation, using the block group produces a smoother and more detailed pattern co-location values variations, sometimes different from the pattern observed at census tract level.

CHAPTER SIX

Geovisualization of Residential Segregation Indices: A Pointillist Approach

6.1 Introduction

The previous chapters focused on the description, interpretation and practical application of co-location as a technique for measuring segregation. One of the drawbacks of a local co-location quotient analysis is an ambiguous inference from visualizing the observed pattern due to a misimpression of the local situation across the area of interest. This is because the measure's numeric value only tells a portion of the story behind the conditions that produced the values. This chapter examines approaches for improving the communication of the results using a co-location quotient or any other segregation measure being mapped.

As has also been the case in this dissertation, most research on the measurement of residential segregation has focused on numerical indices. Different indices measure different aspects or so-called spatial dimensions of segregation. As noted in Chapter Two, the first notion of different spatial dimensions was introduced by Massey and Denton(1988) who analyzed a group of segregation indices and broke them down into five groups according to the spatial property (or dimension) that each of the indices represents. More recent research has compressed the original five dimensions into two dimensions, exposure and evenness (Reardon and O'Sullivan, 2004) and different indices are associated with each dimension (see Table 1).

Also, the initial methods used to measure segregation were aspatial techniques borrowed from other fields of study. The index of dissimilarity (D) used by Duncan and Duncan (1955) is known in economics as the Pietra Index (1915) and in population studies as the Hoover Index (Hoover, 1948). The methods were also global statistics in the sense that a single calculated statistic or index was used to represent or summarize the whole study region. Next, explicitly spatial versions models were developed in which the arrangement of data values affected the index value. The focus was still on developing a global statistic to describe the overall region; thus the D index became the Adjusted D index (Morrill, 1991; Wong, 2003). Later as the trend in statistical methods in geography shifted to local analysis, in which parameters are calculated from the perspective of individual locations rather than as a summary of the whole, local segregation indices were developed; local extensions of exposure indices were created (Wong, 2002) and a geographically weighted index of dissimilarity (GWD) (Lloyd et al., 2004).

Although it is important to provide a useful metric of the extent of someone's spatial separation from members of a particular group that can be properly interpreted, the problem of an effective display of segregation measures is equally important and has not received as much attention. The question of how to display segregation indices in an interpretable manner is related to developments in the area of geovisualization. The geovisualization of residential patterns has also evolved over time independently of the numerical indices. This chapter integrates improved geovisualization techniques with the display of different types of numerical indices, in order to highlight deficiencies in some indices themselves as well as the map display of indices. One of the underlying problems of geovisualization "concerns the interplay between the data that are being visualized, their geographical context and technology used" (Unwin, 2008, in Dodge et al., 2008). Indeed, the nature and structure of the data used to derive segregation measures limits the range of methods to compute and to visualize these measures. The most commonly used data (as a result of its public availability) are associated with aggregated areal spatial units of various sizes and with different population sizes residing in them. The mathematic formulations of the indices are usually based on the count or the proportion of different population groups in every spatial unit that contribute to the computation of the index.

Besides classification of the indices by particular dimension there has been the discussion related to the questions of spatial dependency and heterogeneity. The problem of spatial dependency is solved by using indices that take into consideration spatial arrangement of the units of analysis. The questions of Spatial heterogeneity is posed by using Local rather than Global indices allowing for the level of segregation not to be constant across the space. Global indices characterize segregation as a uniform phenomenon occurring across the study area.

The phenomenon of segregation is produced by groups living in a geographical context that can include any historic, social and economic characteristic of the area (Kaplan and Woodhouse, 2004). When defining the extent of segregation one of the contexts is the degree to which the area is populated by each of the racial or ethnic subgroups. Population size and/or population density are important areal attributes when interpreting segregation measures because the weighting of a particular area over other areas is often done by considering how large a population is contained within it, and this will define the amount of attention that should be given to it.

Table 6.1 Classification of Different Segregation Indices

<table>
<tr><td colspan="3"><i>Aspatial global indices</i></td></tr>
<tr><td>Evenness</td><td>D – index of dissimilarity</td><td>Duncan and Duncan, 1955</td></tr>
<tr><td>Exposure</td><td>xP*y, yP*x / xP*x, yP*y – interaction/isolation indices</td><td>Massey and Denton, 1988; Wong 2002</td></tr>
<tr><td colspan="3"><i>Spatial global indices</i></td></tr>
<tr><td>Evenness</td><td>Adjusted D</td><td>Morrill, 1991; Wong, 2003</td></tr>
<tr><td>Exposure</td><td>Standard Deviation Ellipse
P^*_{xy}, P^*_{xx} – spatial exposure/isolation indices
SD – multigroup spatial index of dissimilarity
I – global Moran’s I
Spatial information theory index</td><td>Wong, 2003
Wong, 2002; Reardon and O’Sullivan, 2004
Wong, 1998
Frank, 2003
Reardon and O’Sullivan, 2004; Fischer et al., 2004</td></tr>
<tr><td colspan="3"><i>Local indices</i></td></tr>
<tr><td>Evenness</td><td>D_i – local index of dissimilarity
GWD – geographically weighted index of dissimilarity</td><td>Wong, 2008
Lloyd, 2004</td></tr>
<tr><td>Exposure</td><td>Local Location Quotient
Local Moran’s I
Local exposure/isolation indices
Potential surface</td><td>Brown and Chung, 2006
Anselin, 1995; Getis and Ord, 1996; Levine, 2004
Morgan, 1983
Osth et al., 2015</td></tr>
</table>

* In general xP*x and yP*y are called isolation indices and xP*y and yP*x are called interaction indices.

6.2 Current Methods for Geovisualizing Segregation Measures

The geovisualization of analyses related to the development of segregation indices depends in part on whether a case study or example using actual data was performed. Research solely on the properties of segregation indices usually have no associated maps or maplike displays (i.e. Duncan and Duncan, 1955; Cortese et al., 1976; Massey and Denton, 1988; Reardon and O’Sullivan, 2004; Alonso-Villar and del Río, 2010). Also studies that do include case data but are limited to regional or metropolitan-wide global index values also normally have no map displays, but instead contain tables of values for the different metropolitan areas and/or years (i.e. Massey and Denton, 1987; Frankel and Volij, 2011). When the case study is included that focuses on a particular metropolitan region, the distribution of the different ethnic populations used as input for the segregation analysis is often displayed as a choropleth map (Wong 2004; Brown and Chung 2006; Dawkins 2006; Reardon 2008; Hong and Sadahiro 2014). Choropleth maps are also common displays involving the mapping of local index values that are either measures of evenness (Lloyd et al., 2004) or exposure (Wong, 2002). Holloway, Wright and Ellis (2012) combined local entropy values with the dominant racial group to create categorical areas similar in design to an areal class map.

An alternative geovisual analytic for summarizing the spatial distribution of individual ethnic groups is the standard deviation ellipse that forms the basis for geostatistical indices (Wong, 1999; Wong, 2002a ; Wong, 2004). Different global values related to the exposure dimension can be derived from the intersection and union relationships among the summary SDEs (Wong, 1999); in this situation the geovisual analytic and the global index are almost interchangeable. Later O'Sullivan and Wong (2007) used the same logic to construct a global index based on kernel density surfaces based on different bandwidths that summarize the each subgroup's spatial distribution; the authors note that their new index is closely relation to the index of similarity (a measure of the evenness dimension). The display of the index is a smooth continuous surface. In a similar manner, Osth Clark and Malmberg (2015) have used k-nearest neighbor bandwidths to create and display a probability map of encountering an individual of a particular subgroup (actually a choropleth map at the census tract level in the case of Los Angeles). Sometimes multiple geovisual analytics are used with respect to both the display of the input data as well as the derived index (see Table 2).

Each of these geoanalytics have advantages noted by the authors but they also have some drawbacks. For example, the utility of a standard deviational ellipse as a summary measure is based on the assumption that the underlying distribution is bivariate normal. Figure 6.1 displays the two SDE summaries for the white and black population of Washington, D.C. in 2010. The assumption is that roughly sixty-seven percent of the white and black populations lie within their respective ellipses.

Table 6.2 Segregation Indices: Visual Medium for Communication of Indices

Author	Index Medium	Input Data Medium
Wong, 1999		SDE
Wong, 2002a		SDE
Wong, 2002b	Choropleth	Choropleth
Wong, 2003		SDE
Lloyd et al., 2004	Choropleth	Choropleth
Brown and Chung, 2006	Choropleth	Choropleth
Dawkins, 2006	Choropleth	
O'Sullivan and Wong, 2007		Kernel Density Surface
Feitosa et al., 2007		Choropleth, SDE
Reardon et al., 2008	Choropleth	
Holloway et al., 2012		Area Class Map
Osth et al., 2015		Probability Surface

The geostatistical segregation index (Wong, 1998) is based on the areas of intersection and union of each ellipse (two or more):

$$S = 1 - \frac{E_1 \cap E_2}{E_1 \cup E_2} \qquad (6.1)$$

where, E_1 *and* E_2 are the ellipse areas for each population groups. This index assumes that the population is uniformly distributed within each ellipse so that the intersection and union areas are proportional to population. Thus, by comparing the magenta colored intersection area to the total area within the SDEs, one has a sense that the two groups are spatially segregated.

The major drawback associated with the probability surfaces created by Osth, Clark, and Malmberg (2015) is that the surface only depicts half of the story. If an individual was at a location, the probability surface would indicate the likelihood of encountering a person of the given racial group, but the map does not indicate the racial group of the individual at the location. An important distinction between evenness and exposure measures is that exposure measures are asymmetric whereas evenness ones are not. For any pair of racial groups, X and Y, there is only one evenness measure, whereas there are four exposure measures, P*xy, P*yx, P*xx, and P*yy. P*xy, P*yx are measures of the *interaction* between the two groups, whereas P*xx, and P*yy are *isolation* measures. The probability surface is similar in meaning to the location quotient maps used by Brown and Chung (2006); the location quotient for each areal unit also indicates an above or below expected chance of meeting a person of the given racial groups. Because it uses a bandwidth to estimate the probability surface, it is closer in structure to a map of focal location quotients (Cromley and Hanink, 2012).

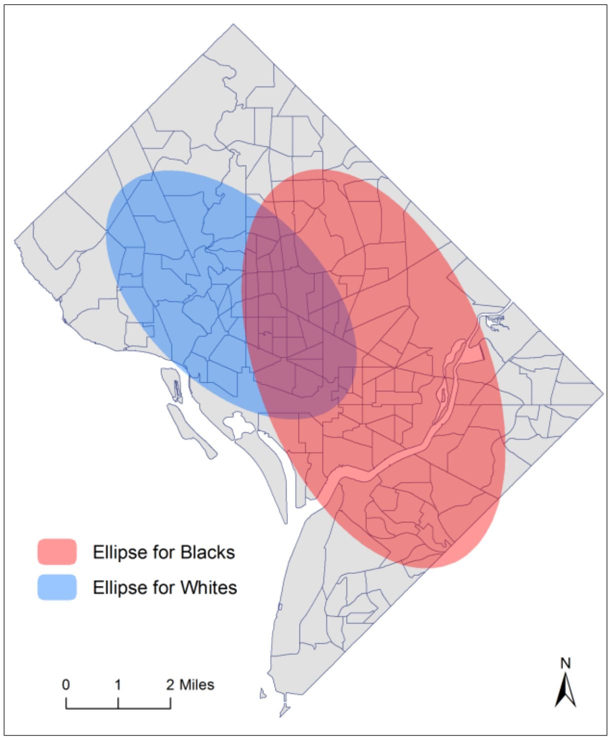


Figure 6.1 Standard Deviational Ellipses for Distribution of Whites and Blacks in Washington D.C.

Choropleth maps of any segregation measure are subject to their own deficiencies. Most critical to discussion here is the problem of *visual equalization* in choropleth maps (Roth, Woodruff and Johnson, 2010). Figure 6.2 shows a choropleth map displaying a geographically weighed index of dissimilarity (GWD) for whites and blacks in Washington, DC using a one mile bandwidth. The areas in southeast Washington DC and through the middle are the most segregated while the northern and western areas and the eastern tip have a more evenly distribution of the two groups. However, the map does not inform the reader as to the dominant group in any area (an importance stressed by Holloway) nor the size of the population associated with the local area. Choropleth maps are generally used to display socio-economic data aggregated into area units; the raw count data are also standardized into a density or rate value before mapping. However, it has been noted (see Roth, Woodruff and Johnson, 2010) that for rates one cannot distinguish between high rate/low denominator and high rate/high denominator areas, or between low rate/low denominator and low rate/high denominator areas in a choropleth map. This is the problem of visual equalization. Mapping local segregation measures have the same issue; one is not able to determine in Figure 6.2 whether census tracts that are more segregated have larger or smaller populations than average.

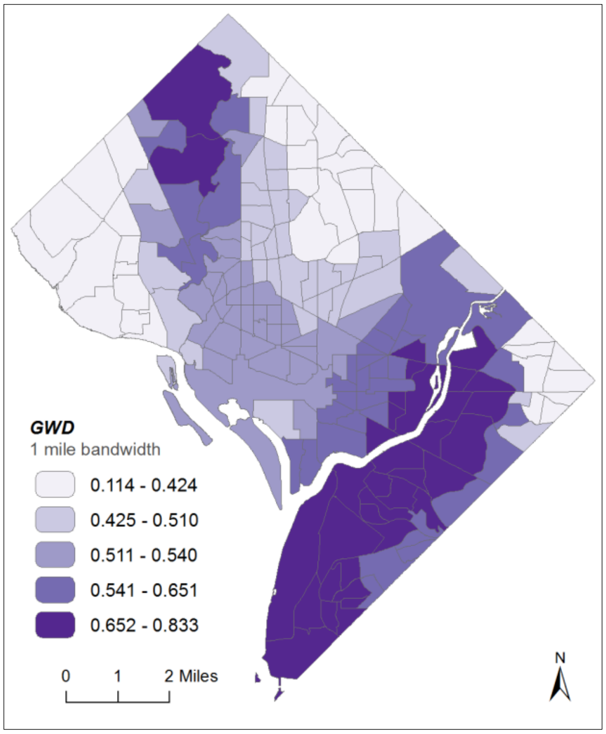


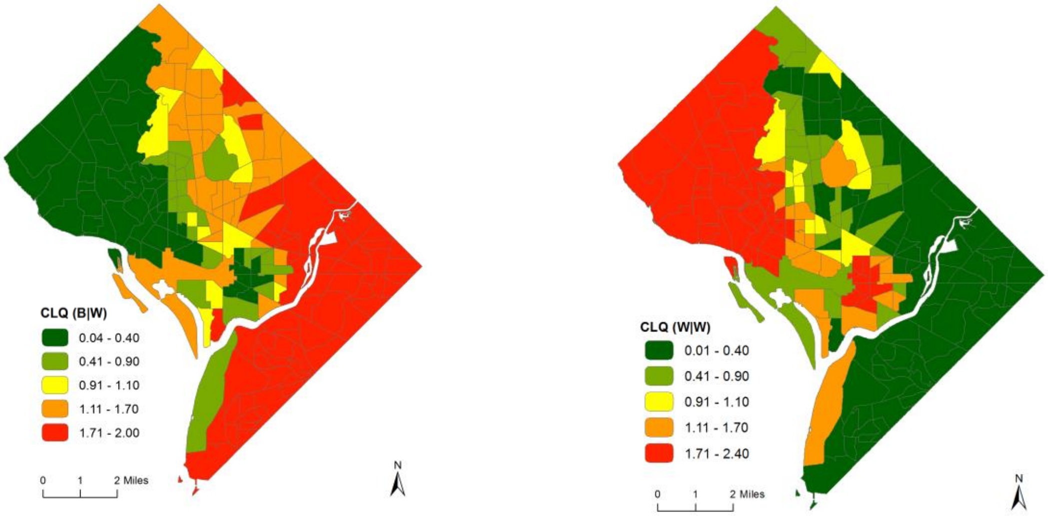
Figure 6.2 Choropleth Map of Geographically Weighted Index of Dissimilarity (GWD).

This problem is compounded for exposure indices. Two different local exposure indices, the spatial segregation index by Wong (2002) and co-location quotient (Vorotyntseva and Cromley, 2014) are given in the following equations respectively:

$$S_{i*ab} = 1 - \frac{a_i \sum_j w_{ij} b_j}{a_i \sum_j b_j} \qquad (6.2)$$

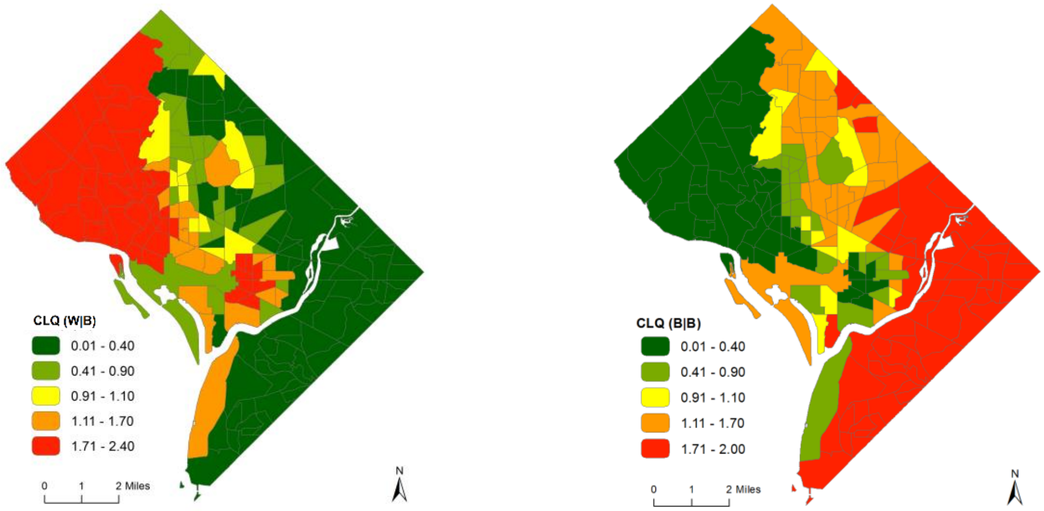
$$CLQ^{L}(A|B) = \frac{a_i(\sum_j w_{ij} b_j)\,/a_i(\sum_{j=1} w_{ij} n_j)}{B/(N-1)} \qquad (6.3)$$

In both formulations there is a term ai representing the population of category A residing in tract i; a_i is present in the numerator and the denominator of the ratios. a_i cancels out except if $a_i = 0$. But ai also tells



a) Co-location with Blacks
Given the Location of Whites

b) Co-location with Whites
Given the Location of Whites



c) Co-location with Whites
Given the Location of Blacks

d) Colocation with Blacks
Given the Location of Blacks

Figure 6.3 Choropleth Map of Local Co-location Quotients (CLQ) for Washington, D.C.

us how many persons are being exposed to b. Figure 6.3 displays the four exposure measures associated with a local co-location quotient.

The choropleth maps in Figure 6.3 give no indication of the size of the a_i values. The map reader can determine of the level exposure to a second racial group given the location of the first racial group, but the reader does not how many of that first racial group are present in each tract. These choropleth maps should be interpreted as potential exposure to one group, if the other group. Thus, Figure 6.3a and Figure 6.3c are identical maps with respect to exposure to blacks and Figure 6.3b and Figure 6.3d are identical maps with respect to exposure to whites. Although there are four exposure measures, there are only two unique maps – one for each race. This is why Osth, Clark and Malmberg (2015) only constructed one potential surface map for each race. However, visual tools are available so that the more complex pattern of potential interaction can be explored.

6.3 Value-by-Area Cartograms

The problem of the visual equalization with respect to choropleth maps of spatially intensive rates has been addressed by the construction of different types of value-by-area maps, commonly known as cartograms. In a value-by-area map, the geographic area within each areal unit is replaced by an area that is proportional to the denominator value that determined the rate. A similar approach can be taken with respect to the mapping of segregation indices. For a local evenness measure the area would be proportional to the total population of an areal unit and for a local exposure measure, the area would be proportional to the a_i value. Because the area within each areal unit is distorted in size according to the underlying values, there are two basic types of cartograms - contiguous and non-contiguous. Each has advantages and disadvantages.

6.3.1 A Contiguous Value-by-Area Cartogram Approach

Most maps preserve at least one metric property of a feature, be it shape, distance or geographic area. Which property (or properties) are preserved depends on the purpose of the map. In a contiguous value-by-area cartogram all three of these properties are distorted because the purpose is to properly present value relationships. It resizes geographic areas according to the variable value assigned to every area, and in doing so it usually distorts the shape of units and distance between a pair of points. If the variable of interest is population size, then densely populated areas will increase in size while sparsely populated regions will shrink. Contiguous cartograms do preserve the mutual boundary between areal units in the process of size transformation so that the relative location of map features is maintained although the shape of individual units may be highly distorted.

Several computer-based algorithms exist for producing contiguous cartograms. One developed by Dougenik et al. (1985) transforms the boundaries using inverse distance proportions based on areas centroids. Henriques et al. (2009) base their algorithm on using self-organizing maps to control the excessive magnification of some areal units when deriving a cartogram from the original map. Borrowing ideas from the heat transfer computations in physics Gastner and Newman (2004) presented an algorithm for generating contiguous cartograms that to some extent preserve the physical shapes of the areal boundaries. The analogous process associated with creation of contiguous cartograms is diffusion, and similarly population surface of the original map is "stretched" until the population density is even across the area. As with other algorithms, this method maintains topological relationships between the areas so that adjacency of regions is maintained. The disadvantage of using a contiguous cartogram is that the excessive distortion of parts of the study area makes it is difficult to recognize the different neighboring units. This issue can lead to a potential problem of interpretation of the mapping results.

The Gastner-Newmann contiguous area cartogram depicting the geographically weighed index of dissimilarity values for Washington, D.C. presented in Figure 6.4 uses total population by tract size as the area value. The center of the city that has a higher concentration of people as shown by larger areal units in that location. It is noticeable that the areas containing nonresidential areas included in the choropleth representation have dramatically decreased in size. The center of the city appears to be 'magnified' because it is more densely populated compared to the outskirts of the area.

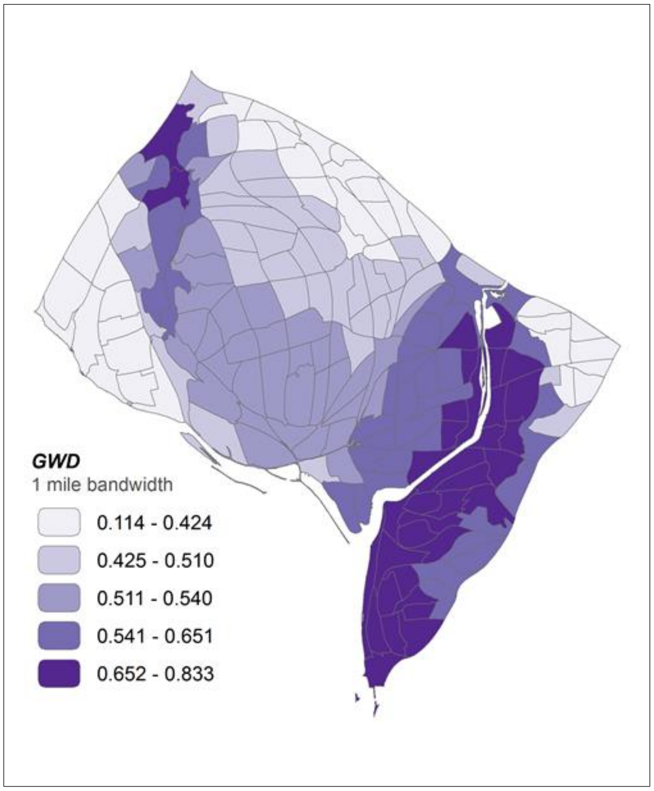
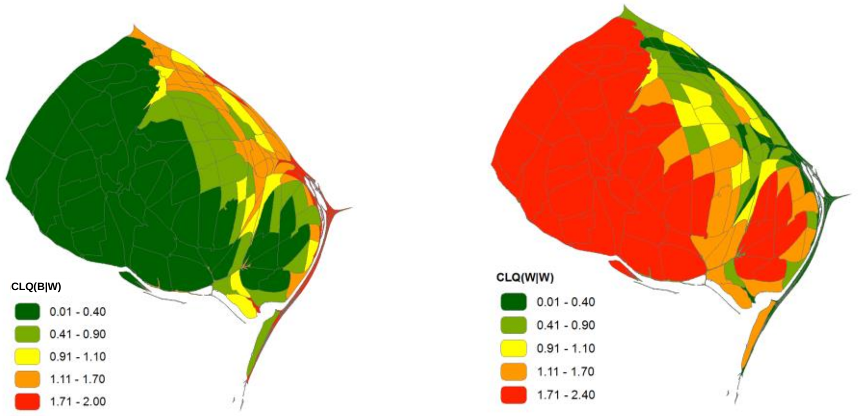


Figure 6.4 Gastner-Newmann Cartogram of Geographically Weighted Index of Dissimilarity (GWD).Census Tract Areas in Contiguous Area Cartogram are Scaled according to Total Population.

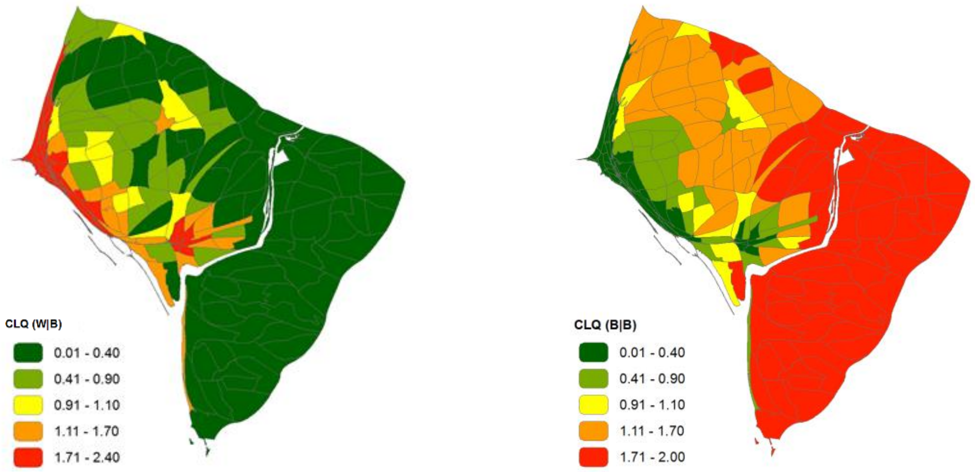
Although the tracts on the periphery of the city shrunk in size relative to the tracts in the center, all tracts were fairly recognizable because the total population of census tracts are kept within a limited range of values. If population increased too much over time, tracts are subdivided and if tracts lost too much population over time, tracts are merged so that the overall range of tract populations is maintained. However, the population of individual racial groups within tracts can vary widely in their a_i values. This is very important for displaying local exposure indices in a value-by-area cartogram. It is possible that some tracts may have zero a_i values for certain groups. In this case, the visual size of the tract would shrink to nothing.

Figure 6.5 presents the local CLQ values for the city of Washington, D.C. using Gastner-Newmann cartograms. A major advantage of this cartogram approach over the original choropleth maps is that there are now four unique maps corresponding to each of the four exposure measures. The map reader can now determine not only the level of exposure to a second racial group given the location of the



a) Co-location with Blacks Given the Location of Whites

b) Co-location with Whites Given the Location of Whites



c) Co-location with Whites Given the Location of Blacks

d) Colocation of Blacks Given the Location of Blacks

Figure 6.5 Contiguous cartogram maps of local co-location quotients (CLQ) for Washington, D.C.

first racial group, but also how many of that first racial group are present for that exposure. These cartograms represent more than potential exposure to one group by another group. Thus, Figure 6.3a and Figure 6.3c are no longer identical maps with respect to exposure to blacks; it is easy to determine that most whites have a low exposure to blacks in Figure 6a. The same is true when comparing Figure 6.3b and Figure 6.3d; most blacks have low exposure to whites. However, the downside to these cartograms is that many tracts are so small that they are hardly recognizable.

6.3.2 Dorling Circle Non-Contiguous Cartograms

Instead of keeping the original areal shapes of the geographic features another method of cartogram converts every area of any shape to a circle placed closely to its neighbors. Dorling (1996) described a method that converts the areas of the map into circles of sizes proportional to population or another variable of interest. Because a circle is a regular shape it does not allow corresponding contiguity between the regions, but, when possible, the algorithm leaves adjacent areas touching. At the same, time the benefit of such a representation is the easily comprehensible pattern that the method produces. The perception of areas with complicated shapes is alleviated by replacing those areas with the simplest and the most compact geometric figure.

Problems for interpreting the pattern or identifying particular locations may arise when the study area has a highly uneven spread of some phenomenon and the number of areal units is too small. Multiple iterations improve the topological fitting of the areas, but Dorling (1996) also notes that the higher number of areas assure better maintenance of topology.

Practical implication of using circle cartograms is that the simplicity of shape gives a straightforward impression of the variable distribution, especially if there is a great variation in values. Figure 6.6 uses the Dorling cartogram method to display circle sizes in proportion to total population, and to color each circle with one of the classed local GWD values. This cartogram also emphasizes areas in the city center as well as on the western edges as the most populated. However, because the number of tracts is not high enough many census units are drawn discontinuously and may be harder to identify comparing with the original map.

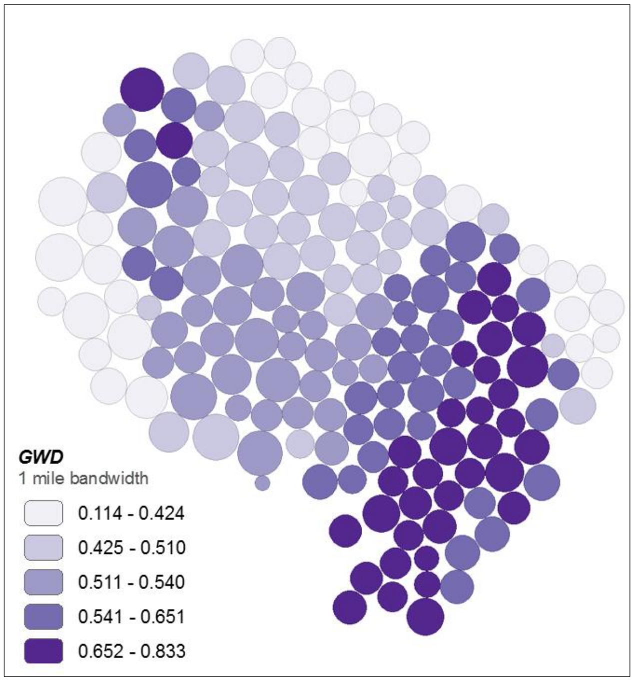
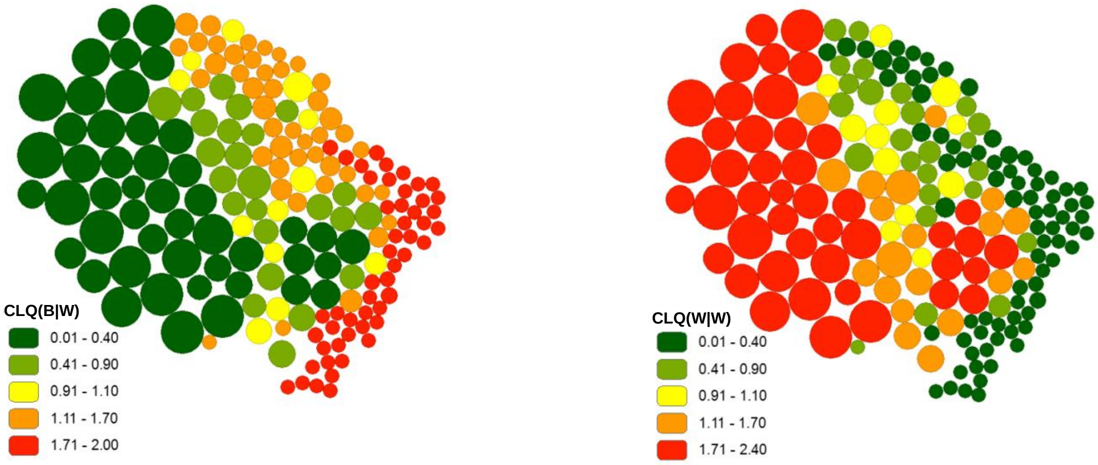


Figure 6.6 A Dorling Circle Cartogram of the Geographically Weighted Index of Dissimilarity (GWD). Census Tract Areas in Each Circle are Scaled according to Total Population.

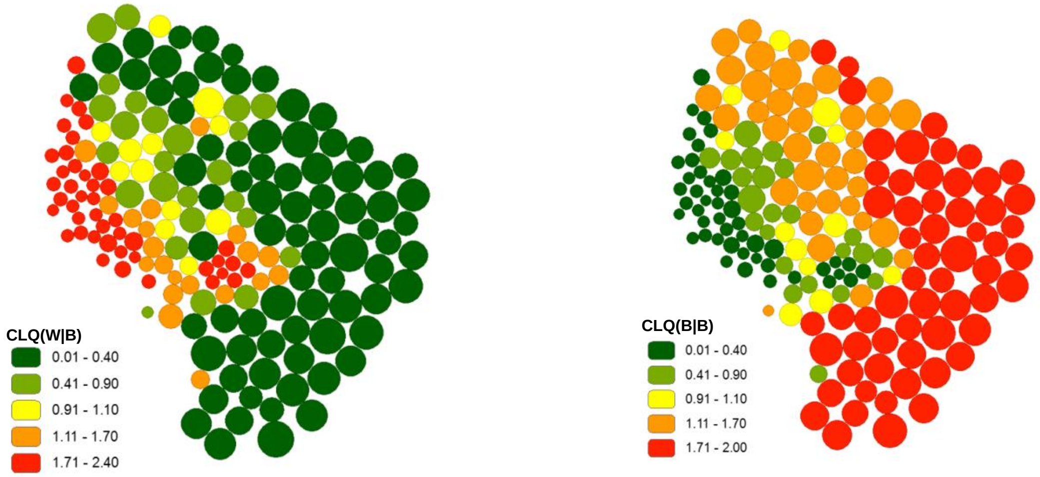
Next, the Dorling circle cartogram is applied to the display of the exposure of the two racial groups with respect to one another in Washington, D.C. As with the Gastner-Newmann cartograms, each map is unique; it is again easy to determine that few whites have a high exposure to blacks (see Figure 6.7a) and vice versa (see Figure 6.7c). However, a greater range of a_i values means that some census tracts almost disappear within the diagrams and it is more difficult to ascertain neighborhood relationships.

Although value-by-area cartograms are improvements over choropleth maps, they do have some drawbacks, especially with respect to situations in which some values of the scaling variable are close to zero, or when there is a large range among the data values. The next section presents another approach that does not scale by area and consequently does not distort geographic area or shape.



a) Co-location with Blacks
Given the Location of Whites

b) Co-location with Whites
Given the Location of Whites



c) Co-location with Whites
Given the Locations of Blacks

d) Colocation of Blacks
Given the Locations of Blacks

Figure 6.7 Dorling circle cartograms of local co-location quotients (CLQ) for Washington, D.C.

6.4 The Pointillist Approach

The use of different colors to represent separate categories is the basis of the “pointillist” approach for the transitional shading of nominal data Jenks (1953). Jenks suggests that if different colors are given to each group being mapped, and these colors are portrayed as dots in their true map position, then the juxtaposition of these dots will form a different color at a given scale. “As the distributions of the phenomena being mapped change, the balance between the colored dots will change and new distinctive colors will result. Each area having its own distributional pattern, will have its own individual color." (Jenks, 1955, p.5).

When mapping population change, Turner and Allen (2010) proposed coloring the dots differently according to whether the population change represented a decrease or an increase in population. The Weldon Cooper Center for Public Service at the University of Virginia has created a racial dot map (web link: http://demographics.coopercenter.org/DotMap/index.html) of individual racial groups to portray the composition of different neighborhoods based on the pointillist principle. The interactive map permits different "zoom" levels so that the viewer can visualize patterns at different geographic scales. The map legend also states that one dot equals one person in the map, but this is a misleading statement. At zoom levels representing larger geographic scales, dots representing individual are smaller than the pixel resolution of the maps. Pixels change colors at the large scale zoom levels because the colors assigned to different racial groups are a mixed according to the proportion of each group within each pixel to produce a color representing the level of integration. Because it is the pixel being displayed, the pixel becomes the "dot" in a dot map. However, there is no standard value for such "dots" as individuals are aggregated into pixel units similar to the collection unit used in a choropleth map.

Rankin (2010) also advocates using the pointillist approach to display simultaneously multiple categories within areal units and to display thematic values associated with a population by the population pattern. For example, in the first situation instead of making a choropleth map that is color-coded by the majority group present in each areal unit, a dot pattern for each group is simultaneously displayed color-coded by group. This permits information regarding all groups to be displayed in one map. In the second situation, instead of making a choropleth map that is color-coded to the thematic value being mapped, a dot map of the population is color-coded to its thematic value. In each of these situations, there is a standard value associated with each dot.

The second situation which color-codes a standard dot value by a thematic value resolves the visual equalization problem.

A pointillist map approximates then the data intensity for the respective populations. The dots can be placed regularly (as in Wright, 1936) or randomly. As a result, density of dots in the map reflects the approximation of respective data intensity for the given attribute. Pointillist maps are not precise representations of geographical references in data, but they provide a sense about the extent of physical presence of particular features in space and approach the idea of the discontinuous distribution of the variable more closely than, for example, choropleth maps. When producing a pointillist map questions arise centering around what size one dot should take, value of one dot so that when placing the dots their total number multiplied by the dot value would maximally approach the attribute value of the area. The latter task is hard to achieve when the study area is split in many areas and there is a great disparity between minimum and maximum mapped values. The Mackay nomograph (Mackay, 1949) is a graphical aid to determine the optimal dot size and dot density for manual cartographic production. The cartographer starts by choosing the size of the dot and eventually extracts the number of dots of a given size that can be placed per square centimeter. But it has a number of drawbacks discussed by Kimerling (2012). They include a narrow range for the dot diameter, so a dot the size of one point is outside the guide. Also the zone of coalescing dots is not indicated clearly in the nomograph; instead of defining a clear shaded region for the zone Mackay uses a curve line calling it a zone. Finally, Mackay is criticized for failing to provide the discussion on the derivation of the measuring axes and their scales. Instead, Kimerling proposed the method based on probability to define the optimal dot density for particular map. This method suits the needs for producing digital maps. He opts for pseudo-random placement of the dots, where each dot gains random placement but still holding a non-overlapping constraint. Maintaining no dot overlap is crucial to conveying a notion of the quantity associated with the variable of interest for each areal unit.

Figure 6.6 provide examples of using above described methods for visualization of segregation levels in Washington, D.C. using census tract level data in 2010. In Figure 6.8 distributions of black and white populations are expressed with dots where one dot corresponds to approximately fifty people of each racial category. The dots are placed inside census tracts without consideration of the nonresidential territories that may exist within tracts. Figure 6.9 improves on the accuracy of placement by including ancillary data reflecting the reservation zones such as parks, public open spaces, road pavements and water bodies. Such objects restrict the placement of the dots by forcing the mapping in the areas that are more likely to be residential. The pattern in Figure 6.8 illustrates the intensity of the racial divide in Washington, D.C. The western part is highly contrasted with eastern city in the dominance of one or another racial category. The most densely populated neighborhoods are located in center city.

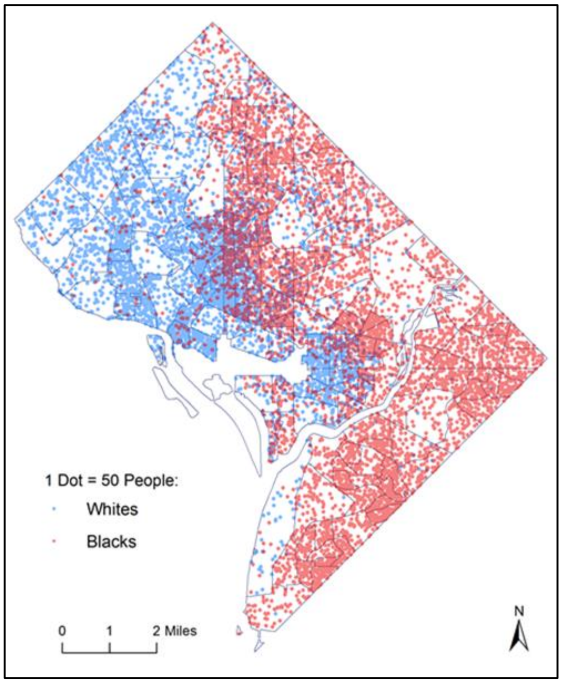


Figure 6.8 Pointillist Map of Black and White Populations. One Dot Represents Approximately Fifty People.

This approach helps provide interpretation of the segregation levels with consideration of the actual population densities in census tracts. Areas of high population densities are of more importance to explore segregation in them than those that are scarcely populated.

The use of the pointillist approach provides an opportunity to evaluate the validity of the standard deviational ellipse index introduced discussed section 6.2. A pointillist representation of the distribution of black and white populations for Washington, D.C. suggests a highly segregated city. The S index based on the ratio of the SDE’s intersection and union is .83 and the D index is .71; both numerical indices confirm that Washington, D.C. has a high level of segregation (Figure 6.10). The visual and the numerical confirm one another.

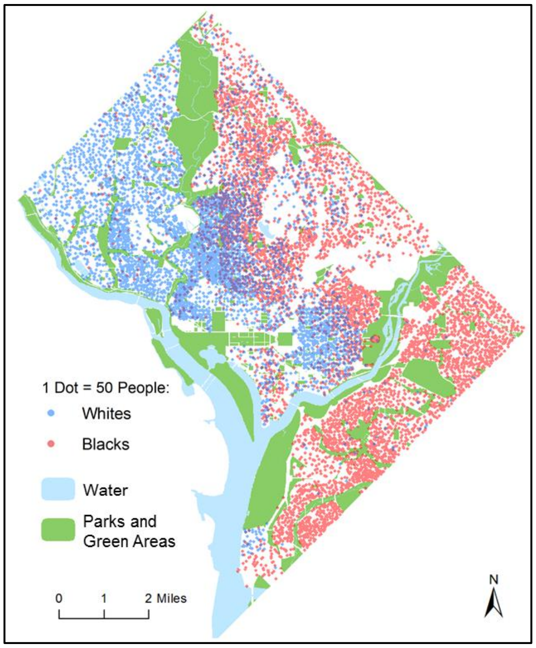


Figure 6.9 Pointillist Map of Population of Two Races Using Ancillary Data where One Dot Corresponds to Approximately Fifty People. (Ancillary Data Source: http://dc.gov/)

This is not always the case. A pointillist representation of blacks and white populations for the city of Detroit in 1980 also suggests that that city was highly segregated at that time (Figure 6.11). A value of 0.68 for the D index also indicates a segregated city; however, the S index only has a value of .43 which suggests a much lower level of segregation.

The later situation arises because the SDE for whites is not a very good summary measure of the distribution of white residents. Because the white population mainly resides around the periphery of the city, a disproportionate number of whites fall outside of their SDE. As such, the S index is not appropriate for measuring the level of segregation for Detroit in 1980.

The pointillist approach can also be combined with local segregation indices. For an evenness index such as the GWD, different hues can be applied to the different racial groups and the intensity of the hue can correspond to the index value as shown in Figure 6.12 for Washington, D.C. This indicates

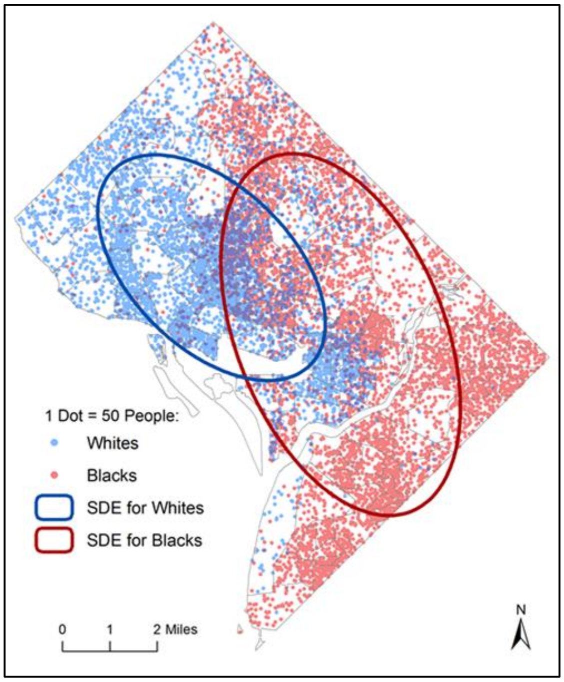


Figure 6.10 Standard Deviational Ellipse and Pointillist Approaches Combined for Washington DC, 2010.

the hue can correspond to the index value as shown in Figure 6.12 for Washington, D.C. This indicates

not only where the GWD are higher or lower but also which racial groups is most associated with the local values. For example, the far western and eastern corners of the city have similarly low GWD values; however, those in the west are associated with a white population and those in the east with a black population.

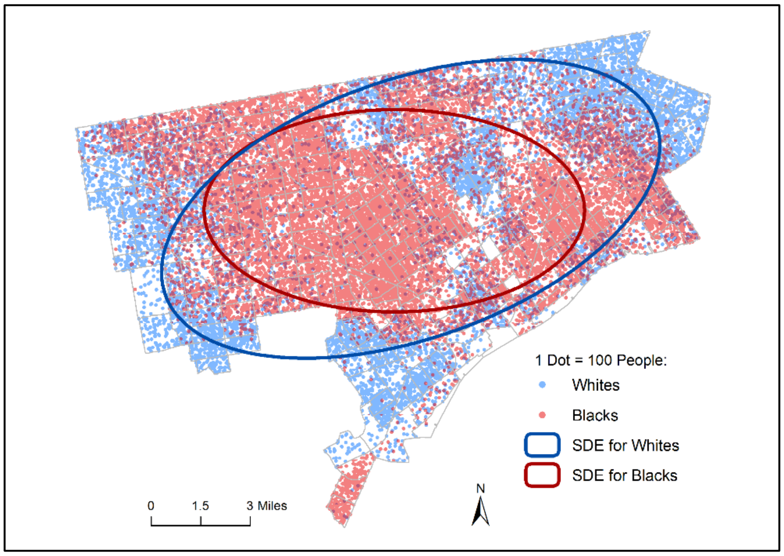


Figure 6.11 Standard Deviational Ellipse and Pointillist Approaches Combined for Detroit, 1980.

Similarly, the pointillist approach can also be applied to local exposure measures. For these maps, the dot pattern is associated with the a_i value for each areal unit (see Figures 6.13). As with the value-by-area cartograms, each map is again unique. It is also easy to determine that few whites have a high exposure to blacks (see Figure 6.13a) and vice versa (see Figure 6.13c).

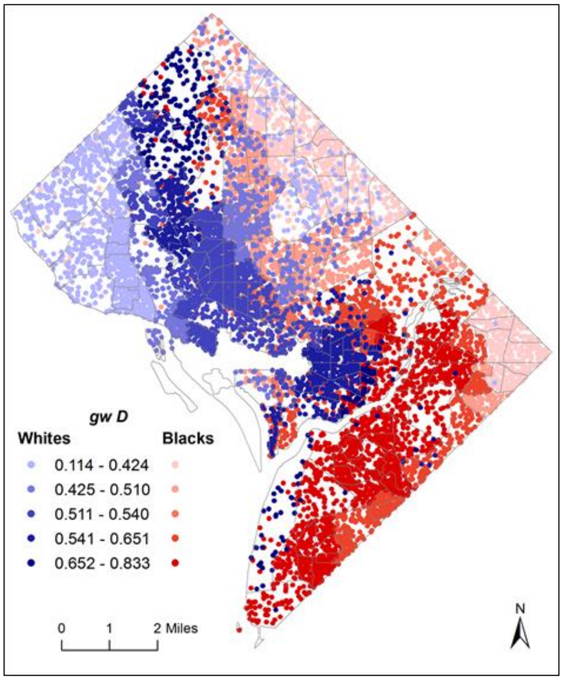
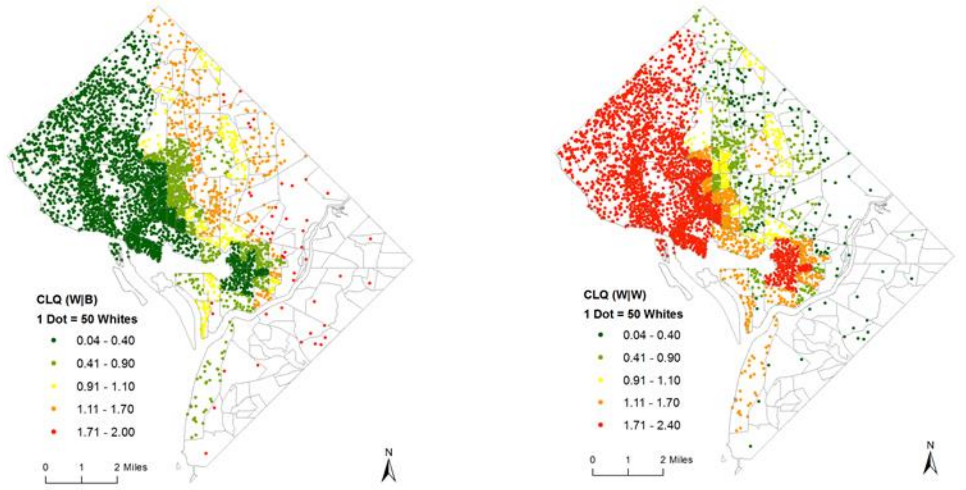


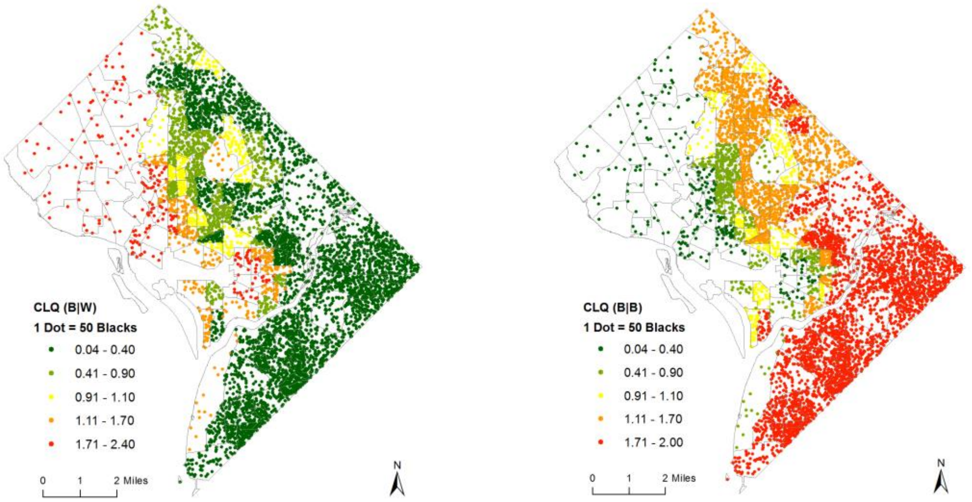
Figure 6.12 Pointillist Map of the Geographically Weighted Index of Dissimilarity.

However, now the areas with a low a_i value do not disappear; they remain but there are very few dots indicating a lack of that racial group in that census tract.



a) Co-location with Blacks Given the Location of Whites

b) Co-location with Whites Given the Location of Whites



c) Co-location with Whites Given the Location of Blacks

d) Colocation with Blacks Given the Location of Blacks

Figure 6.13 Pointillist Maps of Local Co-Location Quotients (CLQ) for Washington, D.C.

6.5 Summary

This chapter has provided the references to the literature that most often uses standard choropleth mapping approach when displaying the results of the computation of segregation levels. However various cartographic approaches can be a source to offer an alternative and to improve the understanding and reading of mapped segregation. Besides the alternative methods are suitable to verify the adequacy of some measures, as demonstrated in this chapter with the standard deviational ellipse approach. The methods presented here include the use of pointillist mapping that depicts the population distribution as a continuous phenomenon. Another method is contiguous cartogram that distorts that areal units according to the underlying attribute values, while maintaining the topology among the areal units. Finally, the last method considered contiguous cartogram that distorts that areal units according to the underlying attribute values, while maintaining the topology among the areal units. Finally, the last method considered here is the Dorling cartogram that replaces the areal units with circles of the size depending of the population size. These approaches have their advantages and flaws, but the use of each method contributes to the area of visualization of segregation.

CHAPTER SEVEN

Summary and Conclusions

7.1 Summary

There are many segregation measures introduced and utilized in geographic research up to this date. Because residential segregation can be defined in more than one way the measure's formulation is dependent on particular definition the researcher is trying to reflect. Another distinctive feature of quantitative exploration of segregation is the role of scale of the problem. Global indices focus on overall level of spatial separation of population in the urban area, while local indices assume that the index magnitude varies from place to place across the city. The main purpose of this study is to introduce a new measure borrowing one of the definitions of segregation as the lack of interactions of the population groups and explore its properties.

The proposed measure is a modified co-location quotient first introduced by Leslie and Kronenfeld (2011) that was originally applied to point data as a measure of spatial association between two categorical variables. The first part of this dissertation has introduced two versions of modified co-location quotient (CLQ) that is applicable to categories of areally aggregated population. One is the global measure that captures the overall likelihood of two categories of population to interact within their neighborhood, and another describing the likelihood at the local level, for every single spatial unit. Both, global and local quotients have two basic specifications. One describes the interaction of two separate population groups – two-group CLQ. Another is the same-group CLQ that evaluates the potential for interaction among same group members compared to the rest of population. Each variant of the measure allows to include the neighborhood size in computation, which theoretically defines the space within which people have the possibility for interaction.

The use of CLQ in the proposed mathematical configuration expands the discussion of dimensions of segregation by suggesting the connection between different dimensions that are covered by co-location measure. Using publicly available data from Census Bureau on population CLQs were computed for thirty urban areas, where twenty nine are metro areas and one is Washington D.C. county territory. The basic units of analysis are census tracts and block groups that contain aggregated population counts. Three decennial releases are used: 1990, 2000 and 2010. As the metropolitan areas extents were changing from census to census the tracts and block groups were used that fall inside the last 2010 metropolitan boundaries. This is done to assure the comparison of index values between multiple years.

The results suggest an overall, but uneven, increase in the potential of interaction between whites and blacks and blacks and whites in metro areas. Patterns of concentration for whites remained stable over the time span. But the concentration of black population as measured by CLQ(B|B) shows a substantial decrease indicating an increasing exposure of blacks in the global sense. The two-group measures differ to a modest degree. Conversely, same-group co-location quotients for whites and for blacks expose unequal experiences for these two population groups in American urban areas.

Also, various visualization techniques related to co-location measure were explored. Because CLQ offers a set of measures referring to different combinations of population groups there are a number of cartographic methods to display the results of analysis. One of the cartographic methods, the pointillist approach, suggested in this study to be the best fitting for the purpose of mapping CLQ results.

7.2 Future research

Further investigations of co-location method are needed to identify the correspondence of co-location results with other studies of residential segregation in the country. There might be the aspects that CLQ reflects better than other segregation indices employed by researches. More work needed in order to identify the potential (if there is any) mathematical relationship between co-location quotient and other segregation indices.

Another area of potential investigation is the in-depth description of sensitivity of CLQ to various spatial configurations and patterns. As CLQ describes certain spatial patterns it is likely to be influenced by other properties of these spatial configurations. Several aspects were mentioned, such as neighborhood size, scale and level of aggregation. These and other topics constitute the major areas of focus for advancement and declaration of the CLQ as a capable and reliable index reflecting the levels of residential segregation.

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