Spatial Boundaries and the Local Context of Residential Segregation *

Elizabeth Roberto
Department of Sociology, Yale University
elizabeth.roberto@yale.edu

April 6, 2015

Paper to be presented at the
2015 Meeting of the Population Association of America
in San Diego, CA, April 30 - May 2

Draft: Please do not quote, cite, or distribute without permission.

Spatial boundaries are a common feature of residential segregation. They include features of the natural or built environment, such as rivers and roads, that create excess distance between locations or become geographic markers of social divisions. Spatial boundaries both shape and are shaped by a city's social and spatial organization.

But there is a paradox of spatial boundaries. Boundaries facilitate separation, but also bring groups into close proximity. They promote local *diversity*, while preventing *integration*. The local area around a boundary is *diverse* and *segregated*. This paradox has important implications for how we understand and measure segregation.

Qualitative studies are rich with insight about spatial boundaries, but their significance has been overlooked in the quantitative segregation literature.[1] In "Black on the Block",

*This work was supported in part by the facilities and staff of the Yale University Faculty of Arts and Sciences High Performance Computing Center.

[1]A notable exception is recent work by Logan and co-authors (Logan and Zhang 2004; Logan et al. 2011; Spielman and Logan 2013).

Pattillo (2007) describes residents' understanding of the new neighborhood boundaries in Chicago's South Side following the urban renewal efforts of the 1950's:

> It was in this era, the 1950s, that the Kenwood neighborhood was split in half. Forty-seventh Street became, in the words of residents, "the dividing line," "the invisible line," "the Mason-Dixon line." To the north of the line, North Kenwood and the neighborhood north of it, Oakland, languished. To the south, South Kenwood and its southern neighbors, Hyde Park and the University of Chicago, flourished... (Pattillo 2007:7)

Segregation patterns cannot be adequately described independent of spatial boundaries. This relationship is reflected in our everyday language about the spatial organization of the cities. In a recent newspaper story, LaQuita Hamilton describes the area where she lives in Wilmington, Delaware:

> North of Ninth Street is the white neighborhood, she said. South of Ninth to about Sixth Street, where Hamilton lives, most residents are black, with a few whites and Hispanics mixed in. Then it's Hispanics below Sixth, then back to blacks at Lancaster Avenue. "Within six blocks, it's like three different neighborhoods," said Hamilton... (Chalmers 2011)

Common methods for measuring segregation are ill equipped to capture the spatial context of segregation. They ignore the spatial features of segregation patterns, such as how neighborhoods are spatially arranged in a city, and they cannot identify the signature of spatial boundaries – creating excess distance between locations and giving social separation a spatial form. By ignoring spatial boundaries, conventional approaches mask important features of a city's social and spatial organization: they fail to capture key aspects of how segregation is locally experienced.

In this paper, I use a new method to examine how spatial boundaries structure racial and ethnic residential segregation patterns in U.S. cities. My approach attempts to align the measurement of distance with the way it is locally experienced, and bridges qualitative insight on spatial boundaries and the quantitative measurement of segregation. It overcomes the limitations of current approaches, and captures the spatial relationships and structured patterns that we intuitively recognize as segregation.

In the first section of the paper, I discuss the advantages of using spatial methods to study residential segregation. I highlight two aspects of local context that have received little attention in quantitative studies: how the level of segregation varies within cities and how spatial boundaries structure segregation patterns. I then describe four types of boundaries that are essential for understanding residential segregation patterns. I outline my approach, and summarize results on racial and ethnic residential segregation in several U.S. cities. I discuss the relevance of my results for each type of boundary, and I compare the local variation of segregation within cities. I conclude by discussing how these findings contribute to our knowledge of the local context of residential segregation.

The Local Context Of Residential Segregation

For several decades, the most popular measure of residential segregation has been the dissimilarity index. Although the dissimilarity index and other summary indexes allow researchers to describe certain characteristics of residential segregation, the indexes are "aspatial" – they do not integrate the fundamentally spatial concepts of proximity and geographic scale into the measurement of segregation. Spatial proximity concerns where areas are located relative to each other, e.g. how neighborhoods are spatially arranged in a city. Geographic scale concerns the relative size of segregated clusters or the geographic extent of segregation patterns.

As a consequence, many studies find the same level of segregation whether the city has a patchwork of racial or ethnic enclaves, or is divided into large areas with little or no diversity. But one can imagine that the experience of living in these cities and the consequence of where one lives are quite different. Although this insight has been shown in ethnographic and other qualitative studies, summary indexes mask central features of a city's social and spatial organization and fail to capture key aspects of how segregation is locally experienced.

Recent years have seen heightened interest in studying the spatial dimensions of residential segregation (Bischoff 2008; Fischer 2008; Grannis 1998, 2002; Hipp 2007; Lee et al. 2008; O'Sullivan and Wong 2007; Reardon and Bischoff 2011; Reardon et al. 2009, 2008; South, Crowder, and Pais 2011; Spielman and Logan 2013). Studies have incorporated information about the contiguity of census tracts or blocks and the proximity of racial or ethnic clusters, and have analyzed the geographic scale of segregation patterns. For example, Reardon and O'Sullivan (2004) developed the spatial information theory segregation index,[2] which they used to measure and compare the geographic scale of racial residential segregation in large metropolitan areas in the U.S. (Lee et al. 2008; Reardon and O'Sullivan 2004; Reardon et al. 2009, 2008).

A key advantage of spatial approaches is that they can distinguish between micro- and macro-scale residential segregation patterns. Micro-scale segregation takes the form of small racial or ethnic enclaves. Residents moving through a city with high micro-scale segregation encounter a patchwork of small homogenous areas, such as those areas commonly known as Little Italy or Chinatown. In contrast, high macro-scale segregation is defined by large monoracial clusters. Residents tend to live in expansive, racially homogenous areas, popularly recognized as "the other side of the tracks," "the high rent district," or "the ghetto."

Micro- and macro-scale segregation may be generated by different mechanisms and have different consequences. Despite residents' geographic proximity, micro-scale segregation may limit opportunities for interaction across the boundaries of clusters, which may, in turn, perpetuate stereotypes and discrimination. Macro-scale segregation may be associated with limited access and availability of resources in one area, and a comparative concentration of

[2]The spatial information theory segregation index is a measure of residential segregation that incorporates information about geographic proximity.

resources in another.

Despite a growing body of scholarship on the spatial dimensions of residential segregation, there has been little attention to the local context of segregation within cities or metropolitan areas. In particular, few quantitative studies have examined how the level of segregation varies within cities and how spatial boundaries structure segregation patterns.

Local Variation

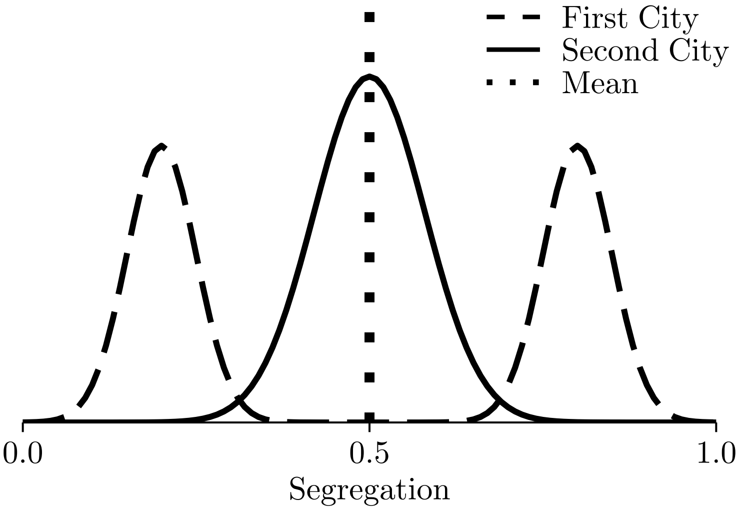
Few studies have analyzed how the level of segregation varies among the local areas (e.g. blocks or neighborhoods) within them, instead focusing on the overall level of segregation in cities or metropolitan areas. But overall segregation may tell us relatively little about the local conditions. A city where segregation varies greatly across local areas can have the same overall segregation as a city where all local areas have a similar level of segregation.[3]

For example, Figure 1 shows the distribution of segregation levels for blocks within two hypothetical cities. In the first city, there is low segregation in half of the blocks and high segregation in the other half. The distribution of local segregation in the first city is bimodal. No blocks experience the mean level of segregation. On the other hand, all blocks in the second city are similarly segregated. The variance among the blocks is low. The city mean is more representative of local segregation in the second city than in the first.

There are good reasons to care about differences in the distribution of local segregation. First, city segregation is a better indicator of local conditions if the variance within a city is low. In cities with high variance, like the second city, local conditions are both better and worse than indicated by the city-level mean. This is second order segregation – *the segregation of segregation.*

[3]City segregation is measured as the weighted mean of local segregation throughout the city, weighted by the population density of each local area.

Figure 1: The Distribution of Local Segregation for
Two Hypothetical Cites with the Same Mean but Different Variance



Second, if local areas are not equally segregated it provides an opportunity to more closely examine reasons for the variation. A city can learn about the areas with low segregation, and apply that knowledge in other parts of the city with high segregation. They can support the diversity of unsegregated areas, and concentrate interventions in areas of the city with the greatest need.

Third, it can enrich our understanding of how segregated local environments matter for individual and community outcomes. There is a growing body of knowledge on the ecological context of neighborhoods and metropolitan areas (Raudenbush and Sampson 1999; Sampson and Raudenbush 1999), including the physical conditions, economic and political dynamics, and social interactions that occur within them (Bader and Ailshire 2014; Crowder, Pais, and South 2012; Papachristos, Hureau, and Braga 2013; Savitz and Raudenbush 2009; Timberlake and Iceland 2007). Numerous studies have established that where a person lives is consequential for a wide variety of life-course outcomes related to education, health, employment, crime, and poverty (for recent reviews, see Charles 2003; Sampson 2012; Sharkey and Faber 2013). The way that segregation affects certain outcomes may depend on the city's level of segregation, while others depend on the degree of local segregation. Further, there may be different consequences associated with living in a highly segregated local area if all areas of the city are similarly segregated than if segregation in the rest of the city is low.

We can better understand second order segregation by analyzing both the mean and the variance of local segregation. Decomposition analysis is an ideal strategy for comparing how segregation within and between different levels of geography contribute to overall segregation. Several recent studies have decomposed the segregation of regions and compared the segregation occurring within and among municipalities (Bischoff 2008; Farrell 2008; Fischer 2008; Fischer et al. 2004; Hipp 2007; Lichter, Parisi, and Taquino 2012; Parisi, Lichter, and Taquino 2011).

Unfortunately, most segregation indexes are not additively decomposable. The information theory index (Reardon and Firebaugh 2002; Reardon and O'Sullivan 2004; Theil and Finizza 1971; White 1986) has become the gold standard for decomposing spatial segregation. However, as I have shown elsewhere (Roberto 2015), it can produce misleading results. In a later section, I describe a new index that I have developed: the divergence index. It is additively decomposable and captures the spatial relationships and structured patterns that we intuitively recognize as segregation.

Spatial Boundaries

Spatial boundaries are a common feature of residential segregation. They facilitate separation between adjacent areas. In some cases, boundaries are sharp lines of demarcation, such as the border of a congressional district, and in others they are zones of transition, such as the overlapping boundaries of two neighborhoods. The durability of boundaries also varies. Some boundaries remain stable over time, while others are constantly being negotiated, constructed, or maintained.

Not all separation is segregation, and I am particularly interested in the spatial boundaries that structure patterns of residential segregation. I focus on four types of boundaries that are fundamental to our understanding of segregation: enumerative, municipal, physical, and symbolic. These categories are not mutually exclusive – for instance, a river may act as both a physical and symbolic boundary in a city. In this section, I describe each type and provide examples of their relevance for residential segregation.

Enumerative Boundaries

Enumerative boundaries define the geographic areas used to process or aggregate data or count the population. Census tracts are the most ubiquitous example. With boundaries defined by the Census Bureau, tracts have an average population of about 4,000 individuals and are intended to approximate neighborhoods. As address-level data are rarely publicly available, researchers rely on data aggregated into larger geographic units, such as census tracts, to study the geographic distribution of the population.

Enumerative boundaries are an artifact of data collection or processing, and are not necessarily observable in the social or physical world. If asked, few people would know the number of the census tract they live in. Enumerative boundaries are updated periodically to reflect changes in the demographic or geographic distribution of the population. For example, the U.S. Office of Management and Budget regularly issues updates to the boundaries of metropolitan statistical areas to reflect new population estimates and economic and commuting flows between cities and surrounding areas.

Enumeration boundaries pose methodological problems for spatial analysis. In particular, the Modifiable Areal Unit Problem (MAUP) occurs when changing the way locations are aggregated leads to different results (Fotheringham and Wong 1991; Openshaw 1984; Openshaw and Taylor 1979). For example, segregation occurring among small spatial units will be misrepresented as diversity if they are aggregated together into a larger unit. MAUP involves the interrelated problems of aggregation and zoning. The aggregation problem concerns the number and size of spatial units used in the analysis. The zoning problem concerns how or where the boundaries of spatial units are drawn, and can result in "edge effects" – distortions in the measured level of segregation along defined boundaries.

Municipal Boundaries

Municipal boundaries define the geographic borders of political or governmental entities. Examples include the borders of towns, cities, states, congressional districts, land use zones, and economic development areas. Municipal boundaries derive power from their institutional status. They confer certain rights and privileges to the residents living within them, and there can be stark differences between the resources and services available to residents on either side of a boundary.

Because municipal boundaries have social meaning, they are less susceptible to the modifiable areal unit problem than enumeration boundaries (Reardon and O'Sullivan 2004). School districts and school attendance areas are prime examples of municipal boundaries. Bischoff (2008:195) argues that they can be thought of as discrete, socially meaningful units. "Proximity alone has no consequences for access to resources. A household must be within the defined political boundaries to gain the right to use the resources; being close is not enough."

Several recent studies have examined the geographic scale of residential sorting by comparing segregation within and between places, school districts, or political units (Bischoff 2008; Farrell 2008; Fischer 2008; Fischer et al. 2004; Hipp 2007; Lichter et al. 2012; Parisi et al. 2011; Reardon and Bischoff 2011). Their findings demonstrate the salience of municipal boundaries for emergent segregation patterns. Fischer et al. (2004) explain that over the course of the twentieth century the geographic basis of segregation patterns has shifted from regions to neighborhoods to the city-suburb line and municipalities.

Physical Boundaries

Physical boundaries create excess distance between locations. They obstruct or reduce the connectivity of locations on either side of the boundary. Physical boundaries are material structures. In contrast, enumerative and municipal boundaries are manifest in the physical world, but are derived through the aggregation of data or the drawing and formalization of geographic borders.

Physical boundaries include features of the natural and built environment, such as rivers, parks, highways, and train tracks. A city's street design can create physical boundaries. The presence of dead end streets and cul-de-sacs prevents through movement, whereas a regular street grid with diagonal avenues provides greater connectivity between locations.

Grannis (1998) studied racial settlement patterns in Los Angeles and San Francisco and found that "segregated networks of neighborly relations emerge from segregated networks of residential streets" [p. 1530]. He showed that connectivity along small, residential streets was more important than geographic proximity in predicting racial segregation patterns.

Symbolic Boundaries

Symbolic boundaries give social separation a spatial form. Examples include the boundaries of neighborhoods, racial or ethnic enclaves, and gang turf. For example, Anderson (1990) describes "the edge," an informal boundary separating two communities in Eastern City . In the Village, residents tend to be middle- and upper-income Whites, while residents of Northton are predominantly working-class and poor Blacks. The edge marks a social division and creates separation. The groups reside in the same area of the city, but on opposite sides of Bellwether Street.

Logan and colleagues (Logan and Zhang 2004; Logan et al. 2011; Spielman and Logan 2013) have developed methods for identifying neighborhood boundaries using detailed population data about residential locations. They conceptualize neighborhoods as "categorizations of urban space defined by both characteristics of individuals (or residential units) and their spatial context," and boundaries as "sharp edges or larger zones of transition" (Spielman and Logan 2013:81). Their place-based approach for studying neighborhoods reveals patterns in the social structure of several late century cities.

The four types of boundaries – enumerative, municipal, physical, and symbolic – are not mutually exclusive. A boundary can span more than one category, as with the Anacostia River in Washington, DC. The river marks a symbolic boundary and imposes physical distance between the Anacostia neighborhood and the rest of the city. The community "east of the river" is predominantly Black and has been stigmatized as an area of high crime and low incomes. The river, as well as a highway, separates the community from their comparatively White and wealthy neighbors to the north in the Capitol Hill neighborhood.

Of the four types, enumerative boundaries have been the dominant presence in the residential segregation literature. Census tracts have long served as proxies for neighborhoods. In recent years, studies have analyzed the geographic scale of racial and economic clustering and the degree to which clustering occurs within or across municipal boundaries. However, there has been little work to identify the spatial location or landmarks associated with the symbolic boundaries of clusters. Physical boundaries have been all but absent from the literature. Current methods are not able to identify the disconnection and excess distance that physical boundaries impose.

Ignoring physical boundaries is problematic because it leads to measurement bias. The bias is caused by the paradox of spatial boundaries. As I explained in the introduction, boundaries facilitate separation, but also bring groups into close proximity. The local area around a boundary is diverse *and* segregated.

On the one hand, the sharp distinction between adjacent areas that are highly segregated and occupied by different groups makes it possible to identify the border as a symbolic boundary. But if measures are unable to detect the disconnection or excess distance imposed by physical boundaries, they will overestimate the proximity of seemingly nearby areas – areas that are close "as the crow flies," but not as a pedestrian walks.

For example, the construction of interstate highways through U.S. cities in the mid-twentieth century disconnected areas on opposite sides of the highway. The Dan Ryan Expressway in Chicago's South Side is a classic example. It is a physical boundary separating the communities on either side. Simple measures of distance, like straight line distance, represent the nearness of the communities, but not their disconnection. Their distance apart is the width of the highway, whether or not there is a route across connecting the communities. The distance is the same as if the highway was never constructed. A realistic measure of distance, such as road distance, identifies the highway as a source of separation. It more accurately represents the distance between the communities as it is locally experienced. The highway is a physical boundary that divides the communities – it facilitates segregation, not diversity.

Data and Methods

I have developed a new method for studying residential segregation that incorporates spatial features, such as physical boundaries, into the measurement of segregation. I use a new segregation index that I developed, called the Divergence Index, which is intuitive to interpret for local areas or the region as a whole. This approach generates results that reveal additional local context, including intra-city variation in segregation levels and the location of symbolic boundaries.

Data

I use publicly available population data from the 2010 decennial census (U.S. Census Bureau 2011), and the corresponding shapefiles for blocks, roads, and municipalities (U.S. Census Bureau 2012). Studies of residential segregation typically use data aggregated at the level of census tracts, which are intended to approximate neighborhoods. Tracts have an average population of 4,000 individuals. Instead, I use census blocks, which are nested within tracts.

The entire area of the city is contained within blocks and tracts. This includes, for example, residential areas, bodies of water, parks, industrial areas, and roads. A single tract can contain all such features, a fact that is not transparent from its population count. For instance, it is not uncommon for a large portion of a populated tract to be covered by water. Although the population of the tract would seem fill the entire area, they actually reside in just one corner of the tract.

Blocks, on the other hand, are much smaller and more detailed. They are the smallest unit of census geography for which data are publicly available. In urban areas, most blocks resemble a typical city block. The population of blocks varies, as does the number of blocks within a tract. It is not uncommon for a quarter or a third of the blocks in a city to not contain any population.

Further, tract-level data are often too blunt to capture fine-grained segregation patterns in cities. Each tract aggregates the population of the blocks it contains. Differences in the population composition of blocks within a tract are misrepresented as diversity at the tract level. By using the smallest unit of census geography, I capture more nuance in the spatial topology and segregation patterns of cities.

Method

The foundation of a spatial measure of segregation is a measure of distance. It represents the geographic proximity of residential locations. Existing approaches use the contiguity of census tracts or the straight line distance between locations. Such measures provide a simple approximation of distance, but they are too abstract to identify the presence and effect of spatial boundaries.

I developed a measure of distance that reflects the unique topology of each city. I measure the distance between locations and the size of local environments along the city's road network. This captures both the connectivity of the city's road network and the physical boundaries that promote separation in a city, such as a river with a limited number of bridge crossings.

Measuring road distance requires freeing the data from the aggregate units of census geography. This removes the enumerative boundaries and allows me to distinguish between the *geographic* and *methodological* scale of segregation (Reardon et al. 2008). Or, in other words, between the scale at which segregation is experienced in social environments on the one hand, and the level of aggregation in the data used to measure segregation, on the other.

I disaggregate the population of census blocks by assigning them to locations on roads (e.g. intersections). Block populations are assigned to road locations that are not exclusive to a single block. Adjacent blocks share roads and intersections and their populations are assigned to one or more of the same locations. Using shared road locations smoothes the distribution of the population and avoids sharp discontinuities along the boundaries of census blocks. By reducing the "edge effects" associated with census block boundaries, the data I use to measure segregation more closely represent the spatial structure of cities.

I measure the shortest distance between all locations along the road network, and the straight line or "as the crow flies" distance between all locations. I collect information about the composition of local environments around each location. I use a proximity function to account for the relative influence of distant versus nearby populations in each location's local environment. Following Reardon and colleagues (Lee et al. 2008; Reardon et al. 2009, 2008), I use a distance-decay function that weighs nearby tracts more heavily than distant tracts. The rate of decay ideally represents the influence of distance on social interaction patterns (White 1983).[4]

I systematically vary the reach of local environments using distances ranging from 0 to 10 kilometers (6.2 miles). I measure segregation separately for each reach of the local environments. Local environments at the low end of the range are the size of city blocks and neighborhoods. They correspond to the distance traveled from one's home for everyday activities, such as walking to the corner market, a public library, or neighborhood school. At the high end of the range, local environments with a reach of 10 kilometers encompass a substantial portion of all but the largest U.S. cities.

I calculate segregation using each measure of distance – road distance and straight line distance. Comparing the results reveals the impact of street design and connectivity on segregation. *If physical boundaries structure segregation patterns, then we should see a difference between the two sets of results.*

I collect information about two types of local environments: 1. local environments that are limited to areas within the city, and 2. local environments that can extend into areas outside the city. The first type are constrained by the city boundary. As their reach increases, any local environments that would extend into surrounding areas are truncated at the city boundary. This way of specifying local environments aligns with previous implementations by Reardon and colleagues (Lee et al. 2008; Reardon and Bischoff 2011; Reardon et al. 2009, 2008).

The second version allows local environments to extend beyond the city boundary and

---

[4] In contrast, a uniform (or rectangular) proximity function weights distant tracts equally to nearby tracts (for examples, see Jargowsky and Kim 2005; Wu and Sui 2001). I calculate results using both types of proximity functions and did not find major differences in the overall trend of results.

incorporate nearby populations. This specification has the largest impact on locations near the city boundary. The size of their local environments will keep pace with more central locations, which is not true if they are truncated. Their local environments will include a higher proportion of the population from surrounding areas, especially as the reach increases.

I compare segregation results using truncated and extended local environments. Local environments will include more population if they extend outside the city, but not necessarily a different composition. *If the city boundary structures segregation patterns, then we should see a difference between the two sets of results.*

Measure

I have developed a new measure of social and spatial inequality called the divergence index. The index is based on relative entropy, an information theoretic measure of the difference between two probability distributions (Cover and Thomas 2006).[5] As an index of residential segregation, it measures the difference between the composition of individuals' local environments and the overall population composition.[6]

To measure segregation spatially, the index is calculated as:

$$\tilde{D}_i = \sum_{m=1}^{M} \tilde{\pi}_{im} \log \frac{\tilde{\pi}_{im}}{\pi_m}$$

where $\tilde{\pi}_{im}$ is group m's proportion of the proximity weighted population in the local environ-

[5] For discrete probability distributions P and Q, the divergence of Q from P is defined as:

$$D\left(P \parallel Q\right) = \sum_{m=1}^{M} P_m \log \frac{P_m}{Q_m}$$

Relative entropy is also frequently called Kullback–Leibler (KL) divergence (Kullback 1987).

[6] In contrast, the recently developed Spatial Information Theory Index (Reardon and O'Sullivan 2004) is a ratio of local population diversity to overall diversity.

ment of location i, and π_m is group m's proportion of the overall population.[7] To summarize for all locations i in the city:

$$\tilde{D} = \frac{1}{T}\sum_{i=1}^{N}\tau_i\tilde{D}_i$$

where T is the overall population count, and τ_i is the population count in location i.

The divergence index can be interpreted as a measure of surprise – how surprising is the composition of local environments given the overall population composition? If all local environments have the same composition as the overall population, then $\tilde{D} = 0$, indicating no segregation in the city. More divergence between the local and overall population composition indicates more segregation.

I use the aggregate population of all local environments as the overall population in calculating segregation. When local environments are truncated at the city boundary, the aggregate population is constant – it is the city population. When they extend outside the city, the aggregate population grows as the reach of local environments increases. The aggregate population includes the city population, plus any population outside the city who are included in the local environment of a city resident.

To summarize, my approach: 1) removes enumerative boundaries, 2) retains municipal boundaries, 3) incorporates physical boundaries, and 4) allows symbolic boundaries to emerge in the results. I use the divergence index to calculate and compare segregation results for each type of distance – straight line and road distance – and both types of local environments – truncated and extended.

I use this approach to analyze racial and ethnic residential segregation in several U.S. cities.[8] I map the local segregation values, which provides a medium for both visualization

[7]Following standard usage, I define $0 \log 0 = 0$, because $\lim_{x\to 0}(x \log x) = 0$.

[8]I use census data for mutually exclusive race categories, combined with Hispanic or Latino ethnicity. The Hispanic category in includes all individuals who identified Hispanic or Latino as their ethnicity, along with any category of race. The remaining categories of race include only individuals who identified their ethnicity

and analysis. To quote Logan (2012:509): "The most powerful spatial tool is the simplest – creation of a map that allows visualization of a spatial pattern." Mapping local segregation values allows patterns to emerge that would not be obvious in summary tables or statistical graphs. Maps deepen our understanding of the local context of segregation patterns.

Results

Enumeration Boundaries

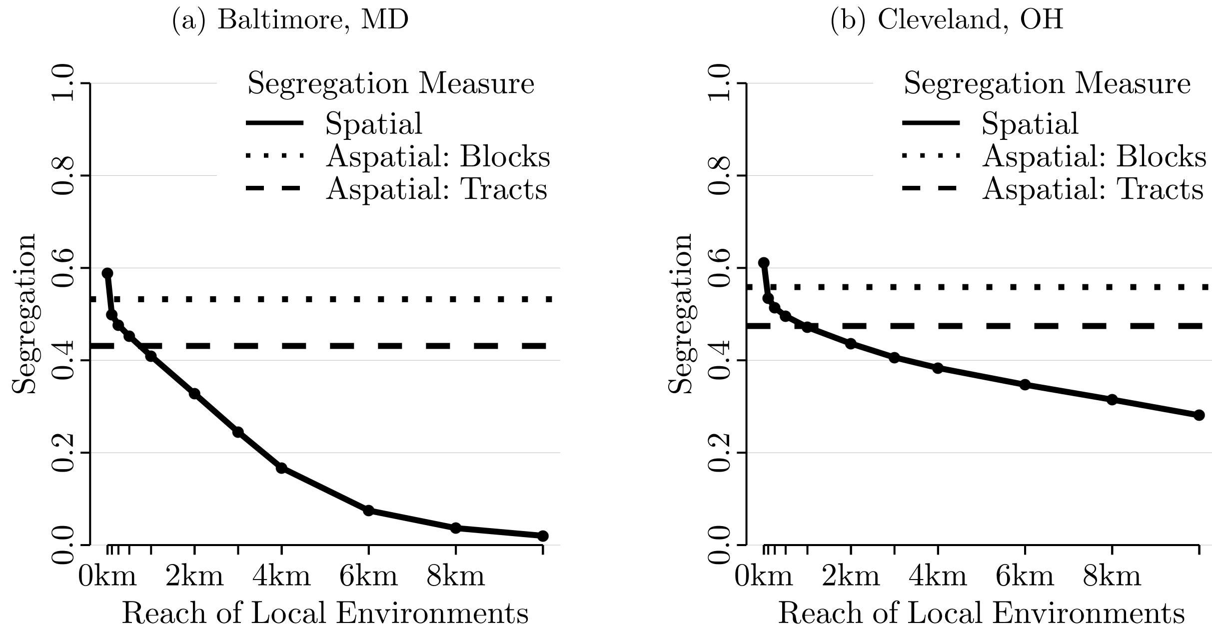
Many aspatial measures find the same level of segregation whether the city has a patchwork of racial or ethnic enclaves, or is divided into large areas with little or no diversity. By removing enumerative boundaries and using a spatial approach for measuring segregation I can study the geographic scale of segregation. This reveals that cities previously thought of as comparable are actually quite different. Even cities with similar aspatial segregation scores can nonetheless have different patterns of spatial segregation.

Baltimore, MD and Cleveland, OH, have similar population compositions and similar levels of aspatial segregation among White and Black residents. However, measuring segregation spatially, reveals that White-Black segregation in Baltimore has more of a micro-scale pattern, occurring in smaller geographic areas, and results for Cleveland show more of a macro-scale pattern, defined by large, monoracial clusters. Figure 2 shows the aspatial and spatial segregation results for both cities. The horizontal lines indicate the level of aspatial segregation for blocks and tracts, and the curved line shows how the level of spatial segregation changes as the reach of local environments increases.

In both cities, segregation decreases at a similar rate as local environments increase their reach from 0 to 0.5 kilometers. There is considerable divergence between the composition

as Not Hispanic or Latino.

Figure 2: White-Black Segregation in 2010 (Truncated Local Environments)



of small local environments and the city's population composition. They tend to be more monoracial than the city's population. As local environments grow, they incorporate more and more of the city's population. Segregation decreases because there is less of a difference between the city's composition and the composition of local environments. The biggest contrast between the two cities is how segregation changes when local environments reach beyond 0.5 kilometers.

In Baltimore, there are large decreases in the level of segregation with modest increases in the size of local environments (see Figure 2a). The steep drop in the level of segregation is consistent with a micro-scale segregation pattern. Micro-scale segregation takes the form of small racial or ethnic enclaves. The difference between the city's composition and the composition of local environments narrows as the reach of local environments increases. The largest local environments are a microcosm of the city's population.

Figure 3: Dot Density Map of the White, Black, and Hispanic Population in Census Blocks in Baltimore, MD in 2010

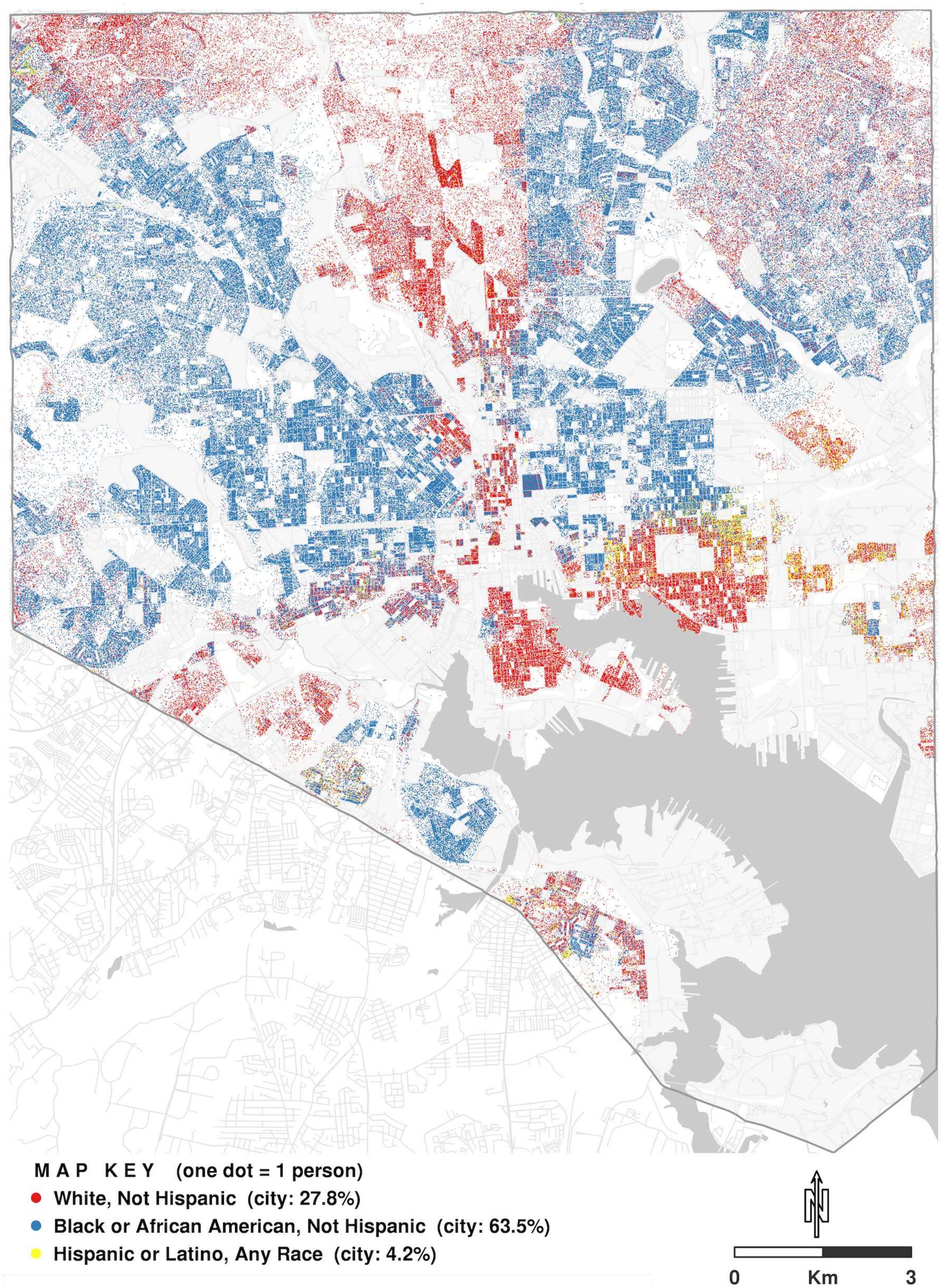
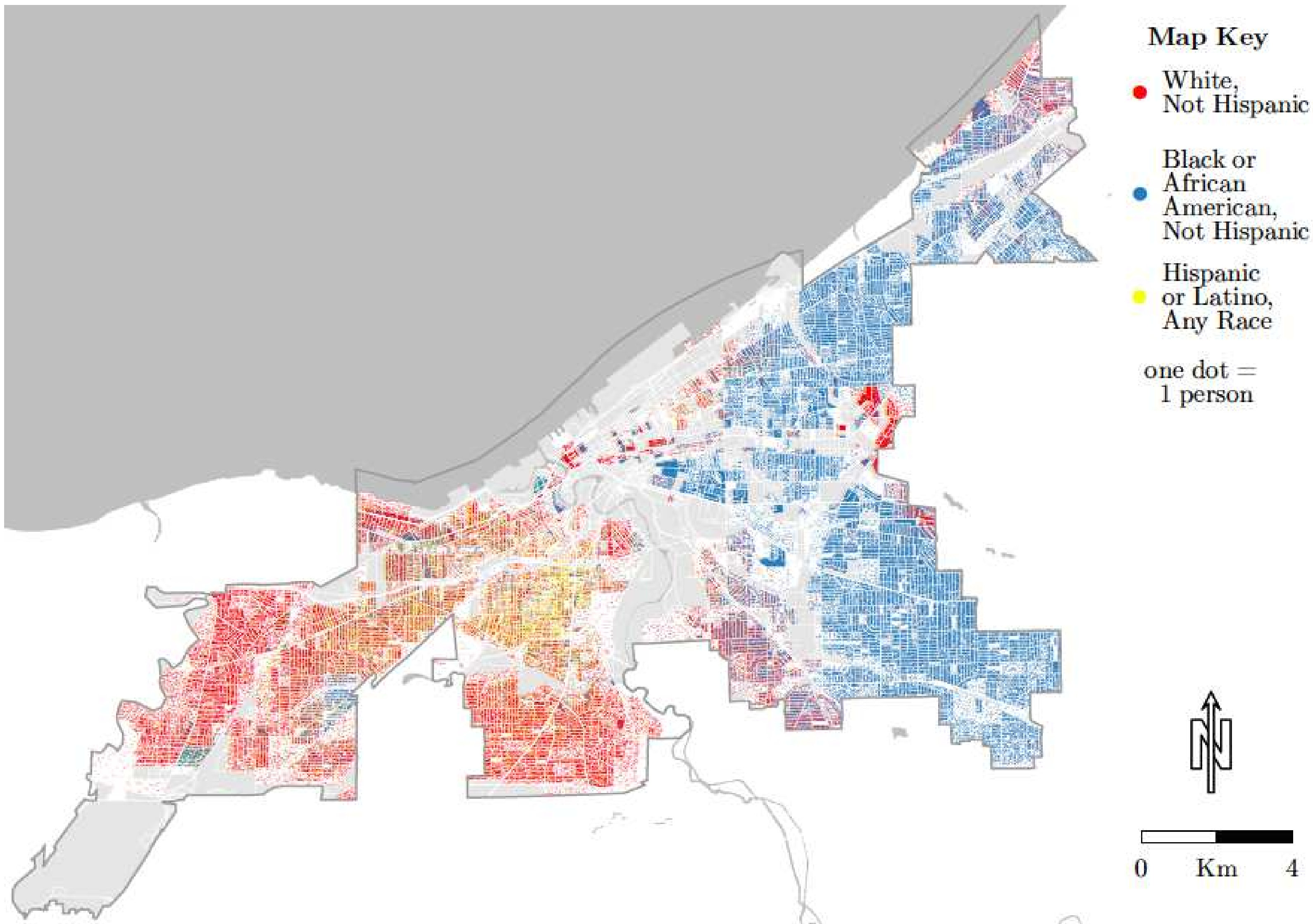


Figure 4: Dot Density Map of the White, Black, and Hispanic Population in Census Blocks in Cleveland, OH in 2010



In Cleveland, the shape of the spatial results indicates a macro-scale segregation pattern (see Figure 2b). Macro-scale segregation is defined by large, monoracial clusters. Segregation shows more gradual decreases than in Baltimore as local environments increase in size, indicating that the population composition of larger areas is only slightly more representative of city diversity than smaller areas. Even at a reach of 10 kilometers, local environments still show considerable segregation.

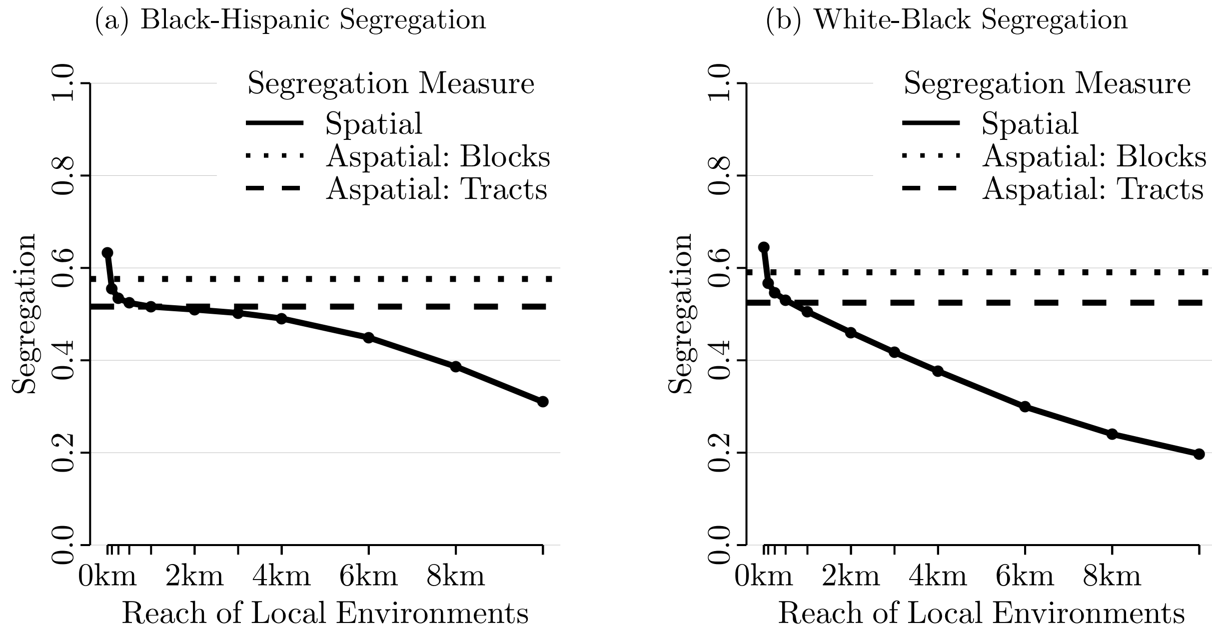
The results for Baltimore and Cleveland are consistent with the patterns of clustering and spatial separation in the dot density maps in Figures 3 and 4.[9] The maps show the White, Black, and Hispanic population in census blocks. Dots are randomly placed within each block, one dot per person, and I use primary colors to indicate the race and ethnicity of the population. In diverse areas, the primary colors mix and the areas appear purple, orange, green, or brown, rather than red, blue, or yellow.

In addition to variation across cities, the geographic scale of residential segregation can also vary substantially for different groups within the same city. In Milwaukee, WI, segregation among Black and Hispanic residents and among White and Black residents is nearly identical when measured aspatially with data for blocks and tracts. However, the geographic scale of the segregation is quite different. Figure 5 shows the contrast between aspatial and spatial results.

The results for Black-Hispanic segregation (Figure 5a) show that there is considerable divergence between the composition of local environments and the city as a whole. The shape of the spatial results indicates a macro-scale segregation pattern, defined by clustering across large geographic areas. The level of segregation decreases from a reach of 0 meters up to about 250 meters, but it then plateaus through a reach of about 4 kilometers. As local environments grow, they incorporate more and more of the city's population. But the plateau indicates that larger areas are only slightly more representative of the city's composition

[9] The design of my dot density maps was inspired by Rankin (2010).

Figure 5: Segregation in Milwaukee, WI in 2010 (Truncated Local Environments)



than smaller areas. These results are consistent with the pattern of clustering and spatial separation in the dot density map in Figure 6.

Compared to Black-Hispanic segregation, White-Black segregation in Milwaukee, WI, has a more micro-scale pattern, occurring in smaller geographic areas (see Figure 5b). There are steady decreases in the level of segregation as the reach of local environments increases. The rate of decrease is greater than for Black-Hispanic segregation in Milwaukee, though not as steep as results for White-Black segregation in Baltimore, MD (see Figure 2a).

Municipal Boundaries

It is common for the racial composition of U.S. cities to differ from the surrounding suburbs (Farrell 2008; Fischer 2008). Detroit, MI shows one of the most pronounced examples of this. Although a large majority of city residents are Black, the surrounding suburbs are predominantly White. The map in Figure 8 shows the White, Black, and Hispanic population in census blocks. It demonstrates the stark difference between the population composition of

Figure 6: Dot Density Map of the White, Black, and Hispanic Population in Census Blocks in Milwaukee, WI in 2010

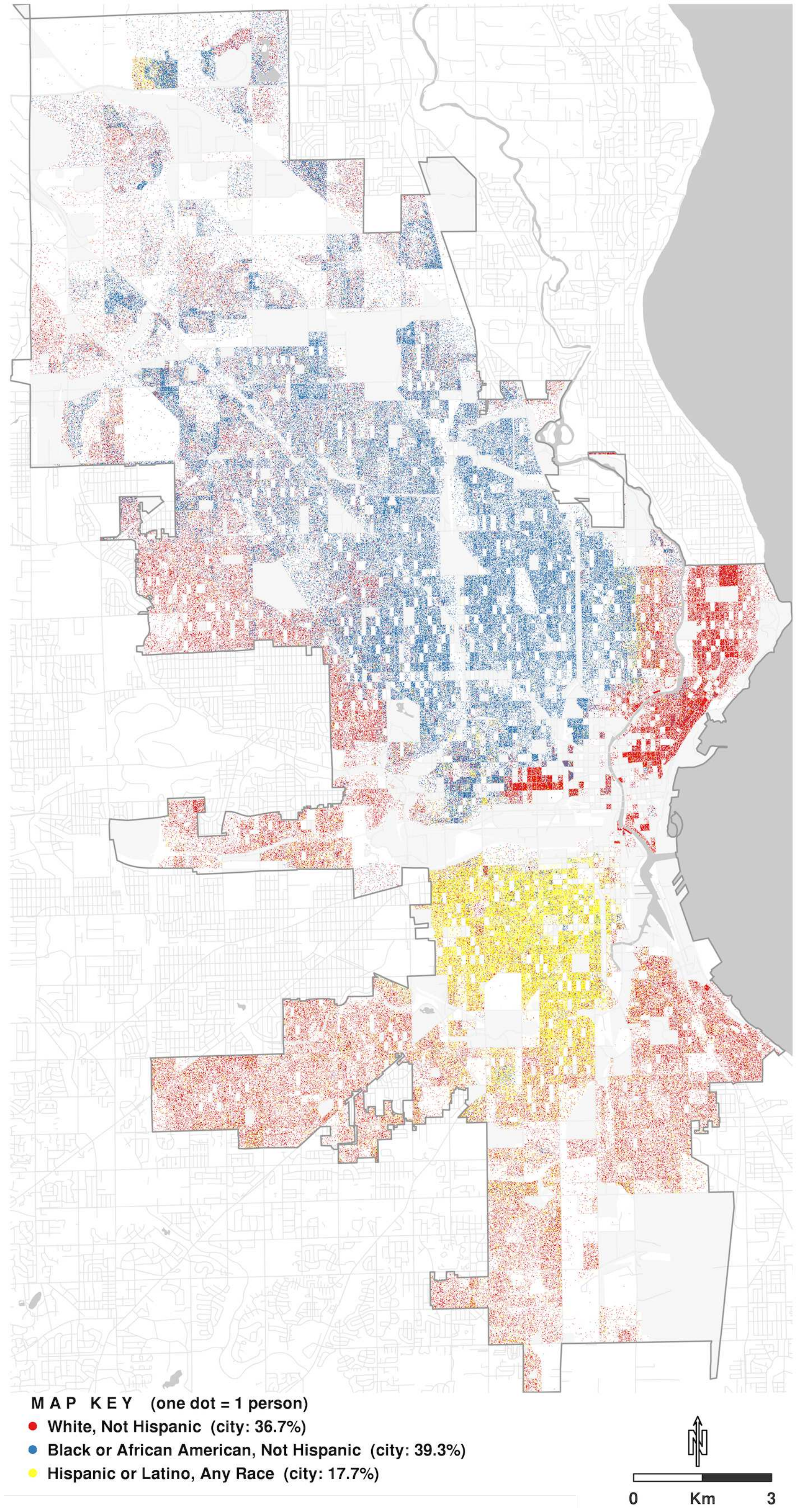
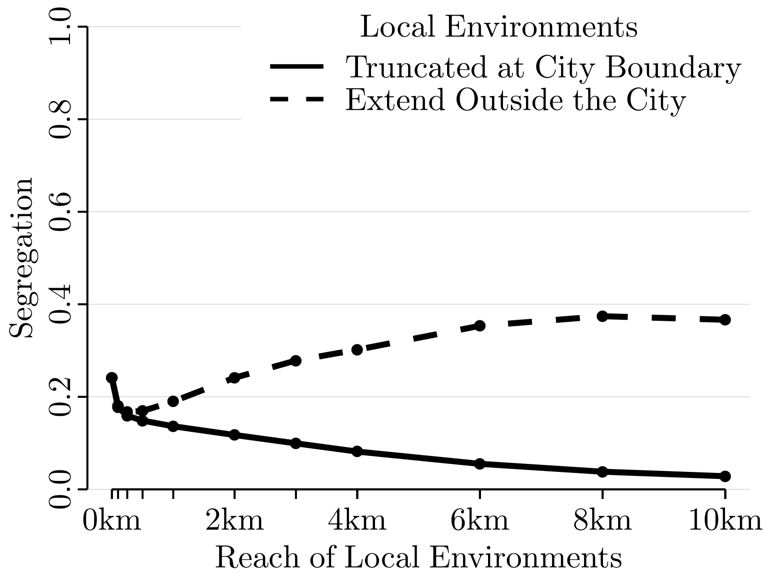


Figure 7: White-Hispanic Segregation in Detroit, MI in 2010



Detroit and the surrounding areas. Along the north edge of the city, 8 Mile Road is a sharp dividing line between the city and its suburbs.

I analyze how surrounding areas impact the dynamics of city segregation by comparing results for local environments that are truncated at the city boundary and those that extend into nearby areas. Figure 7 compares White-Black segregation results for each type of local environments. For both types, segregation is quite low in the smallest local environments and it decreases over short distances. There is little divergence between the composition local environments and the overall population.

If local environments are truncated at the city boundary, segregation continues to gradually decreases as the reach of local environments increases. As the reach of local environments expands to 10 km, they incorporate much of the city's population and are a microcosm of the city's population. Using extended local environments has a large impact on segregation results, as we would expect from the map in Figure 8. There is the same initial decline in segregation over short distances, but beyond a reach of about 0.5 kilometers there is a different trend.

The aggregate population of local environments changes dramatically as the reach of local environments extends outside the city – the population becomes increasingly White. Only the local environments of residents near the city boundary keep pace with this change. On the whole, as the reach of local environments expands beyond 0.5 km, their composition increasingly differs from the aggregation population. This divergence is represented as higher levels of segregation.

When local environments are truncated at the city boundary, segregation is always a non-increasing function of scale (Reardon et al. 2008). As they grow in size, local environments incorporate more and more of the city's population and, on average, they become more representative of the city's composition. However, this is not necessarily the case when local environments extend outside the city.

When local environments extend outside the city, segregation can be an increasing function of scale. In Figure 7, we can see that segregation *increases* as local environments grow and incorporate more population outside the city. There is a steady increase in segregation as the reach expands to about 6 kilometers. Local environments continue to incorporate more population outside the city beyond that reach, but they are better able to keep up with changes in the aggregate population because of their larger size.

Comparing segregation results for local environments that are truncated at the city boundary and those that extend outside the city reveals the impact of surrounding areas on city segregation. Large differences between the two sets of results suggests that the city boundary structures White-Black segregation in Detroit.

Physical Boundaries

Measuring distance along a city's road network can reveal significant differences in the level of segregation, compared to using straight line distance. Road distance is sensitive to the reduced connectivity or excess distance that physical boundaries create. I measure White-Hispanic

Figure 8: Dot Density Map of the White, Black, and Hispanic Population in Census Blocks in Detroit, MI in 2010

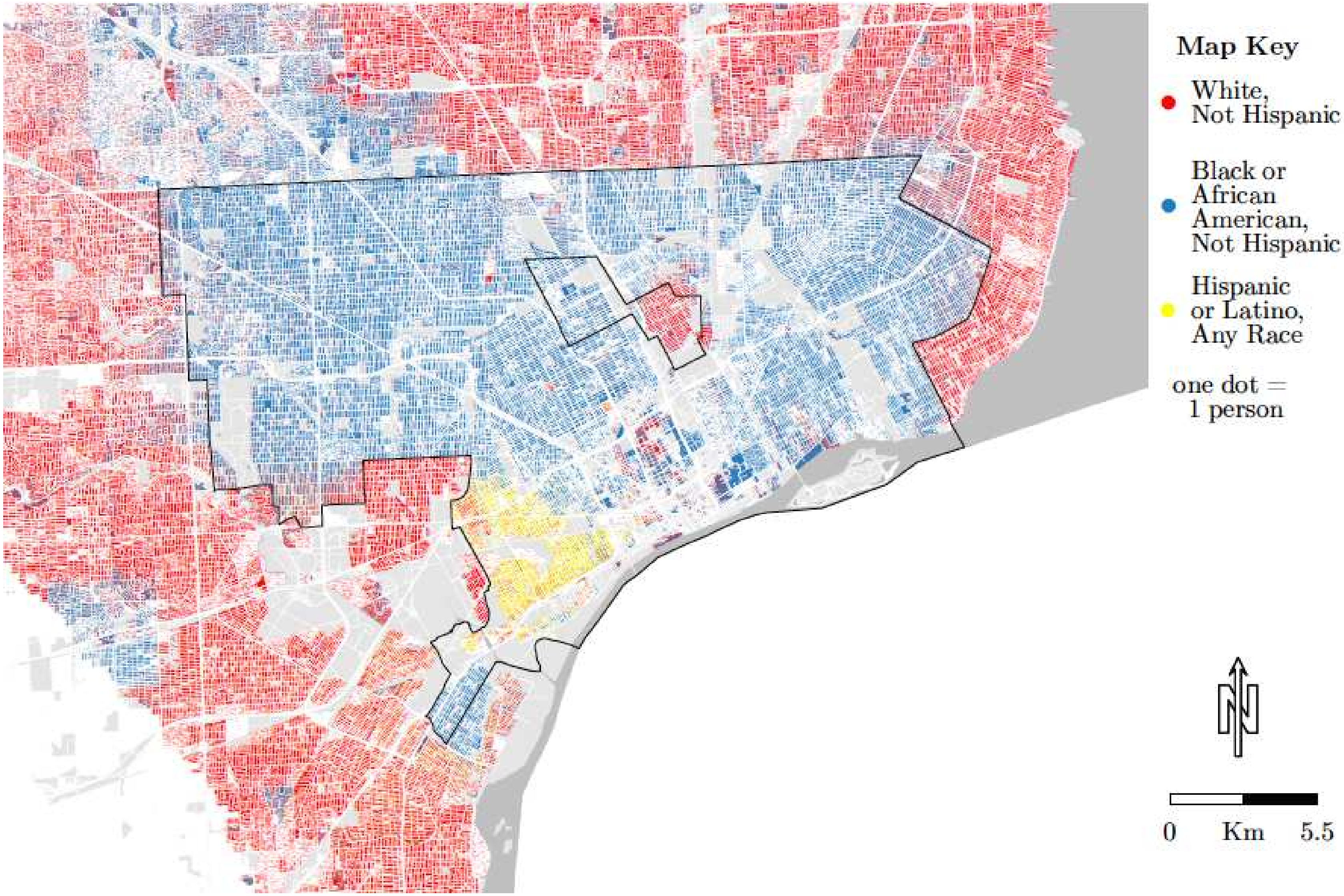
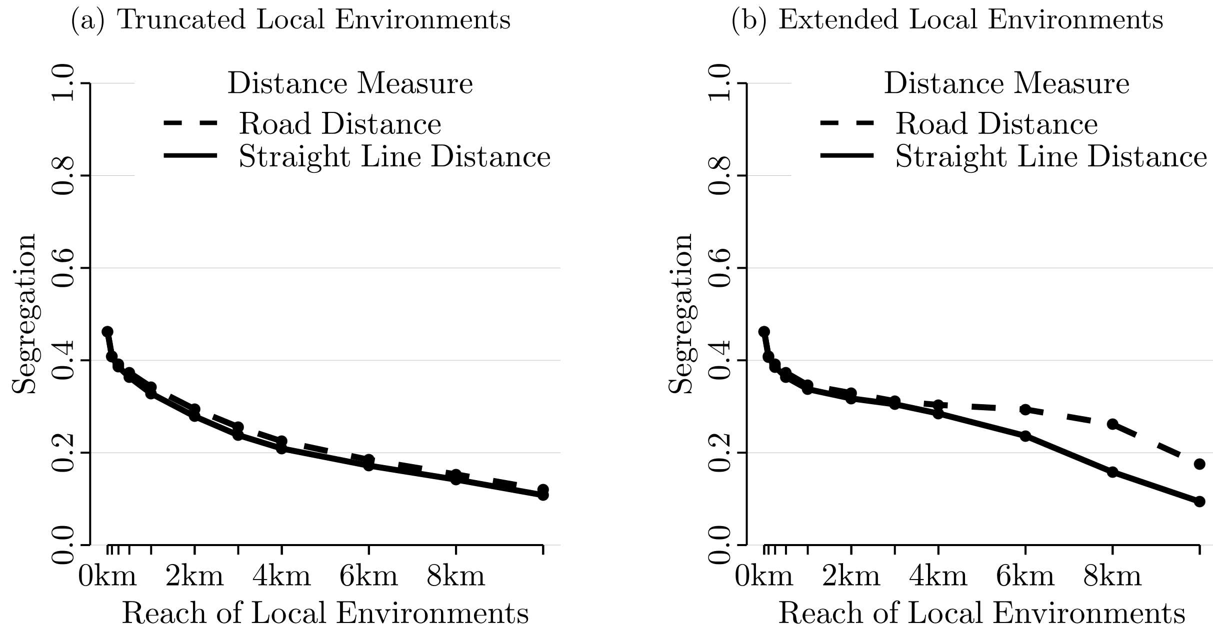


Figure 9: White-Hispanic Segregation in Manhattan, New York, NY in 2010



segregation for the borough of Manhattan in New York, NY using both distance measures and both types of local environments. Comparing results for straight line distance and road distance reveals the impact of physical boundaries – including built or natural barriers and street design – on the segregation of local environments.

If local environments are truncated at the boundary of the borough, segregation levels are similar for both distance measures, though slightly lower for straight line distance (see Figure 9a). The distance between locations along the road network is longer than a straight line connecting the locations. Local environments with the same reach are larger if distance is measured in a straight line rather than along the roads. They include a larger area of Manhattan and more of the population, which makes their composition more representative of the borough as a whole.

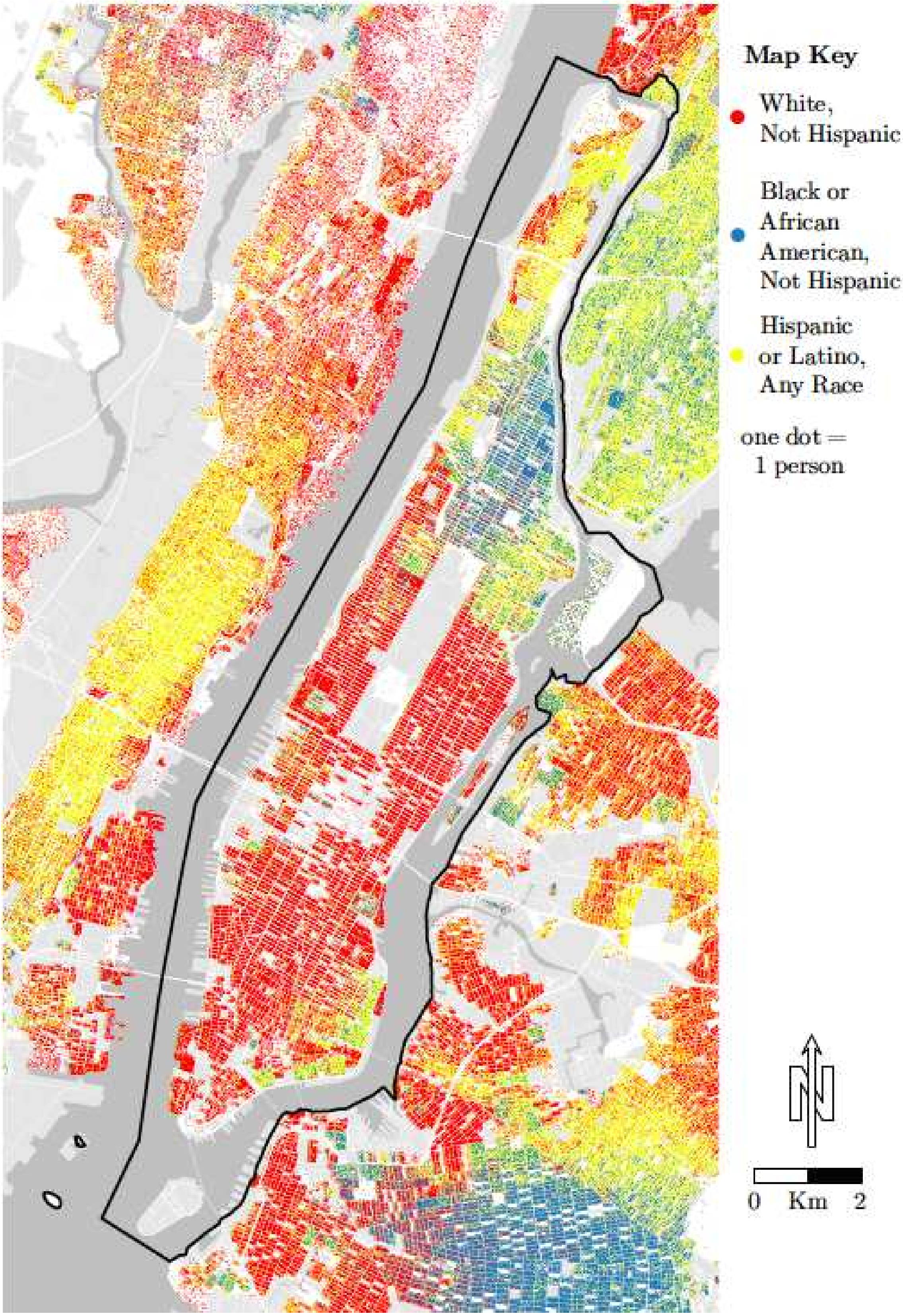
The magnitude of the difference between results for straight line distance and road distance indicates how much of an impact physical boundaries have on segregation. The small difference in Figure 9a suggests that they have little if any effect on truncated local environments in Manhattan. It is possible that there are obstructions that have a significant effect on segregation locally, but not to the extent that it is reflected in the overall segregation results.

Manhattan is surrounded by rivers – the Hudson River to the west, the East River to the east, and the Harlem River to the north. Connectivity between Manhattan and the surrounding areas is provided by several bridges and tunnels. The rivers are physical boundaries. For locations on opposite sides of the East River but not near a bridge or tunnel, their straight line distance apart is simply the width of the river, which ranges from 0.2 to 1.2 kilometers. Measured along the road network, their distance apart is the route to the nearest bridge or tunnel, across the river, and to the location on the other side. The four East River bridges span a distance of between 1.3 and 2.2 kilometers (FHWA 2005).

Not all separation is segregation. I evaluate the effect of these physical boundaries by measuring segregation for local environments that extend outside the borough and comparing results for the two distance measures. Physical boundaries only affect segregation results if the population composition on opposite sides of the boundary differs. In Manhattan, a larger proportion of population are White than Hispanic, but the areas in the immediate vicinity have a larger Hispanic proportion. As the reach of local environments extends outside the city, the aggregate population becomes more Hispanic (see Figure 10).

There are significant differences between segregation measurd with road distance and straight line distance when the reach of local environments is greater than 4 kilometers (see Figure 9b). Local environments are more divergent with the overall population than they otherwise would be because of the presence of the physical boundaries. Locations nearest a bridge or tunnel are better able to keep pace with this change. But overall, as the reach of local environments expands beyond 4 kilometers, their composition differs considerably from the aggregation population. This divergence is represented as higher levels of segregation.

Figure 10: Dot Density Map of the White, Black, and Hispanic Population in Census Blocks in Manhattan, New York, NY in 2010



Symbolic Boundaries

I study symbolic boundaries by mapping the local segregation scores of individual residential locations. Maps allow patterns emerge that would not be obvious in summary tables or statistical graphs. I map White-Black segregation in Philadelphia, PA to illustrate the spatial signature of symbolic boundaries.

Symbolic boundaries separate adjacent areas that are highly segregated but occupied by different groups. The boundary facilitates separation, but it also brings the groups into close

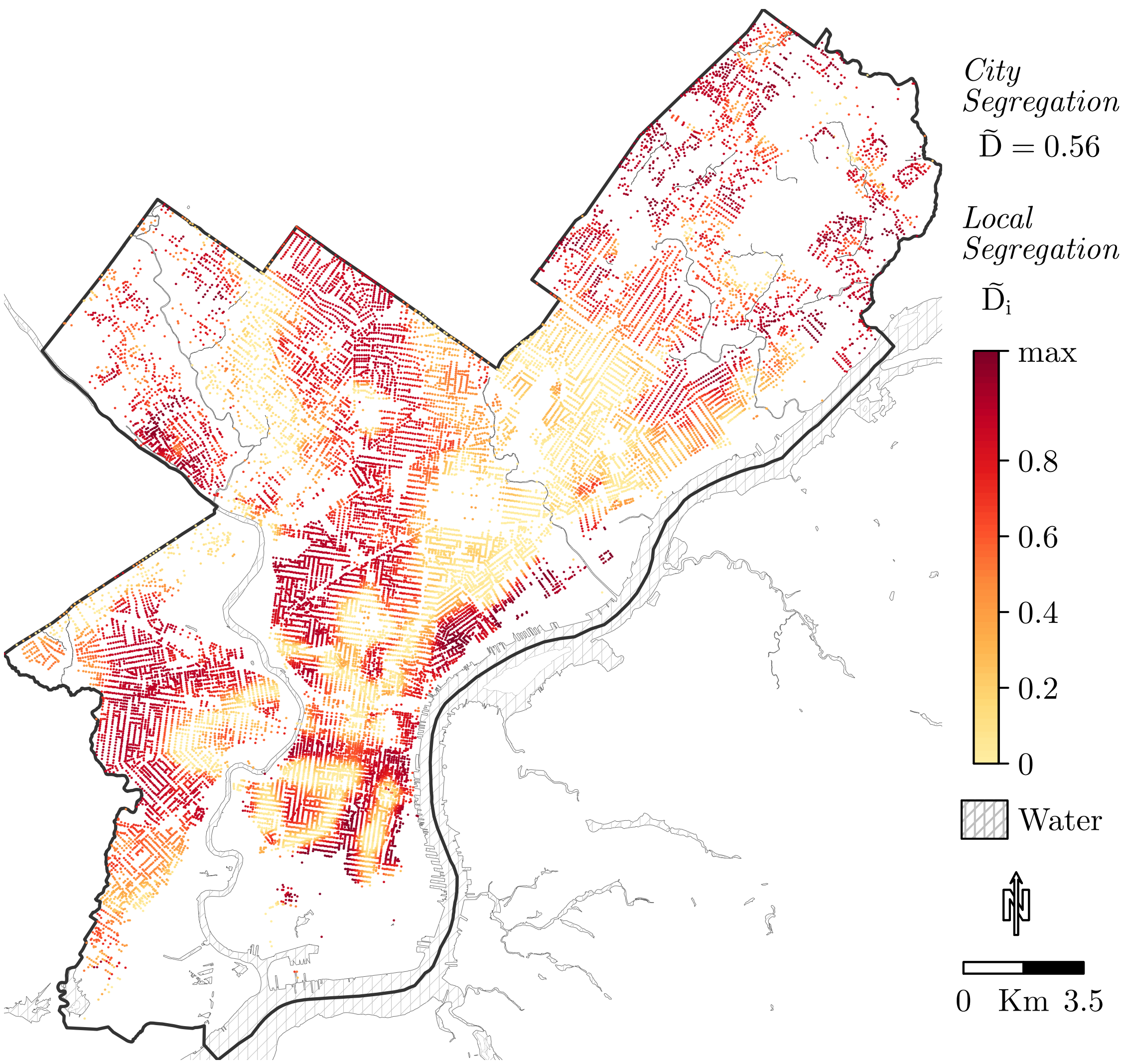


Figure 11: White-Black Segregation in Philadelphia, PA in 2010
(Extended Local Environments, Reach = 0.5 km)

proximity. This is the paradox of spatial boundaries that I discussed earlier in the paper. Along the border, members of different groups live next door or across the street from each other. The boundary divides the groups *and* promotes local diversity along the border.

The paradox of spatial boundaries leads to a pronounced contrast – high segregation within each area and low segregation along the boundary between them. This sharp spatial variation in local segregation levels makes it possible to identify a symbolic boundary.

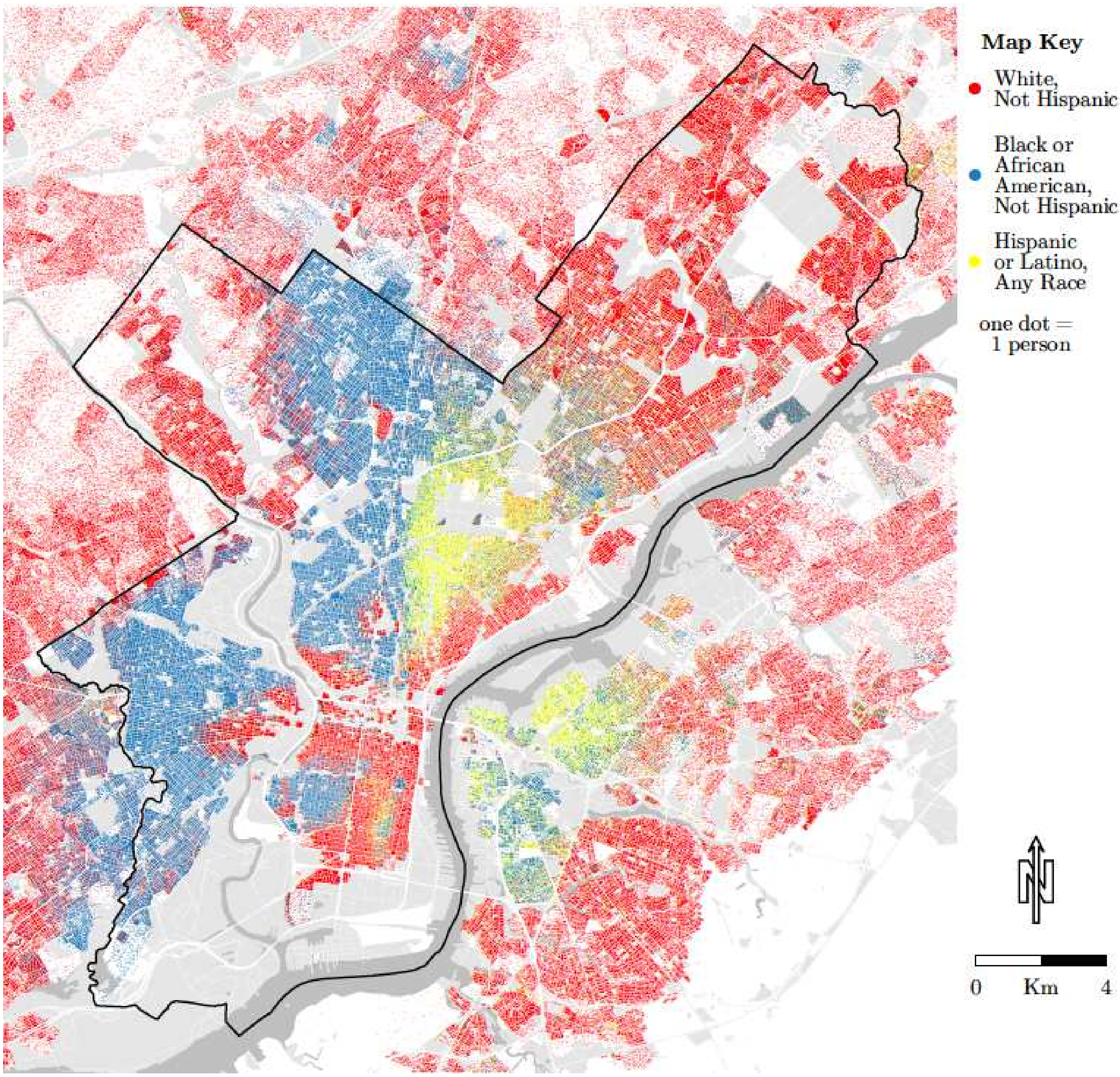


Figure 12: Dot Density Map of the White, Black, and Hispanic Population in Census Blocks in Philadelphia, PA in 2010

Figure 11 maps White-Black segregation for residential locations within Philadelphia. The map show results for extended local environments at a reach of 0.5 kilometers. Each residential location appears as a point on the map. Darker colors indicate higher segregation, and lighter colors indicate lower segregation values. Areas of the map that are White have no population (e.g. industrial or commercial areas, parks, cemeteries, etc.).

The map of Philadelphia demonstrates the spatial signature of symbolic boundaries – they appear as bright lines surrounding areas of high segregation. One such area in the map is in the lower part of the map in Figure 11, where an area of low segregation that encircles an area of higher segregation. This area is the Point Breeze neighborhood of South Philadelphia.

Looking at the same area in the dot density map of Philadelphia in Figure 12, we can see that the population of the area is predominantly Black, and the population of surrounding areas is mostly White. This shift in the population composition is responsible both for the high and low segregation results we observe in the map. Areas that are predominantly of one race or the other have high segregation values. Locations along the boundary of segregated clusters have lower segregation because the groups are in close proximity.

Local Variation

I find substantial spatial variation in the degree of local segregation within cities. In some cases, the variation indicates the presence of symbolic boundaries. But in some cities, the areas of high and low segregation are not bright lines or zones of transition, they are entire neighborhoods or large sections of the city. This is second order segregation – *the segregation of segregation*. Overall city segregation is the weighted mean of local segregation throughout the city, weighted by the population density of each location. In cities with high spatial variance, the city-level mean reveals relatively little about the local context of segregation.

The map of White-Black segregation in St. Louis, MO shows that about half of the city's population experience very high levels of segregation, and half live in areas that are about as diverse as the city as a whole (see Figure 13). Like the map for Philadelphia, it shows local segregation results for extended local environments at a reach of 0.5 kilometers.

There are large areas of high segregation in the north half of the city and the southwest portion of the city. Through the middle of the city and in the southeast portion of the city, there is lower segregation. Very few areas experience the mean level of segregation. There is high local variance – local conditions are both better and worse than indicated by the city mean (0.50).

In some areas of St. Louis, the local population is in close correspondence with the city's composition, and in other areas the population is nearly monoracial. The map in Figure 14 shows that there is a prominent north-south divide in the city. The population in the north is mostly Black and the population in the south is mostly White. There is also an area with considerable diversity in the southeast portion of the city. The large, nearly monoracial clusters in the north and south of the city explain the large clusters of high segregation in Figure 13. The diversity of the area in the southeast, as well as through the middle of the city align with the areas of low segregation in Figure 13.

To better understand the local variation observed in segregation results in St. Louis and Philadelphia, I use the divergence index to calculate the segregation of segregation. I measure the difference between local segregation values and the overall city mean. If there is no segregation of segregation, then all residential locations will have the same value as the mean and the divergence index will equal 0. Larger differences between the mean and the local segregation values indicate more divergence, i.e. high local variation.

Figure 15 shows that both cities have about the same mean level segregation. Segregation is quite high in small local environments and it decreases as their reach increases. Second order segregation is also quite high in both cities, as shown in Figure 16. This indicates high divergence between the mean and local segregation values. Results are similarly high for both cities when local environments have a reach of about 6 to 8 kilometers. Otherwise, there is

Figure 13: White-Black Segregation in St. Louis, MO in 2010
(Extended Local Environments, Reach = 0.5 km)

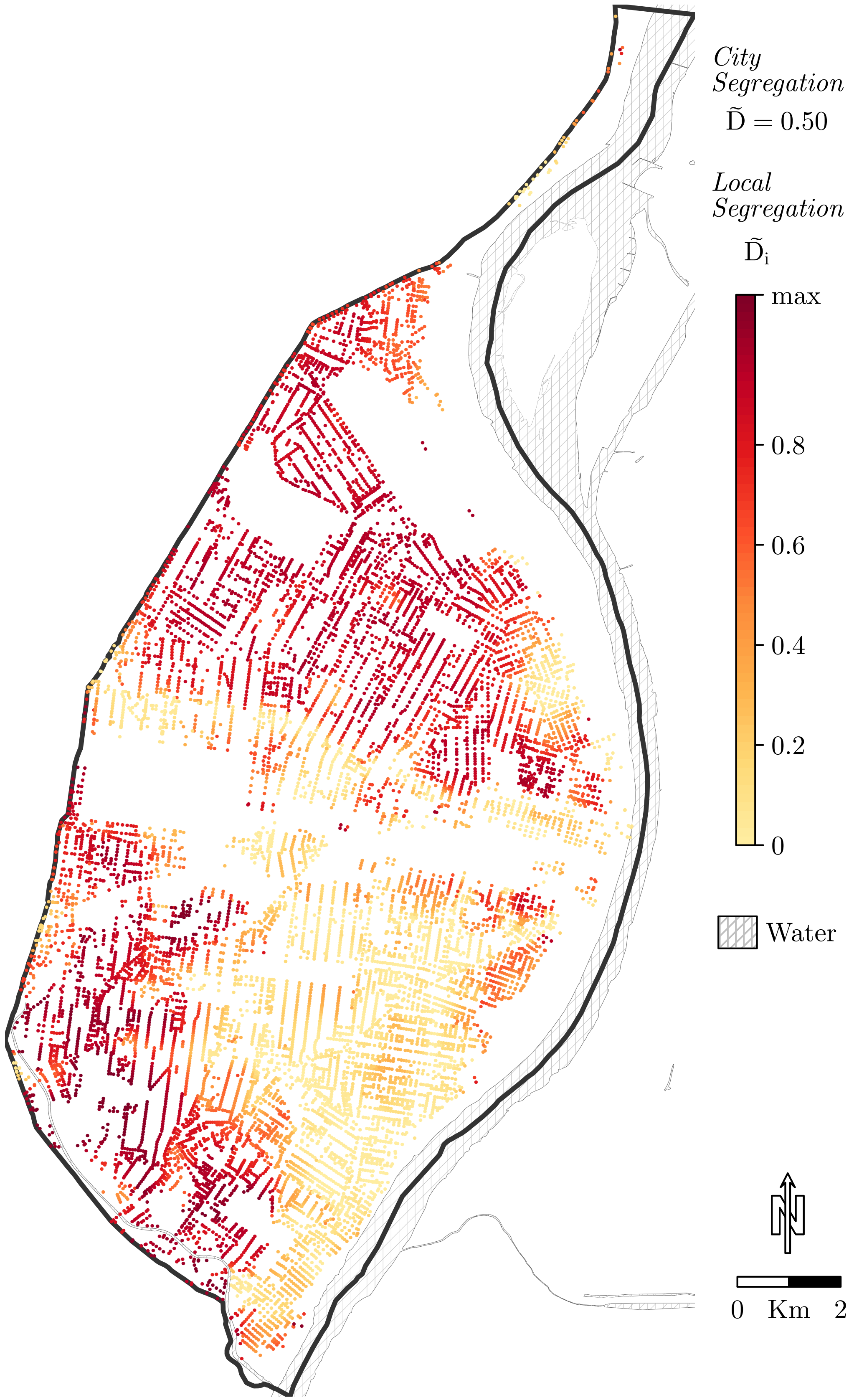


Figure 14: Dot Density Map of the White, Black, and Hispanic Population in Census Blocks in St. Louis, MO in 2010

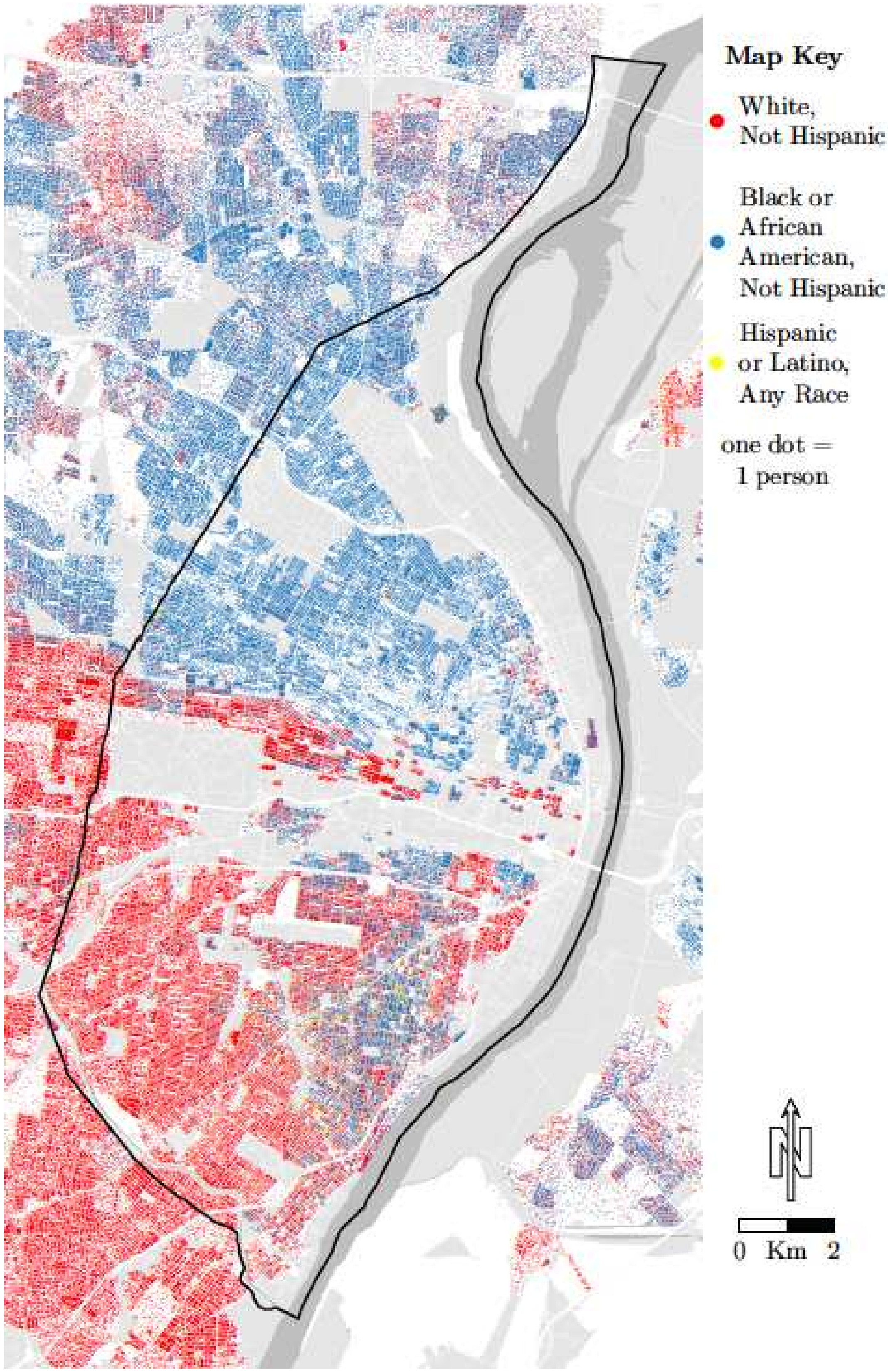
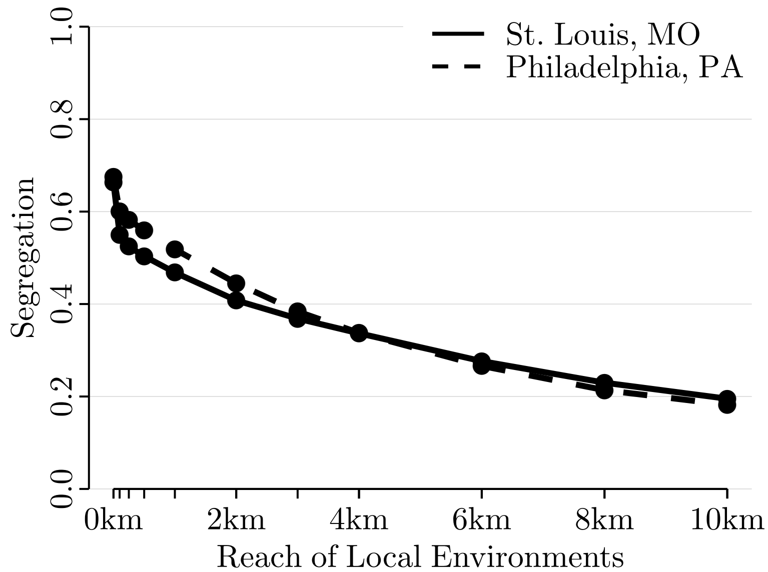


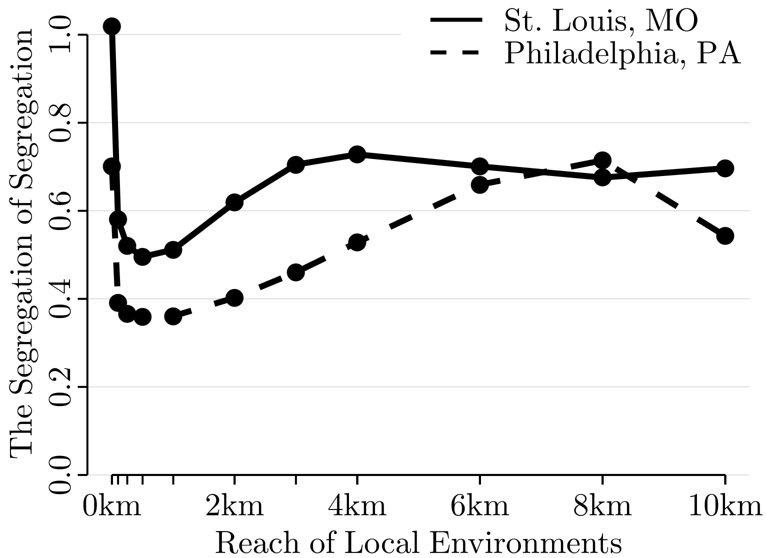
Figure 15: White-Black Segregation in St. Louis, MO and Philadelphia, PA in 2010 (Extended Local Environments)



considerably more divergence in St. Louis than in Philadelphia.

St. Louis is often listed as one of the most segregated cities in the U.S., but the city mean is actually much lower than the segregation of many local environments. The experience of segregation is highly unequal across locations in the city. Some residents experience completely segregated local environments, while others live in areas as diverse as the city. To a large extent, this is also true in Philadelphia.

Figure 16: The Segregation of Segregation: The Divergence between Local and Overall White-Black Segregation in St. Louis, MO and Philadelphia, PA in 2010 (Extended Local Environments)



Discussion

There is a rich literature on the complex social interactions that occur in places: cities, neighborhoods, blocks, street corners. Qualitative studies have described how spatial boundaries shape the experience of discrimination, the emergence community identity, and the process of neighborhood change (Anderson 1990, 1999; Deener 2010; Jacobs 1961; Papachristos 2009; Papachristos et al. 2013; Pattillo 2003, 2007; Suttles 1968; Zorbaugh 1929). Such studies motivate my approach for studying segregation. This paper is a first attempt at bridging qualitative insight on the lived experience of unequal social environments and how we measure segregation for city populations.

I argue that segregation cannot be adequately described independent of spatial boundaries. Emergent patterns of segregation often involve the construction, maintenance, or negotiation of boundaries. In this paper I described four types of spatial boundaries that structure patterns of residential segregation: enumerative, municipal, physical, and symbolic. I used a new approach that incorporates spatial boundaries into the measurement of segregation. It captures the spatial relationships and structured patterns that we intuitively recognize as segregation.

I examined how spatial boundaries structure racial and ethnic residential segregation in a selection of U.S. cities. I showed that Baltimore and Cleveland have similar levels of aspatial segregation, but the geographic scale of segregation varies substantially: Baltimore has more micro-scale segregation and Cleveland has more macro-scale segregation. Further, in Milwaukee Black-Hispanic and White-Black segregation are nearly identical when measured aspatially, but their geographic scale is quite different.

In Detroit, I found large differences between White-Black segregation results for local environments that are truncated at the city boundary and those that extend outside the city. This reveals the salience of the city boundary for structuring segregation patterns. In Manhattan, I found significant differences in White-Hispanic segregation measured with road and straight line distance. Local environments are more divergent from the overall population than they otherwise would be because of the presence of the physical boundaries.

I identified symbolic boundaries in the map of White-Black segregation in Philadelphia, including a bright line of low segregation surrounding the high segregation of the Point Breeze neighborhood. In some cities, the areas of high and low segregation are not bright lines or zones of transition, they are entire neighborhoods or large sections of the city. I showed that *the segregation of segregation* leads to an unequal experience of segregation within cities. I explained that in St. Louis, the White-Black segregation of many local environments is considerably higher than the city mean.

These findings point to further questions about the local context of segregation: Are there certain outcomes that depend on the degree of local segregation, while others depend on the overall level of segregation? How does second order segregation affect the consequences of living in a segregated city? Why is there such high inequality in the segregation of local environments within cities? The magnitude of second order segregation likely has implications for the segregation of other social environments as well, such as schools, workplaces, libraries, and parks.

An emphasis on spatial boundaries and local context reframes our understanding of segregated environments. The results provide deeper insight into the segregation patterns of even the most studied U.S. cities. Spatial boundaries are a critical contextual factor in residential segregation and spatial inequality more broadly. Future research should also examine how spatial boundaries structure multiple forms of spatial inequality, such as the local and city-wide association of racial residential segregation with educational attainment and exposure to crime and violence.

References

Anderson, Elijah. 1990. *Streetwise: Race, Class, and Change in an Urban Community.* Chicago : University of Chicago Press.

Anderson, Elijah. 1999. *Code of the Street: Decency, Violence, and the Moral Life of the Inner City.* New York : W.W Norton.

Bader, M. D. M. and J. A. Ailshire. 2014. "Creating Measures of Theoretically Relevant Neighborhood Attributes at Multiple Spatial Scales." *Sociological Methodology* 44(1):322–68.

Bischoff, Kendra. 2008. "School District Fragmentation and Racial Residential Segregation How Do Boundaries Matter?" *Urban Affairs Review* 44(2):182–217.

Bivand, Roger and Nicholas Lewin-Koh. 2014. *maptools: Tools for reading and handling spatial objects.*

Bivand, Roger and Colin Rundel. 2014. *rgeos: Interface to Geometry Engine - Open Source (GEOS).*

Bivand, Roger, Tim Keitt, and Barry Rowlingson. 2014. *rgdal: Bindings for the Geospatial Data Abstraction Library.*

Chalmers, Mike. 2011. "Despite diversity, a division lingers." *The News Journal.*

Charles, Camille Zubrinsky. 2003. "The Dynamics of Racial Residential Segregation." *Annual Review of Sociology* 29:167–207.

Cover, T. M. and Joy A. Thomas. 2006. *Elements of Information Theory.* Hoboken, N.J.: Wiley-Interscience.

Crowder, Kyle, Jeremy Pais, and Scott J. South. 2012. "Neighborhood Diversity, Metropolitan Constraints, and Household Migration." *American Sociological Review* 77(3):325–53.

Csardi, G. and T. Nepusz. 2006. "The igraph Software Package for Complex Network Research." *InterJournal.*

Deener, A. 2010. "The 'Black Section' of the Neighborhood: Collective Visibility and Collective Invisibility as Sources of Place Identity." *Ethnography* 11(1):45–67.

Emerson, John W. and Michael J. Kane. 2013. *biganalytics: A library of utilities for big.matrix objects of package bigmemory.*

Farrell, Chad R. 2008. "Bifurcation, Fragmentation or Integration? The Racial and Geographical Structure of US Metropolitan Segregation, 1990–2000." *Urban Studies* 45(3):467–99.

Fischer, Claude S., Gretchen Stockmayer, Jon Stiles, and Michael Hout. 2004. "Distinguishing the Geographic Levels and Social Dimensions of U.S. Metropolitan Segregation, 1960-2000." *Demography* 41(1):37–59.

Fischer, Mary J. 2008. “Shifting Geographies: Examining the Role of Suburbanization in Blacks’ Declining Segregation.” *Urban Affairs Review* 43(4):475–96.

Fotheringham, A. Stewart and David W. S. Wong. 1991. “The Modifiable Areal Unit Problem in Multivariate Statistical-Analysis.” *Environment and Planning A* 23(7):1025–44.

Grannis, Rick. 1998. “The Importance of Trivial Streets: Residential Streets and Residential Segregation.” *American Journal of Sociology* 103(6):1530–64.

Grannis, Rick. 2002. “Discussion: Segregation Indices and Their Functional Inputs.” *Sociological Methodology* 32(1):69–84.

Hipp, John R. 2007. “Block, Tract, and Levels of Aggregation: Neighborhood Structure and Crime and Disorder as a Case in Point.” *American Sociological Review* 72(5):659–80.

Jacobs, Jane. 1961. *The Death and Life of Great American Cities.* New York: Random House.

Jargowsky, Paul A. and J. Kim. 2005. “A Measure of Spatial Segregation: the Generalized Neighborhood Sorting Index.” *University of Texas, Dallas*.

Kane, Michael J. 2014. *bigmemory.sri: A shared resource interface for Bigmemory Project packages*.

Kane, Michael J., John W. Emerson, and Peter Haverty. 2013. *bigmemory: Manage massive matrices with shared memory and memory-mapped files*.

Kullback, Solomon. 1987. “Letters to the Editor.” *The American Statistician* 41:338–41.

Lee, Barrett A. et al. 2008. “Beyond the Census Tract: Patterns and Determinants of Racial Segregation at Multiple Geographic Scales.” *American Sociological Review* 73(5):766–91.

Lichter, Daniel T., Domenico Parisi, and Michael C. Taquino. 2012. “The Geography of Exclusion: Race, Segregation, and Concentrated Poverty.” *Social Problems* 59(3):364–88.

Logan, John R. 2012. “Making a Place for Space: Spatial Thinking in Social Science.” *Annual Review of Sociology* 38(1):507–24.

Logan, John R. and Wenquan Zhang. 2004. “Identifying Ethnic Neighborhoods with Census Data: Group Concentration and Spatial Clustering.” Pp. 113–26 in *Spatially integrated social science*. New York: Oxford University Press.

Logan, John R., Seth Spielman, Hongwei Xu, and Philip N. Klein. 2011. “Identifying and Bounding Ethnic Neighborhoods.” *Urban Geography* 32(3):334–59.

Neuwirth, Erich. 2014. *RColorBrewer: ColorBrewer Palettes*.

Openshaw, S. 1984. “Ecological Fallacies and the Analysis of Areal Census-Data.” *Environment and Planning A* 16(1):17–31.

Openshaw, Stanley and Peter Taylor. 1979. “A Million or So Correlation Coefficients: Three Experiments on the Modifiable Area Unit Problem.” Pp. 127–44 in *Statistical applications in the spatial sciences*. London : Pion.

O’Sullivan, David and David W. S. Wong. 2007. “A Surface-Based Approach to Measuring

Spatial Segregation." *Geographical Analysis* 39(2):147–68.

Papachristos, A. V., D. M. Hureau, and A. A. Braga. 2013. "The Corner and the Crew: The Influence of Geography and Social Networks on Gang Violence." *American Sociological Review* 78(3):417–47.

Papachristos, Andrew V. 2009. "Murder by Structure: Dominance Relations and the Social Structure of Gang Homicide." *American Journal of Sociology* 115(1):74–128.

Parisi, Domenico, Daniel T. Lichter, and Michael C. Taquino. 2011. "Multi-Scale Residential Segregation: Black Exceptionalism and America's Changing Color Line." *Social Forces* 89(3):829–52.

Pattillo, Mary. 2003. "Extending the Boundaries and Definition of the Ghetto." *Ethnic and Racial Studies* 26(6):1046–57.

Pattillo, Mary E. 2007. *Black on the Block: The Politics of Race and Class in the City*. Chicago: University of Chicago Press.

Pebesma, Edzer and Roger Bivand. 2015. *sp: Classes and Methods for Spatial Data.*

R Core Team. 2014. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

Rankin, William. 2010. "Cartography and the Reality of Boundaries." *Perspecta* 42:42–45.

Raudenbush, Stephen W. and Robert J. Sampson. 1999. "Ecometrics: Toward a Science of Assessing Ecological Settings, with Application to the Systematic Social Observation of Neighborhoods." *Sociological Methodology* 29:1–41.

Reardon, Sean F. and Kendra Bischoff. 2011. "Income Inequality and Income Segregation." *American Journal of Sociology* 116(4):1092–1153.

Reardon, Sean F. and Glenn Firebaugh. 2002. "Measures of Multigroup Segregation." *Sociological Methodology* 32:33–67.

Reardon, Sean F. and David O'Sullivan. 2004. "Measures of Spatial Segregation." *Sociological Methodology* 34(1):121–62.

Reardon, Sean F. et al. 2009. "Race and Space in the 1990s: Changes in the Geographic Scale of Racial Residential Segregation, 1990–2000." *Social Science Research* 38(1):55–70.

Reardon, Sean F. et al. 2008. "The Geographic Scale of Metropolitan Racial Segregation." *Demography* 45(3):489–514.

Revolution Analytics. 2014. *iterators: Iterator construct for R.*

Revolution Analytics and Steve Weston. 2014. *foreach: Foreach looping construct for R.*

Roberto, Elizabeth. 2015. "The Boundaries of Spatial Inequality: Three Essays on the Measurement and Analysis of Residential Segregation." PhD thesis, Yale University.

Sampson, Robert J. 2012. "Moving and the Neighborhood Glass Ceiling." *Science* 337(6101):1464–65.

Sampson, Robert J. and Stephen W. Raudenbush. 1999. "Systematic Social Observation of

Public Spaces: A New Look at Disorder in Urban Neighborhoods." *American Journal of Sociology* 105(3):603–51.

Savitz, Natalya Verbitsky and Stephen W. Raudenbush. 2009. "Exploiting Spatial Dependence to Improve Measurement of Neighborhood Social Processes." *Sociological Methodology* 39:151–83.

Sharkey, Patrick and Jacob W. Faber. 2013. "Where, When, Why, and For Whom Do Residential Contexts Matter? Moving Away from the Dichotomous Understanding of Neighborhood Effects." *Annual Review of Sociology* 40(1):140512172738005.

South, Scott J., Kyle Crowder, and Jeremy Pais. 2011. "Metropolitan Structure and Neighborhood Attainment: Exploring Intermetropolitan Variation in Racial Residential Segregation." *Demography* 48(4):1263–92.

Spielman, Seth E. and John R. Logan. 2013. "Using High-Resolution Population Data to Identify Neighborhoods and Establish Their Boundaries." *Annals of the Association of American Geographers* 103(1):67–84.

Suttles, Gerald D. 1968. "The Social Order of the Slum: Ethnicity and Territory in the Inner City."

Theil, Henri and Anthony J. Finizza. 1971. "A Note on the Measurement of Racial Integration of Schools by Means of Informational Concepts." *The Journal of Mathematical Sociology* 1(2):187–93.

Timberlake, J. M. and John Iceland. 2007. "Change in Racial and Ethnic Residential Inequality in American Cities, 1970–2000." *City & Community* 6(4):335–65.

U.S. Census Bureau. 2011. "2010 Census Summary File 1—United States."

U.S. Census Bureau. 2012. "2010 TIGER/Line Shapefiles."

White, Michael J. 1983. "The Measurement of Spatial Segregation." *American Journal of Sociology* 88(5):1008–18.

White, Michael J. 1986. "Segregation and Diversity Measures in Population-Distribution." *Population Index* 52(2):198–221.

Wu, X. B. and D. Z. Sui. 2001. "An Initial Exploration of a Lacunarity-Based Segregation Measure." *Environment and Planning B: Planning and Design* 28(3):433–46.

Zorbaugh, Harvey Warren. 1929. *The Gold Coast and the Slum: A Sociological Study of Chicago's Near North Side*. Chicago: University of Chicago Press.