Irregularly-Shaped School Attendance Zones and Racial Integration

Salvatore Saporito

Acknowledgements: George Reed Ruddy and Thomas Crocket wrote and installed computer code on William and Mary's High Performance Computing Cluster to help me calculate values of concavity. Deenesh Sohoni and Elizabeth Yost provided substantive advice. I also wish to thank the following members of the SABINS advisory board: Andrew Beveridge, Michael Goodchild, Kim Goyette, Samuel Lucas, Sean Reardon, Jan Stets, and Regina Werum. The Advisory Board provided initial guidance regarding the subject matter of this paper. This research was supported with grants from the National Science Foundation (SES-1123727, SES-1123894, SES-0921794 and SES-0921279). The author is responsible for all errors and omissions.

Irregularly-Shaped School Attendance Zones and Racial Integration

Abstract

This paper investigates how much the geographic shapes of school attendance zones within urban school districts are associated with levels of attendance zone racial segregation (while holding constant levels of residential segregation). Based on an analysis of 304 school districts, findings show that more irregularly-shaped school attendance zones are correlated with lower levels of racial segregation in attendance zones after accounting for residential segregation. In fact, not one school district contains both highly irregularly-shaped attendance zones and unusually high levels of attendance zone racial segregation—although there are several school districts with irregularly-shaped zones and unusually high levels of racial integration. These findings undermine recent claims that irregularly-shaped attendance zones generally serve to segregate students by race. In addition to these empirical findings, this paper introduces a variation of the spatial information theory segregation index that is useful for predicting segregation in school attendance zones and other types of geographic boundaries containing roughly equal populations.

Keywords: Racial Segregation; Educational Inequality; Gerrymandering.

INTRODUCTION

Two realities of contemporary American cities drive racial segregation in public schools—people of the same race tend to live closer to each other than to people of different races and the majority of public school students are assigned to school based on their residential address. As a result of these two social facts, public schools embedded in metropolitan areas are almost as segregated today as they were two decades ago (Reardon and Owens 2013; Stroub and Richards 2013; Fiel 2013, 2015). Analyses of trends in racial segregation in the largest school districts show that racial segregation in public, elementary schools increased very slightly between 1987 and 1999 and remained virtually unchanged between 1999 and 2013.¹ What makes consistent levels of school racial segregation surprising is that residential, racial segregation within urban areas has diminished steadily every decade since 1970 (Timberlake 2016; Iceland 2009).

The persistence of high levels of school segregation despite declining residential segregation raises two questions addressed in this paper: how closely linked are racial segregation across school attendance zones and residential areas? How much racial segregation across school attendance zones is driven by their geographic shapes? It is logically possible that persistently high levels of school segregation (despite declines in residential segregation) are partly driven by an increase in school attendance zone “gerrymandering”—where educational gerrymandering is a practice in which school districts delineate irregularly-shaped attendance zones to increase racial segregation above that due to residential segregation. Indeed, a recent

¹ These calculations parallel the data and methods used throughout this study. Specifically, I used Theil’s Entropy index (or H) to calculate school segregation between white and non-white students enrolled in first grade and located in the largest school districts in the U.S.

publication implies as much: “attendance zones are highly gerrymandered...and are becoming more gerrymandered over time” (Richards and Stroub 2105, p. 1). The claim that many school districts gerrymandering their attendance zones to increase racial segregation is echoed by other scholars (Orfield 2015; Orfield et al. 2009; Orfield et al 2010; Richards 2014; Siegel-Hawley 2013). It is also possible that “gerrymandered” school attendance zones are associated with racial integration—a contention I make in this paper. The logic of this claim is straightforward: since people of the same race tend to cluster together in residential areas, irregularly-shaped zones that sprawl hither and yon have the potential to draw children from distant “black,” “brown,” and “white” residential areas (Saporito and Van Riper 2016).

The strong association between racial segregation in residential areas and attendance zones—and the potential for districts to engage in racial gerrymandering in order to racially segregate students—is problematic since school attendance zones are the principal way districts assign public school students to schools. Higher rates of racial segregation intensify socioeconomic segregation (Massey and Denton 1992). The link between racial segregation and poverty concentration leads to a condition in which many black and Hispanic students are enrolled in public schools with higher poverty rates than would be the case in the absence of racial segregation. Indeed, recent research shows that black and Hispanic students are much more likely to attend a higher-poverty school in 2014 than they were fifteen years ago (U.S. Government Accounting Office).

Recent research shows that black and Hispanic students do less well academically than white students of comparable socioeconomic status when they are enrolled in school districts

with higher levels of racial segregation (Reardon, Kalogrides and Shores 2016). The correlation between levels of racial segregation across school districts gaps in academic achievement between white and non-white students arises primarily because racial segregation leads to racial disparities in exposure to school-level poverty (Reardon 2015; Card and Rothstein 2007). Literature shows that racial segregation leads to negative educational outcomes for non-white children (Mickelson and Bottia 2010; Mickelson et al., 2013; Hanushek et al., 2009). Thus, any school district that manipulates attendance zones to maximize racial segregation inflicts educational injury to many black and Hispanic students by isolating them in schools with higher poverty rates. For this reason, the prospect that educational gerrymandering exacerbates racial segregation is alarming. One goal of this research is to investigate how many school districts do, in fact, delineate irregularly-shaped school attendance zones. Another is to determine whether this alleged practice reduces (or increases) racial segregation in attendance zones below (or above) that which exists due to residential segregation.

Following previous scholars (Ong and Rickles 2004), I argue that racial segregation in school attendance zones is driven primarily by racial segregation in residential areas. This argument is based on an assumption that, in most school districts, most attendance zones are relatively compact—a condition in which locations within attendance zones are near one another,

as in a circle, pentagon or square.² Assuming zone compactness is reasonable on theoretical grounds since “overcoming space requires expenditure of energy and resources, something that nature and humans try to minimize (although not exclusively, of course)” (Miller 2004, p. 284). As applied to attendance zones, it is economical to delineate compact attendance zones to minimize transportation costs. If attendance zones are compact, many school districts will have racially segregated attendance zones given racial segregation across their residential areas. As Rader (1970) suggests of compact zones, a “neighborhood school [zoning] plan, even if ostensibly racially indifferent, is clearly incompatible with racial mixing” (p. 597).

Case Studies of School Rezoning

Case studies of the attendance rezoning process reveal the social processes at work when school districts delineate attendance zones. School rezoning is highly contentious—but is even more so when school districts attempt greater racial integration by delineating irregularly-shaped zones. Among the most notable examples is Eden Prairie, MN. District administrators in Eden Prairie appointed a committee of citizens to reconfigure the district’s elementary-level attendance zones, primarily to eliminate overcrowding in some schools—but administrators also emphasized socioeconomic balance across zones. The proposed plan—implemented for 2011-2012 school year—met these goals by adding an additional attendance zone and moving

² Compact attendance zones generally have the following properties: they consist of a single polygon, are convex and are not elongated. In this paper, the term compactness infers scale invariance—meaning that a compact zone of one square mile is as equally compact one that is larger or smaller. In contrast to compact shapes, irregularly-shaped attendance zones might consist of multipart polygons, have many indentations and can be quite elongated.

from somewhat compact, single-part attendance zones to less compact, multi-part zones, as shown in Figure 1.

The top panel of Figure 1 shows the original zones. The bottom panel shows the revised zones. The change to more socioeconomically balanced, more irregularly-shaped zones increased racial integration.³ The slight decrease in racial segregation resulted in protests, petitions, protracted board meetings filled with jeering, and the issuance of restraining orders to prevent disruptive citizens from attending board meetings (Eaton 2012; Hawkins 2010; Samuels 2011; Singleton 2013; Smith 2010a, 2010b; Toppo and Overberg 2014).

After the new zones were implemented, an organization tellingly called *Yes for Neighborhood Schools* hired an attorney who threatened litigation to, “Assess whether the District’s plan is consistent with recent decisions by the United States Supreme Court that ban the use of race as the sole or principal factor in deciding where public school students attend school” (Shaffer 2011). While no lawsuit was filed, the superintendent was removed from office due to the social conflicts emerging from the rezoning process (Smith 2011). The case of Eden

³ Based on 2010 complete-count census data, 29 percent of the children in Eden Prairie School District were non-white. The percent of non-white children across 2010-2011 attendance zones ranged from 19 and 40 percent. This range shrank to 24 to 34 percent for the 2011-2012 school year.

Prairie is consistent with the academic literature examining the school rezoning process. Many parents express a desire for compact, “neighborhood” zones containing children from residential areas proximal to the schools that serve them (Bartels and Donato 2009; Diem et al. 2014; Gumas-Dawes et al. 2012; Kahlenberg 2007; McDermitt et al. 2015; McQuillan and Englert 2001; Parcel and Taylor 2015; Roscigno and Condron 2003).

Other case studies underscore the necessity of creating irregularly-shaped attendance zones to achieve social integration. Wake County, NC created irregularly-shaped, socially heterogeneous attendance zones by agglomerating over 1,300 geographic “nodes” into highly irregular, multi-part polygons (Hui 2014; McMillan et al. 2015; Williams and Frankenberg 2011). Brandywine, DE delineates irregularly-shaped, multi-part attendance zones to achieve socioeconomic integration. As shown in Figure 2, irregularly-shaped zones lead to many racially balanced zones⁴.

⁴ As documented by Boyer and Ratledge (2014), Brandywine’s school board had to obtain approval of its zones from Delaware’s State Board of Education to override the State’s *Neighborhood Schools Act* (Title 14, Chapter 1, § 224a), which requires that districts assign students to the nearest school and disregard school racial composition when constructing zones.

Figure 2. Distribution of Black and White Children across Multi-Part Attendance Zones, Brandywine School District, DE: 2009-2010 School Year

As the top panel of Figure 2 shows, zones 1, 2 and 3 consist of multiple parts. The northern portions of these zones contain mostly white children (red dots) while the southern portions contain mostly black children (black dots). These irregularly-shaped zones approximate the racial composition of the entire school district. If these multi-part zones were eliminated—and zone 4 altered to contain the southern parts of zones 1, 2 and 3—racial segregation across zones would increase.

The school districts of Eden Prairie, Brandywine, and Wake County illustrate, the geographic logic underlying the current study: In order to overcome geographic distance between different social groups, these school districts delineate irregularly-shaped zones to create social integration. Otherwise, compact zones would largely replicate existing residential segregation. These case studies also demonstrate a key sociological point: most parents—particularly white parents—favor compact, “neighborhood” zones. Thus, in addition to expending economic resources to overcome geographic distance, school districts must also expend political resources to overcome social opposition to irregularly-shaped zones, particularly when such zones are racially (or socioeconomically) integrated.

Based on these case studies, I derive and test three hypotheses. First, as the *intensity* of racial segregation across school districts’ residential areas rises, so too will racial segregation in school districts’ attendance zones. Here, the intensity of segregation measures the degree to which members of racial groups are near one another while members of different racial groups are far apart. Second, increases in the geographic *scale* of residential, racial segregation will be associated with greater attendance zone racial segregation. The scale of residential, racial

segregation measures the extent to which large regions within a school district are comprised of people from a single racial group. Third, irregularly-shaped attendance zones are associated with higher levels of racial *integration* while holding constant the intensity and scale of residential segregation.

Plan of Analyses

The remainder of this paper proceeds as follows: I review nascent empirical literature describing the shapes of attendance zones across the U.S. (Richards 2014; Richards and Stroub 2015). These two publications reach tentative (and somewhat mixed) conclusions regarding the relationship between attendance zone shape and attendance zone racial segregation. Still, both studies emphasize the need to account for residential segregation when interpreting the correlation between attendance zone racial segregation and attendance zone geography—one task that lies at the heart of my analyses.

I then describe the data and measures I use throughout this paper. In particular, I devise and describe a novel way of measuring racial segregation across residential areas. My approach is a variation of Reardon and O’Sullivan’s (2004) spatial information theory segregation index (of residential segregation. compares the racial diversity in “local environments” with the racial diversity of the larger region in which these local environments are located (Reardon and O’Sullivan 2004; Reardon et al. 2008; Lee et al. 2008). In existing research, local environments are essentially operationalized as areas of fixed size “drawn” around the approximate residential locations of every child within a region. The racial diversity within each fixed area is compared with racial diversity within the entire region in which each local environment is situated.

Operationalizing local environments as fixed areas is entirely appropriate as means of measuring residential segregation. But this approach does not adequately predict racial segregation in school attendance zones because fixed areas vary much more in the number of children they contain than do school attendance zones.

My approach is to build local environments around each child so that they all contain the same number of children. Specifically, I determine the racial diversity of the *N nearest* children to each child in a region. This alternative way of operationalizing “local environment” essentially builds compact attendance zones of a fixed population around each child in a school district. I call this operationalization of local environments the *proximity-based population threshold*. It is a much more accurate predictor of racial segregation across districts’ attendance zones than a measure relying on fixed areas. So far as I am aware, a spatial segregation measure based on *proximity-based population thresholds* has never been used in prior research.

I end the paper with three closely related analyses. The first is a straightforward description of the typical geographic shapes of attendance zones. Specifically, I measure the shapes of attendance zones and examine their statistical distribution. I then undertake multivariate regression analyses to examine the three hypotheses presented at the outset of this paper. In particular, I predict racial segregation in districts’ school attendance zones based on the intensity and scale of racial, residential segregation—along with mean irregularity scores of districts’ attendance zones. The third and final analysis identifies school districts with much higher or lower levels of attendance zone racial segregation than expected based on residential segregation in the district. It is rare for a school district to have much higher levels of attendance

zone racial segregation than that which exists in its residential areas. But I do find school districts have less-than-expected levels of racial segregation—and some of these have highly irregularly-shaped attendance zones.

Existing literature on attendance zone shape and attendance zone segregation

A number of scholars speculate that school districts may gerrymander their attendance zones (Clotfelter 2004; Frankenberg and Orfield 2012; Leigh 1997; Orfield 2015; Orfield and Luce 2009; Siegel-Hawley 2013). Yet, there are only a few studies examining the relationship between attendance zone shape and attendance zone segregation. One study compares racial segregation in actual attendance zones with racial segregation across very compact, hypothetical attendance zones surrounding each school location (Richards 2014). Results show that, on average, racial segregation between black and white children is .002 percentage points higher in actual than hypothetical zones (Table 4, p., 1141). Based on this finding, Richards concludes: “By comparing the characteristics of current attendance zones to the attendance zones that would be expected in the absence of gerrymandering, I find that first grade attendance zone boundaries generally serve to segregate students by race and ethnicity” (Richards 2014, p. 1150). Using methods similar to those of Richards (2014), Rickles, Ong and Houston (2002) study attendance zones segregation in five California metropolitan areas—and find results strikingly similar to those in Richards’s work.

In a follow-up study, Richards and Stroub (2015) determine if irregularly-shaped attendance zones vary by the level of racial segregation across schools in a district. They find what they describe as a “counterintuitive” result: “school districts that are more segregated have

less gerrymandered boundaries than districts that have higher levels of racial integration” (Richards and Stroub 2015 p. 22). The authors provide a cautious interpretation of this association:

Certainly, [our finding] may indicate that gerrymandering is being used affirmatively to engineer more integrated districts....However, this finding may be interpreted to suggest that gerrymandering is primarily employed as a tool to subvert higher levels of residential integration (p. 22).

Both of these interpretations are plausible since, as the authors acknowledge, their work does not account for residential segregation—a limitation I address in the current study.

DATA AND MEASURES

I analyze a geographic dataset called the School Attendance Boundary Information System (SABINS) (College of William & Mary and the Minnesota Population Center 2011).⁵ SABINS is the first database to collect and publicly disseminate thousands of attendance zones on a national level. Data are available for the 2009-2010 school year. I analyze first grade attendance zones since they closely approximate what most people think of as an elementary school attendance zone (SABINS only disseminates grade-specific attendance zones). It is reasonable to use a lower grade since attendance zones for grades seven and higher are so expansive that they often coincide with the school district in which they are located.

Attendance zones in the SABINS database are available for most of the largest 350

⁵ Ideally, a national, longitudinal database of school attendance zones would be available to researchers. In lieu of this, the SABINS data would ideally contain information describing the last year a district rezoned its attendance areas, allowing researchers to restrict analysis to districts that established new zones for the 2009-2010 school year. This information does not exist.

school districts in the U.S. Of these 350 districts, 329 are relevant to this study. Eleven of the 350 are irrelevant because they have open enrollment policies allowing any child to attend any school⁶. The remaining irrelevant districts serve children in grades six or higher.

The SABINS staff requested attendance zone maps from all of the 329 relevant districts and 304 districts complied—resulting in a 92 percent compliance rate⁷. It is not possible to know if the zoning practices of complying districts are different from non-complying districts. Still, a compliance rate of 92 percent is high for social science research, suggesting that the results in this study are not compromised by non-response bias. It is important to emphasize that results apply only to the largest school districts—and not all school districts across the country. Nevertheless, over a third of public school children are enrolled in these 304 districts.

Dependent Variable

In this paper, the intensity of racial segregation refers to how racially diverse, on average, children within attendance zones are compared with the racial diversity of their encompassing school district. I measure racial segregation across school attendance zones between non-Hispanic white children and children from all other racial groups. I use two groups since the case studies cited above indicate that many white families oppose racially integrated attendance zones (Appendix B shows analyses based on three group segregation).

⁶ These districts are Boston, Buffalo, Garland, Hartford, Lee, Providence, Rochester, San Francisco, Springfield, St. Lucie, and Yonkers.

⁷ The SABINS database also includes a non-random sample of school districts that are smaller than the largest 350. I did not analyze smaller districts since they were not sampled randomly. Moreover, it does not make sense to study segregation in school districts containing two or three zones.

To determine the racial composition of attendance zones, I use 2010 block-level SF1 Census Data (which corresponds with 2009-2010 attendance zones). Following Clark's example (1987), I do this for children less than 18⁸. In the SABINS data, census blocks nest entirely within attendance zones and it is a straightforward process to locate blocks within attendance zones and sum the number of children (by race) who reside within each zone. It would be ideal to have data for children enrolled in public school (by age, race and Hispanic origin) but these variables are not available for U.S. census blocks.⁹

I calculate racial segregation using Theil's multigroup entropy index, hereafter abbreviated as H (Theil and Finezza 1971). Appendix A provides formulas. Values of H range from zero to one. Values of one represent complete segregation—a condition in which every zone in a district is comprised of members of a single race. Values of zero represent complete integration—a condition in which the racial diversity of each attendance zone is the same.

Independent variables

⁸ The Census Bureau does not provide detailed, block-level tabulations by age, race and Hispanic origin. While it does provide counts of children ages 5 to 9 who are, for example, black, Asian or Native American, it does not provide tabulations of children aged 5 to 9 who are *non-Hispanic* black, *Non-Hispanic* Asian and so on. Still, some may wonder if the racial composition of areal units is the same for children ages 0 to 17 and 5 to 9. Across 1990 census tracts, the correlation between the share of white children ages 5 to 9 and the share aged 0 to 17 is .992. Based on this, I feel comfortable using more detailed racial categories for a larger age span rather than less detailed racial categories for a smaller age span.

⁹ The last time the U.S. Census Bureau published census tract tabulations of race, grade span and public or private school enrollment was 2000. I analyzed these tract data for children enrolled in grades one to eight to determine whether there are substantial differences in proportions of children of a given race enrolled in *any school* compared with shares of children of a given race enrolled in *public school*. There is a .989 correlation between shares of white children enrolled in any school and shares in public school. The comparable correlation for black children is .993.

A major predictor of the intensity of racial segregation in attendance zones is the intensity of racial segregation across residential areas—a critical variable that has not been used in previous analyses of attendance zone shape. I measure the intensity of residential, racial segregation using a modified version of Reardon and O’Sullivan’s (2004) spatial information segregation index (. Spatial segregation indices eliminate the use of administrative geographies such as census tracts,¹⁰ and, in their place, substitute “local environments.” In the existing literature, local environments are created by estimating the residential location of every child (hereafter, “focal child”) in a region and then calculating the straight-line distance between each focal child and every other child in the region. Each focal child’s local environment consists of the population within a fixed radius of that focal child. The racial diversity within each fixed area is then calculated and compared with the racial diversity of the larger region.

The limitation of using equal areas as local environments is that they vary greatly in population size (given fluctuating densities of children within and between school districts). As I explain in detail in Appendix A, variation in the population size of local environments is undesirable for predicting attendance zone segregation (since attendance zones presumably contain roughly equal numbers of children). For this study, a more suitable operationalization of

¹⁰ Administrative geographies are deficient in several ways. First, they are not always available. For example, if a scholar wanted to use administrative geographies to predict segregation across 8th grade or 12th grade attendance zones (or U.S. Congressional Districts) they would have to rely upon spatial measures of segregation since there are no administrative geographies at an appropriately large population scale. Second, administrative geographies do not necessarily nest within a larger region. For example, census tracts do not nest within school districts, making it difficult or impossible to measure segregation using census tracts. Third, administrative geographies cannot be used to measure the scale of segregation (Reardon et al., 2008) (I describe the scale of segregation below).

local environment is based upon what I call a *proximity-based population threshold*, which is calculated by determining the nearest N children surrounding each focal child. To create local environments containing a specified population threshold, I calculate the distance between the approximate residential location of each focal child and the approximate residential location of every other child. I then determine the population characteristics (i.e., racial composition) of the nearest children up to some predetermined population threshold (see appendix for formulas and other details). In this study, I use a threshold of 2,000 children (since this is about the average number of children within school attendance zones).

As with H for school attendance zones, D compares the mean racial diversity of each child's local environment with the racial diversity of the entire school district. Conceptually, D is similar to building (extremely compact) school attendance zones around every focal child and then calculating racial segregation across those zones. Values of D generally range from zero to one (although negative values are possible). Values of zero represent complete integration and values of one represent complete segregation.

There are limitations of using D to predict racial segregation across school attendance zones: some children who are nearest “as the crow flies” may not interact since a major geographic impediment (e.g., a river) lies between them. Residential racial segregation is probably underestimated in some school districts since many local environments cross physical barriers such as rivers—and attendance zones typically do not draw children from either side of such barriers. I think of this as a conservative bias since my argument is that, on average, attendance zone segregation is less than residential segregation.

Despite the limitations of H based on equal area and H based on administrative geographies, I calculate racial segregation based on these alternative measures to show the advantages of using H based on population thresholds. Specifically, I measure spatial segregation based on areas of one mile radii (abbreviated H_1). I also measure aspatial segregation using blocks. I then compare the performance of these two approaches with spatial segregation based on proximity-based population thresholds.

Measuring the Scale of Segregation

While I expect that variation in attendance zone racial segregation will be highly associated with the intensity of racial segregation, the *scale* of residential segregation may also influence attendance zone segregation. In this study, the scale of segregation refers to the extent which very large numbers of children from the same racial group are clustered closer together than members of more distant racial groups. This concept is illustrated by Figure 3—which shows the

Figure 3. The Scale of Racial, Residential Segregation in Atlanta and Pittsburgh.

distribution of non-Hispanic black, non-Hispanic white and all other racial residential areas in Atlanta and Pittsburgh. While these school districts have intense residential segregation, the scale of segregation in Atlanta is much greater than that in Pittsburgh. Almost all white children are clustered in the northeast portion of Atlanta while black children are primarily located in the southwest. By contrast, the scale of segregation in Pittsburgh is less severe since clusters of different racial groups are interspersed in something like a checkerboard fashion.

Given these differences in the scale of racial segregation, it may be more difficult in Atlanta than Pittsburgh to randomly place a compact attendance zone and achieve racial balance within it. This suggests that the scale of racial segregation likely influences racial segregation in attendance zones. The scale of segregation can be measured using the *macro-micro segregation ratio* (Lee et al. 2008). This is created by dividing based of larger population thresholds by based on smaller population thresholds. In this paper, I divide by. (Results do not change when different numerators or denominators are used.)

When the macro-micro segregation ratio is one, this indicates that the intensity of racial segregation is the same at lower and higher scales—and thus the overall scale of segregation is high. That is, the typical child would not experience more racial diversity whether they interacted with the nearest 6,000 children rather than the nearest 1,000 children. When values of macro-micro segregation approach zero, the intensity of racial segregation within a school district is driven by micro-level segregation. That is, clusters of 1,000 children from one racial group are

interspersed with clusters of 1,000 children from another racial group in a “salt and pepper” fashion.¹¹

Identifying Irregularly-shaped Attendance Zones

There are numerous ways to measure shape and most are highly correlated (Niemi et al., 1990). Given these high correlations, I use one measure called concavity (Chambers and Miller 2010).¹² To describe concavity, it is helpful to first describe convexity. Perfectly convex shapes (e.g., circles, triangles, and rectangles) are those in which the approximate residential locations of every unique pair of children within an attendance zone can be connected by a straight line that *does not* pass through the zone’s boundary.¹³ In such cases, concavity is zero and a zone is completely compact. In contrast, concave shapes have at least one straight line (connecting a unique pair of children within it) passing through the boundary of an attendance zone. The higher the proportion of lines that pass through the boundary of the zone, the more concave (i.e., irregularly-shaped) it is. Crescents, sea stars or other polygons with indentations are examples of shapes that are be highly concave (assuming the children within them are dispersed evenly

¹¹ For reasons too lengthy to explain here, macro-micro segregation can exceed value of 1.

¹²I assessed two additional measures of shape to predict racial segregation in zones. The first is a population-based measure of convex hulls (Hofeller and Grofman 1990). The second is the Polsby-Popper measure (Polsby and Popper 1991). I obtain nearly identical results regardless of the measure I use. Results are available upon request.

¹³The advantage of concavity is that leverages information about the geographic distribution of populations within attendance zones. This is critical. As Clark (1987) notes, the boundaries of some irregularly-shaped attendance zones are “distended” by non-residential land use (e.g., city parks). The residential locations of children within a zone are important—not only the shape of a zone’s outline. Incorporating population characteristics in the measurement of attendance zone shape represents an advancement over previous studies (Richards and Stroub 2015) that rely solely upon the outlines of attendance zone boundaries.

throughout such polygons). Since the unit of analyses in this study is a school district, I calculate the mean concavity score of attendance zones for each school district. (Using median concavity scores does not change the conclusions of this paper.) Hereinafter, I refer to “concavity” with generic term “irregularly-shaped.”

Using Census Tract Shapes to Account for School District Topography

The shape of attendance zones are influenced by topographic features. In some cases, these topographic features are convoluted (e.g., water bodies, mountains, highways, and city parks). Attendance zones abutting them are shaped irregularly. In other cases, the landscape is flat, lacks water features and, as in many western states, is governed by the Public Land Survey System. In such places, roadways form a square grid and, when school attendance zones follow these roadways, they are likely more compact than attendance zones in a “metes and bounds” system. I control for the influence of topography by measuring the mean irregularity score of census tracts within school districts. If a district’s topography influences the shapes of its census tracts, it will also likely influence its attendance zones¹⁴.

Additional Control Variables

Analyses control for the density of children per square mile and the number of square miles per attendance zone. It may be that districts with larger attendance zones also have less segregated zones. I also control for the share of children in a school district who are non-Hispanic black and non-Hispanic white. Similarly, I control for the proportion of families in a

¹⁴ Since census tracts do not nest entirely within school districts, I used GIS to eliminate any portion of a census tract the extended outside of a school district using a “clip” procedure. Any census tract that is modified in this way shares a border with a school district.

district that are poor. Attendance zone racial segregation across may be influenced by the overall racial composition or poverty rate of a school district.

ANALYSES

As Miller (2004) argues, overcoming geographic distance is expensive. In the case of educational geography, most school districts probably try to minimize travel expenses by delineating compact zones. Moreover, as case studies of the attendance zone creation process suggest, a school district might bear political costs when proposing irregularly-shaped zones. Based on basic geographic principles and case studies of school zoning practices, I argue that the average school district has compact attendance zones. I examine this assumption here.

Prior literature (Saporito and Van Riper 2016) shows that attendance zones are about one standard deviation less irregularly-shaped than U.S. Congressional Districts. Since some Congressional Districts are notoriously irregular, this does not necessarily mean that the typical attendance zone in the typical school district is compact. Another geographic zonal system against which to compare attendance zones is U.S. census tracts.

Table 1 shows the mean irregularity value of 2009-2010 school year attendance zones and 2010 census tracts. As the table indicates, within the typical school district, the typical census tract is almost completely compact (i.e., the mean irregularity value is .05) with little variation across districts. By contrast, the typical district's attendance zones are more irregularly-shaped, with a mean irregularity values of .16. Perhaps more importantly, there is much greater variation in the shapes of attendance zones than census tracts. Many school districts have mean irregularity values exceeding .33.

Table 1. Summary Statistics of 304 School Districts

	Med.		Min	Max
<i>H</i> Attendance Zones	.13	.10	.10	.55
	.14	.11	.10	.52
	.61	.67	.26	1.2
	.19	.18	.11	.56
	.44	.44	.17	.84
	.30	.29	.12	.73
Irregularity, Attendance Zones	.16	.15	.07	.45
Irregularity, Census Tracts	.05	.04	.03	.14
Proportion of Children who are African American	.17	.12	.17	.82
Proportion of Children who are White	.43	.45	.23	.88
Proportion of Families who are Poor	.26	.26	.10	.69
Population Density (in 1,000s)	.35	.24	.40	2.69
Median Square Miles of Attendance Zones	8.03	3.70	11.82	.46 102.23
Notes: All Segregation indices are between Non-Hispanic white children and all other racial groups. N is 304 cases.				

To obtain a sense of exactly how irregularly-shaped a *typical* school district's attendance zones are, Figure 4 shows first grade attendance zones in Cabarrus County, NC. Irregularity values are expressed as the percentage of unique pairs of children who live in the zone and whose "line-of-sight" passes through the boundary of the zone. The mean irregularity score for the district is .16. While many zones are almost completely compact, zones 1 through 4 are irregularly-shaped. For example, in Zone 1, the irregularity score is .48.

Figure 4. Attendance Zones and Corresponding Irregularity Values, Cabarrus School District, NC. Higher Percentages Represent More Irregularly-Shaped Attendance Zones.

Reasonable people can debate whether the average zone in Cabarrus is, in some absolute sense, shaped compactly or irregularly. But other districts contain some truly irregular, multi-part attendance zones, such as Pitt County School District, NC (Figure 5). Some of its first grade attendance zones contain four or five isolated parts. For example, Zone 1 has five parts (labeled

1A through 1E) as does Zone 6. Other multi-part zones contain only two parts but these are many miles apart (e.g., parts 4A and 4B are nearly five miles apart).

Figure 5. 2009-2010 Attendance Zones in the center of Pitt County School District, NC.

The mean irregularity value in Pitt County is .35. It is difficult to imagine that Pitt County's zones were not purposefully drawn to be irregularly-shaped, especially since it was

under a Federal Court Order to racially integrate its zones and, for decades, “Repeatedly rejiggered attendance zones to ensure integration” (Hannah-Jones 2014, p. 1). Once the desegregation order was lifted, Pitt County consolidated most multi-part zones into fewer parts (recent maps are available upon request). The historical variation Pitt County’s attendance zones illustrates the argument that school districts typically contain compact zones unless compelled to integrate children by race or, perhaps, by socioeconomic status.

Multivariate Analyses

Given the travel costs and political upheaval associated with irregularly-shaped zones, it is intriguing to find a fair number of school districts in which the typical attendance zone is shaped irregularly. Still, it remains an open question as to whether irregularly-shaped attendance zones are correlated with higher or lower levels of racial segregation in school districts. To address this question, I use OLS regression models¹⁵ to predict racial segregation across attendance zones using (1) the intensity of racial segregation across residential areas (i.e.,); (2) the scale of residential segregation (i.e.,); and (3) the shapes of attendance zones.

Table 2. Regression Models Predicting White/Non-White Segregation Across School Attendance Zones

Proximity-Based Segregation		Area-Based Segregation		Block-Based Segregation	
<i>b</i>	<i>se</i>	<i>b</i>	<i>se</i>	<i>b</i>	<i>se</i>

¹⁵ It is technically inappropriate to use Theil’s *H* as a dependent variable in OLS regression since it ranges from zero to one and OLS can results can lead to predicted values below zero or above one. To ensure that OLS regression produces reliable results, I compare results produced from OLS with results from beta regression (Ferrari and Cribari-Neto 2004). I find no differences in terms of statistical significance and effect size. I present OLS results for ease of interpretation.

	.908*	.015				
			.775*	.028		
					.675*	.024
Constant	.000	.003	-.021*	.006	-.077*	.008
R-Squared	.927		.713		.730	

N=304. All residential segregation measures compute spatial inequality between white and non-white children. *p<.001

I begin with a minimal specification in which I predict attendance zone segregation using the intensity of segregation across residential areas (Table 2). Results show that the intensity of residential racial segregation—based on spatial H derived from proximity-based population thresholds (i.e., —is highly correlated with racial segregation across school attendance zones. Several details are noteworthy. The slope for the intensity of residential racial segregation is a bit less than one. Given that the constant is nearly zero, a regression coefficient of slightly less than one indicates that, in a typical school district, there is somewhat less attendance zone segregation than residential segregation. (More precisely, the difference between attendance zone and residential segregation increases the more residentially segregated a school district is.) Finally, the proportion of variance in attendance zone segregation explained with is .93, suggesting that, for most school districts, it is possible to accurately predict attendance zone segregation by knowing the level of residential segregation. These results are consistent with the hypotheses that the intensity of residential, racial segregation is highly correlated with racial segregation in school districts' attendance zones.

Table 2 also compares the accuracy of spatial segregation based on proximity-based population thresholds (i.e.,) with: (1) spatial H based on equal area (i.e.,) and (2) aspatial H based on census blocks (i.e., and). Results show that measuring spatial H using local environments based on proximity-based population thresholds performs much better than spatial H using local environments based on equal area. Specifically, the proportion of variance in attendance zone segregation explained with is .93 while the comparable figure is .71 for . This clearly shows that spatial based on population thresholds is highly useful in predicting segregation across zonal systems in which the areal units contain roughly equal numbers of people (e.g., elementary, middle and high school attendance zones or legislative districts).

Finally, Table 2 provides a comparison of spatial and aspatial segregation. Results show that performs far better than aspatial H based on blocks. Specifically, the proportion of variance in attendance zone segregation explained with is .93 while the comparable figures for blocks is .73.

Table 3 includes the scale of residential segregation for the population-based regression model. The association between the scale of residential segregation and attendance zone segregation is not statistically significant and is substantively irrelevant since its inclusion does not increase explained variance. There is no support for the hypothesis that the scale of residential segregation is related to racial segregation in attendance zones—at least when residential segregation is based on population thresholds.

Table 3. Regression Models Predicting White/Non-White Segregation Across School Attendance Zones

	Population-Based Segregation		Area-Based Segregation		Block-Based Segregation	
	<i>b</i>	<i>se</i>	<i>b</i>	<i>se</i>	<i>b</i>	<i>se</i>
	.914*	.022				
	-.015	.008				
			.776*	.029		
			.077*	.014		
					.755*	.028
Irregularity of Zones	-.163*	.024	-.214*	.028	-.206*	.037
Irregularity Census Tracts	.116	.063	.034	.076	.089	.099
Pct. Children who are Black	.030	.012	.018	.015	.026	.019
Pct. Children who are White	.036	.011	.017	.012	-.040	.016
Pct. Families who are Poor	-.002	.019	-.003	.022	-.271*	.033
Population Density (in 1000s)	-.005	.005	.028*	.006	.007	.007
Median Square Miles of Zones	.000	.000	-.002*	.000	-.002*	.000
Constant	.012	.012	-.025	.012	.024	.015
R-Squared	.936		.908		.842	

N=304. All residential segregation measures compute spatial inequality between white and non-white children. *p<.001

How much do the shapes of attendance zones matter?

While the intensity of residential segregation is strongly correlated with attendance zone segregation, it does not predict attendance zone segregation perfectly. This leaves the possibility that attendance zone irregularity scores might be associated with lower (or higher) levels of racial segregation in attendance zones. To address this possibility, Table 3 includes the mean irregularity values of attendance zones within each district. The regression coefficients for attendance zone irregularity scores are statistically significant, negative and substantively meaningful across all models. As school districts' attendance zones become increasingly

irregular, racial segregation decreases. This relationship persists when the potentially confounding effects of residential segregation, topography, and the racial compositions and poverty rates of districts' students are controlled. The more compact school district attendance zones are, the more racially homogenous they are. Put another way, school districts that delineate irregularly-shaped zones have more racially heterogeneous attendance zones than districts with compact zones, *ceteris paribus*.

Are there Exceptionally Integrated or Segregated School Districts?

Regression coefficients summarize the overall influence of a variable—a useful tool to show that irregularly-shaped attendance zones are *generally* associated with less racial segregation in attendance zones. But regression coefficients do not determine how many school districts have much more (or much less) racial integration in their attendance zones than would be predicted based upon residential segregation. Identifying the existence of potential outliers is

Figure 6. Attendance Zone Segregation by Residential Segregation, Outliers Shown in Red

useful since they can show exactly how much more integrated or segregated “unusual” school districts are.

To identify potential outliers, I calculate the difference between attendance zone segregation and residential segregation. I convert this difference into z scores and display the results in a scatterplot (Figure 6)¹⁶. A school district with attendance zone segregation two z-

¹⁶An alternative approach is to use regression to identify outliers. The limitation with this approach is that some school districts that have the exact same levels of attendance zone and residential segregation are considered “outliers.” This results from the fact that the a few school districts with exceptionally integrated attendance zones “pull down” the regression line.

scores above or below the expected level of residential segregation is labeled and marked with a red dot. The scatterplot shows 11 school districts with much lower-than-expected levels of attendance zone racial segregation. For example, racial segregation in Pitt County, NC's attendance zones is less than half than in its residential areas, and, as Figure 5 showed, its attendance zones are highly irregular. Similarly, attendance zones in Hillsborough, FL, Manatee, FL, and Wake County, NC are all irregularly-shaped (i.e., one standard deviation above the mean value of irregularity). Moreover, 8 of the 11 school districts with less segregation in their attendance zones than their residential areas have shapes that are above the mean irregularity score; that is, most districts with less-than-expected attendance zone segregation have attendance zones with higher-than-average irregularity values.

Perhaps more telling is that, of the 304 districts analyzed in this study, only two districts (Denver, CO and Washington, UT) have substantially greater attendance zone segregation than residential segregation (and, in the case of Washington, UT, attendance zone and residential racial segregation are well below their respective means). It is noteworthy that Denver has below average irregularity scores (indicating that its attendance zones are compact). This further substantiates the overall conclusion that irregularly-shaped attendance zones are generally associated with greater-than-expected racial integration than compact zones.¹⁷

STUDY LIMITATIONS

Geographic data of school attendance zones are available for one year. Thus, the cross-sectional analyses presented in this research make causal claims difficult to substantiate. I do not infer that districts “gerrymandered” zones to racially integrate (or segregate) children. Indeed, I avoid the term gerrymandering since the term explicitly connotes intentionality. Ideally, I would like to follow yearly alterations in school attendance zone irregularity and predict how much such changes are associated with changes in attendance zone racial segregation. As the example of Eden Prairie suggests, minor increases in attendance zone irregularity may lead to minor decreases in attendance zone racial segregation—and, at least in Eden Prairie, this change can be understood by the school district’s attempt to integrate students by social class. It is not possible to know if this one example is representative. Still, the findings presented in this paper rule-out

¹⁷If I loosen the criterion for detecting outliers to one standard deviation from the 45 degree line, I still cannot find a school district with both greater-than-expected segregation and highly irregular zones. The closest district I can find is Lamar, TX. Residential segregation in Lamar is .19 and its z-score for zone irregularity is .76.

recent claims that irregularly-shaped first grade attendance zones are generally associated with higher levels of racial segregation (Richards 2014; Richards and Stroub 2015). Indeed, in the sample used in this paper, I could not identify a single school district that had both highly irregular attendance zones and higher-than-expected levels of attendance zone racial segregation.

A more daunting limitation is determining whether school districts with both higher-than-expected attendance zone segregation and compact attendance zones delineated zones in a way that was indifferent to race. Denver, CO illustrates this challenge. It has reasonably compact zones with much higher-than-expected racial segregation. Denver is also racially diverse (30 percent of its residents are white) and residentially segregated (i.e., is about a standard deviation greater than the average school district). Based on the methods and evidence generated in this study, it is highly problematic to claim that Denver's administrators considered the racial composition of residential areas when it delineated its (reasonably compact) zones. Methods that rely solely on attendance zone shape cannot determine whether districts with greater-than-expected levels of attendance zone racial segregation intended to "maximize" school segregation by placing its zones (or schools) strategically within the district.

CONCLUSIONS

Existing research shows that public schools embedded in metropolitan areas has changed little (Stroub and Richards 2013). What is puzzling about the persistence of racial segregation in public schools is the simultaneous decline in residential segregation over this same time period. Indeed, I show that the intensity of racial segregation across residential areas predicts almost all variation in racial segregation across school attendance zones. Given the nearly one-to-one

correspondence between residential segregation and attendance zone segregation, one would expect that public school segregation would have declined at the same pace as residential segregation.

One conceivable way of explaining divergent patterns of school and residential segregation is to suggest that school districts have increasingly resorted to drawing irregularly-shaped attendance zones in order to increase racial segregation above that which would occur if districts simply drew compact zones. Indeed, recent research claims that school attendance zone “gerrymandering has increased substantially over the 1990s” (Richards and Stroub 2015, p. 17) and the alleged increase in gerrymandering may be a force that sustains racial segregation in public schools. The results of this paper do not support this interpretation.

I find that the great majority of school districts delineate reasonably compact attendance zones—and that these compact zones are either indifferent to residential segregation or do little to exacerbate it. In fact, the data show that, on average, school districts with the most irregularly-shaped attendance zones have lower levels of racial segregation than comparable school districts with highly compact attendance areas—even after accounting for residential segregation. These empirical findings are new to the literature on “educational gerrymandering” and stand in stark contrast to studies that argue “gerrymandered” attendance zones “generally segregate” children by race (Richards 2014, p. 1150). Previous studies have the possibility of becoming quite controversial since they suggest school districts violate U.S. Supreme Court rulings:

Troublingly, as with electoral gerrymandering, our analyses underscore the racial/ethnic and, to a lesser extent, socioeconomic character of educational gerrymandering. Our findings are consistent with the argument that

gerrymandering may serve primarily as a means of excluding non-white and poor students from whiter and more affluent schools, in violation of [the U.S. Supreme Court's ruling in] *Keyes* (Richards and Stroub 2015, p. 21).

I argue that the presence of irregularly-shaped zones in 21st Century school districts is not troubling at all—at least not within the sample of large school districts I analyze. Districts with the most irregularly-shaped zones generally have higher levels of racial integration than one would expect given their levels of residential segregation. School district personnel who oversee residentially segregated school districts and who want to reproduce residential segregation (or who are indifferent to residential segregation) can, in most instances, delineate compact attendance zones. This is because the nearest children are more alike racially than other children, and, by definition, compact attendance zones draw children who are nearest to one another. On the other hand, school districts with attendance zones that consist of sprawling, multi-part polygons stretching hither, thither and yon, typically pull students from distant and racially diverse neighborhoods.

School districts serving racially diverse and residentially segregated communities must (quite literally) go to extraordinary lengths to integrate students. Indeed, in a 2007 opinion, a majority of U.S. Supreme Court Justices intuited the usefulness of educational gerrymandering to achieve school integration: “School boards may pursue the goal of bringing together students of diverse backgrounds and races through...drawing attendance zones with general recognition of the demographics of neighborhoods” (*Parents Involved in Community Schools v. Seattle School District No. 1*, 551 U.S. 701 (2007)). This ruling echoed the earlier *Swann v. Charlotte-Mecklenburg Board of Education* (402 U.S. 1 (1970)), which explicitly called for

gerrymandering attendance zones to achieve racial integration. Findings presented in this paper show that school districts must often draw irregularly-shaped school attendance zones to achieve racial (or economic) balance within them and this practice is consistent with the most recent Supreme Court Decision on racial integration in K to 12 public schools.

Recent research shows that reducing school segregation—however that is achieved—may have educational benefits for students of color. While white children generally perform better on academic tests than do children of color—the racial gap in academic achievement is greater in school districts with greater levels of white/non-white segregation (Card and Rothstein 2007; Condron et al., 2013; Reardon et al 2016; Vigdor and Ludwig 2008). While the close association between racial segregation across residential areas and school zones certainly contributes to the lower achievement of non-white children compared with white children, the evidence shows that, on average, school districts do not aggravate the negative effects of residential segregation by delineating irregularly-shaped and highly segregated school attendance zones.

References

- Bartels, Bradley and Ruben Donato. 2009. "Unmasking the School Rezoning Process: Race and Class in a Northern Colorado Community." *Latino Studies* 7(2) 222-249.
- Boyer, William and Edward Ratledge. 2014. *Pivotal Policies in Delaware: From Desegregation to Deregulation*. Lanham, MD: University of Delaware Press.
- Card, David and Jesse Rothstein. 2007. "Racial Segregation and the Black–White Test Score Gap." *Journal of Public Economics*. 91(11):2158-2184.
- Chambers, Christopher and Alan Miller. 2010. "A Measure of Bizarreness." *Quarterly Journal of Political Science* 5(1):27-44.
- Clark, William. 1987. "Demographic Change, Attendance Area Adjustment and School System Impacts." *Population Research and Policy Review*. 6(3):199-222.
- Clotfelter, Charles. 2004. *After Brown: The Rise and Retreat of School Desegregation*. Princeton, N.J.: Princeton University Press.
- College of William & Mary and the Minnesota Population Center. 2011. "School Attendance Boundary Information System ([SABINS](#)): Version 1.0." Minneapolis, MN: University of Minnesota.
- Condrón, Dennis, Daniel Tope, Christina Steidl and Kendralin Freeman. 2013. "Racial Segregation and the Black/White Achievement Gap, 1992 to 2009." *The Sociological Quarterly*. 54(1): 130-157.
- Diem, Sarah, Erica Frankenberg, Colleen Cleary, and Nazneen Ali. 2014. "The Politics of Maintaining Diversity Policies in Demographically Changing Urban-Suburban School Districts." *American Journal of Education*. 120(3):351-389
- Eaton, Susan. 2012. "Not Your Father's Suburb." *One Nation Indivisible*. <http://www.onenationindivisible.org/our-story/not-your-fathers-suburb-race-and-rectitude-in-a-changing-minnesota-community/>
- Ferrari, Silvia and Francisco Cribari-Neto. 2004. "Beta Regression for Modelling Rates and Proportions." *Journal of Applied Statistics* 31: 799–815.
- Fiel, Jeremy. 2013. "Decomposing School Resegregation: Social Closure, Racial Imbalance, and Racial Isolation." *American Sociological Review*. 78(5):828-848.

-
- _____. 2015. "Closing Ranks: Closure, Status Competition, and School Segregation." *American Journal of Sociology*. 121(1):126-70
- Frankenberg, Erica and Gary Orfield. 2012. *The Resegregation of Suburban Schools: A Hidden Crisis in American Education*. Cambridge, Mass.: Harvard Education Press
- Gumas-Dawes, Baris, Myron Orfield and Thomas Luce. 2012. "Dividing Lines: East Versus West in Minneapolis Suburbs." Frankenberg, Erica and Gary Orfield, eds. In *The Resegregation of Suburban Schools*. Cambridge, MA: Harvard Education Press.
- Hannah-Jones, Nikole. 2014. "Lack of Order: The Erosion of a Once-Great Force for Integration." *ProPublica*. May 1. <http://www.propublica.org/article/lack-of-order-the-erosion-of-a-once-great-force-for-integration>
- Hanushek, Eric, John Kain and Steven Rivkin. 2009. "New Evidence about Brown v. Board of Education: The Complex Effects of School Racial Composition on Achievement." *Journal of Labor Economics* 9(4):49-56.
- Hawkins, Beth. 2010. "Eden Prairie School Board to Grapple with Contentious Boundary Plan Tonight." *Minnesota Post*. 11/23/2010. <https://www.minnpost.com/learning-curve/2010/11/eden-prairie-school-board-grapple-contentious-boundary-plan-tonight>
- Hofeller, Thomas and Bernard Grofman. 1990. "Comparing the Compactness of California Congressional Districts Under Three Different Plans: 1980, 1982, and 1984." Pp. 281-288 in *Toward Fair and Effective Representation*, edited by B. Grofman. New York: Agathon.
- Iceland, John. 2009. *Where I Live Now: Immigration and Race in the United States*. Berkeley, CA: University of California Press.
- Keyes v. School District No. 1, Denver, Colorado*. 1973. 413 U.S. 189.
- Kahlenberg, Richard. 2007. *Rescuing Brown v. Board of Education: Profiles of Twelve School Districts Pursuing Socioeconomic School Integration*. Washington, DC: The Century Foundation.
- Hui, Keung. 2014 "Wake County Dropping Use of Nodes in Student Assignment." *The News & Observer*. August 28.

- Lee, Barrett, Glenn Firebaugh, Stephen Matthews, Sean Reardon, Chad Farrell and David O'Sullivan. 2008. "Beyond the Census Tract: Patterns and Determinants of Racial Segregation at Multiple Geographic Scales." *American Sociological Review* 73(5):766-791.
- Leigh, Patricia R. 1997. "Segregation by Gerrymander: The Creation of the Lincoln Heights (Ohio) School District." *The Journal of Negro Education* 66(2):121.
- Massey, Douglas and Nancy Denton, 1992. *American Apartheid: Segregation and the Making of the Underclass*. Cambridge, MA: Harvard University Press.
- McQuillan, Patrick and James Englert. 2001. "Return to Neighborhood Schools, Concentrated Poverty, and Educational Opportunity: An Agenda for Reform." *Hastings Constitutional Law Quarterly*. 28(4): 739-770.
- McMillan, Monique, Sarah Fuller, Zoelene Hill, Kate Duch, and William Darity. 2015. "Can Class-Based Substitute for Race-Based Student Assignment Plans? Evidence from Wake County, North Carolina." *Urban Education*. <http://uex.sagepub.com/content/early/2015/11/26/0042085915613554.full.pdf>
- McDermitt, Kathryn, Erica Frankenberg and Sarah Diem. 2015. "The 'Post-Racial' Politics of Race: Changing Student Assignment Policy in Three School Districts." *Educational Policy*. 29(3):504-554.
- Mickelson, Roslyn, and Martha Bottia. 2010. Integrated Education and Mathematics Outcomes: A Synthesis of Social Science Research. *North Carolina Law Review*. 87(1) 993–1089.
- Mickelson, Roslyn, Martha Bottia, and Richard Lambert. 2013. "Effects of School Racial Composition on K–12 Mathematics Outcomes: A Metaregression Analysis." *Review of Educational Research*. 83(1):121-158.
- Miller, Harvey. 2004. "Tobler's First Law and Spatial Analysis." *Annals of the Association of American Geographers*. 94(2):284-289.
- Niemi, Richard, Bernard Grofman, Carl Carlucci and Thomas Hofeller. 1990. "Measuring Compactness and the Role of a Compactness Standard in a Test for Partisan and Racial Gerrymandering." *The Journal of Politics* 52(4):1155-1181.
- Ong, Paul and Jordan Rickles. 2004. "The Continued Nexus between School and Residential Segregation." *Berkeley Journal of African-American Law & Policy* 6(2):54-70.

- Orfield, Myron. 2015. "Milliken, Meredith, and Metropolitan Segregation." *UCLA Law Review*. 62(2):364-462.
- Orfield, Myron, Baris Gumus-Dawes, Thomas Luce, and Geneva Finn. 2010. "Neighborhoods and School Segregation" Pp. 85-174 in *Region: Planning the Future of the Twin Cities*. Minneapolis, MN: University of Minnesota Press.
- Orfield, Myron and Thomas Luce. 2009. *Region Planning the Future of the Twin Cities*. Minneapolis: University of Minnesota Press.
- Parcel, Toby and Andrew Taylor. 2015. *The End of Consensus: Diversity, Neighborhoods and the Politics of Public School Assignments*. Chapel Hill, NC: The University of North Carolina Press.
- Parents Involved in Community Schools v. Seattle School District*. 2007. 551 U.S. 701.
- Polsby, Daniel and Robert Popper. 1991. "The Third Criterion: Compactness as a Procedural Safeguard against Partisan Gerrymandering." *Yale Law and Policy Review* 9(2):301-353.
- Rader, R.M. 1970. "Demise of the Neighborhood School Plan." *Cornell Law Review*. 55(4): 594-610.
- Reardon, Sean. 2015. "School Segregation and Racial Academic Achievement Gaps." (CEPA Working Paper No.15-12.) Retrieved from Stanford Center for Education Policy Analysis: <http://cepa.stanford.edu/wp15-12>.
- Reardon, Sean, Demetra Kalogrides and Ken Shores. 2016. "The Geography of Racial/Ethnic Test Score Gaps." (CEPA Working Paper No.16-10.) Retrieved from Stanford Center for Education Policy Analysis: <http://cepa.stanford.edu/wp16-10>.
- Reardon, Sean and David O'Sullivan. 2004. "Measures of Spatial Segregation." *Sociological Methodology*. 34:121-162.
- Reardon, Sean and Ann Owens. 2014. "60 Years after *Brown*: Trends and Consequences of School Segregation." *Annual Review of Sociology*. 40(1):199-218.
- Reardon, Sean, Stephen Matthews, David O'Sullivan, Barrett Lee, Glenn Firebaugh, Chad Farrell and Kendra Bischoff. 2008. "The Geographic Scale of Metropolitan Racial Segregation." *Demography*. 45(3):489-514.
- Richards, Meredith. 2014. "The Gerrymandering of School Attendance Zones and the Segregation of Public Schools: A Geospatial Analysis." *American Educational Research Journal*. 51(6):1119-1157.

- Richards, Meredith and Kori Stroub. 2015. "An Accident of Geography? Assessing the Gerrymandering of School Attendance Zones." *Teachers College Record*. 117(7):1-32.
- Rickles, Jordan, Paul Ong and Doug Houston. 2002. *The Integrating (and Segregating) Effect of Charter, Magnet and Traditional Elementary Schools: The Case of Five California Metropolitan Areas*. Working Paper #41. UCLA, School of Public Policy and Social Research. Retrieved from <http://files.eric.ed.gov/fulltext/ED473461.pdf>
- Roscigno, Vincent and Dennis Condon. 2003. "When Busing Ends: Resegregation and Inequality in an Urban School District." Bankston, Carl and Stephen Caldas, eds. *The End of Desegregation?* New York, NY: Nova Science Publishers.
- Samuels, Christina. 2011. "School Boundary Plan Divides Minnesota Suburb." *Education Week*. http://www.edweek.org/ew/articles/2011/10/05/06eden_ep.h31.html
- Saporito, Salvatore and David Van Riper. 2016. "Do Irregularly-Shaped School Attendance Zones Contribute to Racial Segregation or Integration?" *Social Currents*. 3(1):64-83.
- Shaffer, Leah. 2011. "Update: Lawyer for "Yes for Neighborhood Schools" Group Says Lawsuit May be Warranted." *Eden Prairie News*. 03/11/2011. http://www.swnewsmedia.com/eden_prairie_news/news/education/update-lawyer-for-yes-for-neighborhood-schools-group-says-lawsuit/article_d14e8e64-c615-5c7e-b4d4-732ffa2eb06a.html
- Siegel-Hawley, Genevieve. 2013. "Educational Gerrymandering? Race and Attendance Boundaries in a Demographically Changing Suburb." *Harvard Educational Review* 83(4): 580-612.
- Singleton, Glenn. 2013. *More Courageous Conversations about Race*. Thousand Oaks, CA: Corwin, a Sage Company.
- Smith, Kelly. 2010a. "Aiming to Desegregate, Eden Prairie Schools Redraw Lines." *StarTribune*. 9/4/2010. <http://www.startribune.com/aiming-to-desegregate-eden-prairie-schools-redraw-lines/102229224/>
- _____. 2010b. "All Eyes on Eden Prairie School Boundary Vote." *StarTribune*. 12/20/2010. <http://www.startribune.com/all-eyes-on-eden-prairie-s-school-boundary-vote/112163674/>
- _____. 2011. "Eden Prairie School Chief is Leaving 9 Months Early." *StarTribune*. 09/14/2011. <http://www.startribune.com/eden-prairie-school-chief-is-leaving-9-months-early/129807088/>

- Stroub, Kori and Meredith Richards. 2013. "From Resegregation to Reintegration: Trends in the Racial/Ethnic Segregation of Metropolitan Public Schools, 1993–2009." *American Educational Research Journal*. 50(2):497-531.
- Timberlake, Jeffrey. 2015. "Residential Segregation." *The Wiley Blackwell Encyclopedia of Race, Ethnicity and Nationalism*. 1-4.
- Theil, Henri and Anthony Finezza. 1971. "A Note on the Measurement of Racial Integration of Schools by Means of Informational Concepts." *Journal of Mathematical Sociology* 1(2): 187-194.
- Toppo, Greg and Paul Overberg. 2014. "Diversity in the Classroom: Sides Square off in Minnesota." *USA Today*. 11/25/2014. <http://www.usatoday.com/story/news/nation/2014/11/25/minnesota-school-race-diversity/18919391/>
- U.S. Government Accounting Office. 2016. "Better Use of Information Could Help Agencies Identify Disparities and Address Racial Discrimination." (GAO Publication No. 16-345). Washington, DC: U.S. Government Printing Office.
- Vigdor, Jacob and Jens Ludwig. 2008. "Segregation and the Black-White Test Score Gap." *Steady Gains and Stalled Progress: Inequality and the Black-White Test Score Gap*, K. Magnuson and J. Waldfogel, eds. New York: Russell Sage.
- Williams, Sheneka and Erica Frankenberg. 2011. "Using Geography to Further Racial Integration." In Frankenberg & E. DeBray (Eds.), *Integrating Schools in a Changing Society: New Policies and Legal Options for a Multiracial Generation* (pp.223-231). Chapel Hill: University of North Carolina Press.

APPENDIX A

This methodological appendix covers several topics. First, preparing school attendance zones for measure of segregation entails a few nuances, the description of which may benefit future researchers who work with school attendance zone GIS data. In particular, I discuss how populations within school attendance zones are counted so that attendance zone segregation can be measured appropriately. In the next section, I describe how I modify the GIS procedures used in Reardon and O’Sullivan (2004) in construction of spatial segregation indices. In particular, I rely on census block centroids to estimate the residential locations of children (whereas previous researchers estimate the residential locations of children by distributing them over a 50 by 50 meter raster). I also defined local environments based nearest children up to some predetermined, fixed population threshold (whereas the literature typically defines local environments based on equal area).

Preparing Attendance Zones for Measuring Segregation

The relationship between school attendance zones and the schools that serve them are a bit counterintuitive. For example, a single school might serve two different geographic areas (i.e., attendance zones) at different grade levels. For example, Los Angeles School District has several dozen schools that serve one zone for grades K to 5 and a different zone for grades 6 to 8. There are variations of this basic relationship at all grade levels across hundreds of school districts. This necessitates using a single grade when constructing a database of attendance zones. A related issue is the creation of population counts for school attendance zones. Some zones “overlap,” as in a Venn diagram. While the children who live in the non-overlapping portion of

an attendance zone are served by a single school, children who live in the overlapping portion are assigned to one of the schools.

The relationship between attendance zones and schools presents something of a challenge. Most researchers are interested in examining the population characteristics (e.g., racial composition) of the geographic area served by each school in a district. Since some schools serve the same geographic area, it is important to avoid counting the children in these geographic areas multiple times when calculating segregation indices. It is a premise of many segregation indices (such as H) that complete integration is reached when every geographic area within a school district has the same racial composition as the entire district. It is thus essential that the racial composition of the district—and the sums of racial groups across all of its attendance zones—are the same. To achieve this, the number of children in each sub-area of an attendance zone is divided by the number of schools that serve that sub-area. These weighted counts are summed to each school. This procedure preserves the population totals for school attendance zones in a district.

Calculating Segregation across Attendance Zones

I use Theil's multigroup entropy index (Theil and Finezza 1971) to measure racial segregation across attendance zones within school districts. To calculate H , it is necessary to first calculate the racial diversity—or entropy—of an entire school district:

where P is the proportion of children in the school district consisting of racial classification r .

Entropy is then calculated for each attendance zone within the school district:

where i indexes attendance zones. After calculating the racial diversity of the school district and each zone within it, H is calculated:

In the formula above, t is the total children in zone i , and T is total children in the school district.

Calculating Spatial Segregation using Population Thresholds

Formulas for measuring spatial segregation are from Reardon and O’Sullivan’s 2004 publication and the general concept of “local environment” is also theirs. In the main body of this paper, I calculate spatial segregation for residential areas using the multigroup, spatial information segregation index () based on local environments of a pre-determined, proximity-based population thresholds of 2,000 children (abbreviated). Specifically, for each child (called a focal child) I determine the racial composition of the nearest 2,000 children.

Building local environments based on proximity-based population thresholds requires estimating the residential locations of children. I assume that children live at the center of their census block. (I use block centroids created by the U.S. Census Bureau since they are more accurate than those created by commercial software). Hereafter I use the symbol to designate a census block point. Assuming that all children live at is reasonable since most blocks within the school districts included in my study are relatively small in geographic area and population size. The median area of populated blocks is about nine acres and the median number of children per populated block is about 12.

Conceptually, is similar to creating a school attendance zone (containing 2,000 children) around each . An extreme example can illustrate the usefulness of with respect to predicting racial segregation in school attendance zones. Suppose a child lives in a densely populated area of a school district that has many high-rise buildings with many housing units. Such a housing complex will cover a relatively small geographic area but contain a relatively large number of children. It is likely that attendance zones in this area will be relatively small in geographic area as well. By contrast, the same school district may contain regions with low densities of children. Think of expansive areas of single-family dwelling units situated on multi-acre parcels; in such places, attendance zones are larger so that they contain sufficient numbers of children. Deviations in population densities within (and between) districts make it necessary to define local areas based on based on population thresholds rather than creating local environments of a predetermined area. (Future researchers may want to vary the size of the population threshold for individual school districts so that population threshold matches the average number of children in a particular school district's attendance zones.)

The first step of calculating the multigroup, population-based spatial information segregation index is creating local environments based on *proximity-based population thresholds*. To do this, I create a “near table” in Geographic Information System (GIS) software that measures the distance between each and all other points (hereafter, in the district. Then, for each , I use statistical software to create a running sum of the population characteristics (in this case, for each racial group) in the area immediately surrounding each , beginning with the population characteristics in , the nearest , the next nearest and so on until the running sum

reaches a predetermined population threshold. Once the population characteristics of each p are calculated, the proportion of racial group r in each p 's local environment is calculated:

$$(A1)$$

where p_r is the proportion of children of racial group r in the local environment surrounding point p . Further, n_p is the total number of children in all points p closest to a given p (and including p in p). Since I am using population thresholds of 2,000 children, the sum of n_p will typically be 2,000 children—although this figure may vary slightly since more than one child can reside at any p . (I use the local environment closest to 2,000 children; distributing children over a small scale raster would reduce—but not eliminate—the possibility of creating local environments with $<$ or $>$ 2,000 children. The little added accuracy of distributing children across a raster would vastly increase computational expense.)

Once p_r is calculated, the racial entropy (i.e., racial diversity) of the local environment surrounding each p is calculated:

$$(A2)$$

where M is the number of racial groups for which segregation is assessed and serves as the base of the log.

H_p can be calculated as follows:

$$(A3)$$

where the racial entropy of every local environment surrounding p (i.e., H_p) is weighted by the total number of children in p (i.e., n_p) and then summed across all p . This sum is divided by the

product of the total population in the school district (T) and the racial entropy (E) of the entire school district, calculated as:

(A4)

Values of D_i generally range from zero to one (although negative values are theoretically possible). Values of one represent complete segregation. This occurs when each child's local environment is comprised of a single racial group. Complete segregation could occur in a school district that is divided by wide topographic barriers (e.g., several rivers) and all members of different racial groups live on different sides of those barriers. Values of zero equal perfect integration (i.e., the racial composition of each local environment is the same as a school district as a whole).

Calculation Spatial Segregation using Equal Area.

With one exception, all of the formulas for calculating spatial segregation based on equal area of fixed radii remain the same as they do for spatial segregation based on population thresholds. The one difference is that, for local environments based on equal areas, the distance between each focal child and every other child is weighted (such that closer children are given more weight than those who are farther). I do this to maintain consistency in the literature. Following Reardon and O'Sullivan (2004), I modify formula A1 above so that includes a spatial weight (abbreviated as w_{ij}):

(A5)

where w_{ij} is the biweight kernel:

(A6)

Spatial Segregation using Equal Area Versus Proximity-Based Population Thresholds

In the main body of the paper I show that spatial measures of segregation derived from proximity-based population thresholds are conceptually and empirically better than local environments based on equal areas—providing that the goal is to predict segregation in geographic units that contain roughly equal numbers of people (e.g., elementary, middle and high school attendance zones or U.S. Congressional Districts). The chief advantage of using a proximity-based population thresholds to measure local environments is that it eliminates the effects of geographic scale when trying to predict the relationship between residential segregation and attendance zone segregation. The geographic scale (e.g., square miles) of attendance zones varies greatly. For example, the mean square miles of attendance zones in Anchorage, Alaska is 135.2 (with a minimum and maximum of 1.4 and 2,416 square miles, respectively). By contrast, in Chicago the mean square miles of attendance zones is 1.1 square miles (with a minimum and maximum of .06 and 20.9 square miles, respectively). Yet, school attendance zones in both school districts contain roughly equal numbers of children. In Anchorage and Chicago the number of children per attendance zone is 1,430 and 1,595, respectively.

In order to build local environments that serve as realistic proxies for school attendance zones, it is necessary to ensure that every local environment has the same number of children. The examples of Anchorage and Chicago help explain this. As a general rule, white children cluster together residentially (as do non-white children). For example, there are areas in Anchorage that are occupied primarily by non-white children while other areas are occupied

primarily by white children. If local environments of fixed areas are delineated around each child, this could overstate racial segregation. Each local area could conceivably consist of a couple of hundred children, all of whom are of the same race. Yet, the average square miles Anchorage's attendance zones is 135. These zones could conceivably be racially integrated since they contain children from racially distinct (but geographically distant) residential areas. So, it is better to create local environments that contain roughly equal numbers of children (and let the square miles per local environment vary).

Chicago presents the opposite challenge. Like many cities, Chicago's residential areas are highly segregated. Yet, unlike most residential areas within Anchorage, Chicago's residential areas are densely populated and closer together—for example, a high-rise apartment complex with 1,500 white children could be located within a mile of a high rise apartment complex with 1,500 non-white children. If local environments of fixed area are delineated around each child, this could understate racial segregation since these local environments could contain 3,000 children. Yet, most of the white children live in a “white neighborhood” and most of the non-white children live in a “non-white neighborhood.” As in Anchorage, it is better to create local environments that contain roughly equal numbers of children (and let the square miles per local environment vary).

The results in Table A1 are consistent with the reasoning of building local environments using population thresholds rather than fixed areas. A bivariate regression model based on fixed areas produces an R^2 value of .71 while that based on proximity-based population thresholds produces an R^2 value of .93. When the scale of segregation is added to these bivariate models, R^2

for the area-based model increases from .71 to .81. Yet, an area-based segregation model that accounts for the geographic scale of racial segregation still performs less well than that based on

Table A1. Regression Models Predicting White/Non-White Segregation Across School Attendance Zones

	Proximity-Based Segregation Model 1		Proximity-Based Segregation Model 2		Area-Based Segregation Model 1		Area-Based Segregation Model 1	
	<i>b</i>	<i>se</i>	<i>b</i>	<i>se</i>	<i>b</i>	<i>se</i>	<i>b</i>	<i>se</i>
	.908*	.015	.944*	.017				
			-.027*	.007				
					.775*	.028	.591*	.028
							.206*	.017
Constant	.000	.003	.012	.004	-.021*	.006	-.081*	.007
R-Squared	.927		.931		.713		.809	

N=304. All residential segregation measures compute spatial inequality between white and non-white children. *p<.001

a population model; specifically, the R^2 of a model based population thresholds is .93 while it is .81 based on fixed areas. This indicates that predicting racial segregation across areal units of roughly the same population size using proximity-based population thresholds accounts for population density within a region—whereas an approach that relies on local environments based on fixed area does not.

APPENDIX B

An intriguing question is whether segregation should be measured using more than two groups—(i.e., among Non-Hispanic blacks, non-Hispanic whites, and all other racial groups). To address this question—and to insure that results are robust across various specifications—I provide regression results and accompanying scatterplots for three-group segregation. Results

show that multi-group residential segregation drives multi-group attendance zone segregation. Moreover, school districts with many irregularly-shaped attendance zones are more racially integrated than districts with many compact attendance zones (a finding consistent with the segregation measured using white and non-white children).

Table B1. Regression Models Predicting Multi-Group Racial Segregation Across School Attendance Zones

	Model 1			Model 2			Model 3		
	<i>b</i>	<i>se</i>	<i>beta</i>	<i>b</i>	<i>se</i>	<i>beta</i>	<i>b</i>	<i>se</i>	<i>beta</i>
	.914	.015*	.961	.949	.018*	.998	.912	.022*	.959
				-.026	.007*	-.066	-.019	.007	-.049
Irregularity of Zones							-.143	.020*	-.112
Irregularity Census Tracts							.105	.056	.030
Percent Children who are Black							.038	.010*	.072
Percent Children who are White							.027	.009	.070
Percent of Families who are Poor							.007	.017	.008
Population Density (in 1000s)							.000	.000	-.025
Median Square Miles of Zones							.000	.000	-.028
Constant	.004	.002		.017	.004*		.019	.011	
R-Squared	.924			.927			.939		

N=304. All segregation measures compute spatial inequality among black, white and all other racial groups.

*p<.001

Figure B1. Attendance Zone Segregation by Residential Segregation, Outliers Shown in Red