American Educational Research Journal
December 2014, Vol. 51, No. 6, pp. 1119–1157
DOI: 10.3102/0002831214553652

The Gerrymandering of School Attendance Zones and the Segregation of Public Schools: A Geospatial Analysis

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In this study, I employ geospatial techniques to assess the impact of school attendance zone "gerrymandering" on the racial/ethnic segregation of schools, using a large national sample of 15,290 attendance zones in 663 districts. I estimate the effect of gerrymandering on school diversity and school district segregation by comparing the racial/ethnic characteristics of existing attendance zones to those of counterfactual zones expected in the absence of gerrymandering. Results indicate that the gerrymandering of attendance zones generally exacerbates segregation, although it has a weaker effect on the segregation of Whites from Blacks and Hispanics. Gerrymandering is particularly segregative in districts experiencing rapid racial/ethnic change. However, gerrymandering is associated with reductions in segregation in a substantial minority of districts, notably those under desegregation orders.

KEYWORDS: gerrymandering, attendance zones, segregation, geospatial analysis

In 1968, the Kerner Commission famously concluded that America was "moving towards two societies, one black, one white—separate and unequal" (U.S. National Advisory Commission on Civil Disorders, 1968). In the decades following the Kerner report, the Fair Housing Act of 1968 and other achievements of the civil rights era ushered in substantial improvements in residential segregation by race and ethnicity (Charles, 2003; Clark, 2002; Iceland, Weinberg, & Steinmetz, 2002; Logan, Stults, & Farley, 2004; Timberlake & Iceland, 2007). Despite the strong association between where students live and where they attend school, segregation trends for public schools have been much less promising than residential trends

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(Fiel, 2013; Frankenberg, Lee, & Orfield, 2003; Frankenberg & Orfield, 2012; G. Orfield, Kucsera, & Siegel-Hawley, 2012; Reardon & Owens, in press; Reardon, Yun, & Eitle, 2000; Stroub & Richards, 2013).

As a result of these trends, in the decades following *Brown*, schools were consistently less segregated than the neighborhoods in which they were situated, suggesting that schools played an important role in ameliorating social inequities by mitigating the association between patterns of residence and school attendance (Reardon & Yun, 2001). However, as residential segregation has continued to decline despite increases or, at best, plateaus in school segregation, schools are now often as segregated as the neighborhoods in which they are situated (Ong & Rickles, 2004), or even *more* segregated than their neighborhoods (M. Orfield, 2002; Reardon & Yun, 2001; Saporito & Sohoni, 2006, 2007; Sohoni & Saporito, 2009). This suggests that schools, which served as mechanisms of racial integration after *Brown*, now are not only reproducing existing patterns of residential segregation, but may also be actively facilitating segregation beyond residential patterns.

This shift in the role of schools from an instrument of integration to a mechanism for segregation underscores the importance of understanding the causal mechanisms by which public schools perpetuate stratification by race and ethnicity. Accounts of changes in public school segregation generally fall into two camps. First, a large body of work has considered the impact of eroding legal support for desegregation efforts and the dismantling of desegregation policies (Frankenberg et al., 2003; Logan, 2002; G. Orfield, Bachmeier, James, & Eitle, 1997; G. Orfield & Monfort, 1992; G. Orfield, Schley, Glass, & Reardon, 1993; G. Orfield & Yun, 1999; Reardon et al., 2000; Reardon & Yun, 2001). Consistent with this perspective, several studies have empirically linked the end of desegregation and grants of unitary status to subsequent resegregation in schools (An & Gamoran, 2009; Lutz, 2011; Reardon, Grewal, Kalogrides, & Greenberg, 2012).

Second, an emerging body of work has examined the expanding role of school choice as a mechanism of stratification beyond residential location, documenting associations between choice policies and racial/ethnic stratification, including charter schools (Bifulco & Ladd, 2007; Renzulli & Evans, 2005), magnet schools (Saporito, 2003), private schools (Saporito & Sohoni, 2006, 2007), voucher programs (Brunner, Imazeki, & Ross, 2010), intradistrict choice/open enrollment (Holme & Wells, 2008), and interdistrict choice (Holme & Richards, 2009). Despite the growing emphasis on public school choice, however, roughly four fifths of public school students still attend the traditional school to which they are geographically assigned (National Center for Education Statistics [NCES], 2009).

An alternative, albeit related, explanation for increasing rates of school segregation vis-à-vis residential segregation focuses on the role of educational boundaries themselves. According to this perspective, schools may be more segregated than residential patterns would suggest because

educational institutions have established inequitable boundaries that allow schools to maximize the inequities of their surrounding areas. By carving up a geographic area in a manner that is nonneutral with respect to the race of the student population, educational boundaries may have lasting and profound consequences for equity in American schools. Despite their profound effect on the educational opportunities of the vast majority of public school students, by determining who attends which schools and districts, educational boundaries have received scant empirical attention.

The bulk of empirical research on the effects of educational boundaries on segregation has focused on the indirect effects of boundaries on segregation. Drawing on Tiebout's (1956) theory of public choice, these perspectives generally argue that educational boundaries facilitate segregation through their effects on residential choices or "foot voting." Individuals choose where to live as a function of their individual preferences and the public services offered by a given jurisdiction. Applied to the educational context, because individuals choose where to live in part on the basis of their neighbors—often opting to live near people more similar to them in terms of race/ethnicity—as well as on the basis of the school that their child will attend, educational boundaries hold the potential to segregate (Clotfelter, 2004; Holme & Finnigan, in press; M. Orfield, 2002; Weiher, 1991). Consistent with this perspective, research has demonstrated that metropolitan areas that are more "fragmented," in that they have more educational boundaries per capita, are more segregated than metropolitan areas with relatively fewer educational boundaries to signal residential sorting (Bischoff, 2008). It should be emphasized that such accounts generally explain school segregation as a function of residential segregation along school boundaries. As such, they contribute little to understanding the differences in segregation between schools and their neighborhoods.

This study adopts an alternative perspective on the role of educational boundaries in perpetuating the problem of educational segregation and the residential-educational segregation gap. Rather than focusing on the indirect role that educational boundaries play in facilitating residential decisions, I examine the direct effect that one important type of educational boundary, school attendance zones, plays in structuring the equity of schools. According to this perspective, by carving up the area of a district in ways that are not racially neutral, "gerrymandered" boundaries may provide an additional layer of stratification that exacerbates existing patterns of residential segregation. Alternately, however, gerrymandered boundaries may serve to ameliorate residential segregation.

Attendance Zone Gerrymandering

Ample anecdotal and historical evidence suggests that the gerrymandering of school attendance zones was a common practice for school districts to

achieve greater homogeneity in response to racial diversity or change. Despite the absence of de jure segregation, northern school districts often responded to the skyrocketing Black population in the 1940s and 1950s by achieving de facto segregation by drawing their school boundaries to maintain racial separation (Clark, 1987; Leigh, 1997). As Gunnar Myrdal observed, "[s]chool boundaries . . . are usually set at the boundary of the white and Negro neighborhoods" (Sugrue, 2009, p. 187). Jacobs (1998) describes how Columbus, Ohio, used school siting, as well as gerrymandered and noncontiguous district boundaries, to maintain a "dual system" in the 1970s. Although such efforts were deemed unconstitutional in *Keyes v. Denver School District No. 1* (1973), they were only justiciable if it could be demonstrated that they resulted from discriminatory intent, often a difficult evidentiary burden (Douglas, 1995). As a result, it has been reported that school districts in the post-*Brown* era responded to desegregation pressures by locating schools and drawing their attendance boundaries to intensify segregation and undermine integration efforts (Clark, 1987; G. Orfield & Eaton, 1997). Evidence from current zoning proceedings and case studies suggests that districts continue to draw racially inequitable boundaries (League of Women Voters, 2008; M. Orfield & Luce, 2009; Siegel-Hawley, 2013; Vaznis, 2009).

However, attendance zone boundaries may not always be gerrymandered to segregate—indeed, it is both logically and historically feasible that they may be gerrymandered for the purpose of achieving greater integration. Drawing race-conscious boundaries for the purposes of remedying past discrimination was endorsed by the Supreme Court in *Swann v. Charlotte-Mecklenburg Board of Education* (1971), a ruling that reinforced the irregular boundaries and busing strategies of the desegregation era. Proponents of integration have often decried the attempt to return to "neighborhood schools" (Frankenberg et al., 2003; G. Orfield & Eaton, 1997), arguing that the irregular boundaries and busing systems that are still employed by many districts as legacies of the desegregation era are necessary to promote racial diversity in highly segregated areas. Indeed, in the only direct examination of the effects of educational gerrymandering, Clark (1987) concluded that gerrymandering of attendance zone boundaries in Topeka in the 1950s and 1960s were either neutral or desegregative in nature. More recently, in his deciding opinion in *Parents Involved v. Seattle School District No. 1* (2007), which rendered unconstitutional the use of student race in voluntary student assignment plans, Justice Kennedy endorsed the adoption of race-conscious districting plans as a means of achieving racially balanced schools. Thus, while race-conscious attendance zone boundaries may be responsible in part for the resegregation of schools relative to neighborhoods, in other contexts they may also have the positive effect of ameliorating severe patterns of residential segregation.

The anecdotal and historical nature of prior evidence on gerrymandering in education highlights the necessity of empirical evidence examining the direct role that attendance zone boundaries play in perpetuating or ameliorating racial inequities. Fortunately, advances in geospatial techniques, coupled with recent release of spatial data on educational boundaries, including school attendance boundaries via the School Attendance Boundary Information System (SABINS), discussed at length below, have rendered empirical investigation of inherently spatial issues such as gerrymandering more methodologically tractable (Hogrebe & Tate, 2012).

In this vein, recent research directly examining contemporary public school attendance zones (Richards & Stroub, in press) has demonstrated that attendance zone boundaries are highly gerrymandered. Using a large national sample of 23,945 attendance zones from SABINS, Richards and Stroub computed geospatial measures of gerrymandering derived from the electoral literature. Using these metrics, Richards and Stroub concluded that attendance zones are only slightly less gerrymandered than legislative districts. However, the researchers found significant variability in gerrymandering across contexts. Attendance zones of schools established since 1991 are substantially more gerrymandered than those of schools of schools established earlier, suggesting that attendance zone gerrymandering may be worsening over time. Gerrymandering was also particularly severe in school districts in the formerly de jure segregated South, in suburban and rural districts outside the urban core, and in districts experiencing rapid increases in racial/ethnic diversity. Interestingly, gerrymandering was inversely related to segregation, such that districts with higher levels of segregation were less gerrymandered than less segregated districts.

Thus, empirical evidence on the gerrymandering of contemporary attendance zones indicates that school attendance zone gerrymandering is severe, and may be worsening over time. Moreover, it underscores the racial dimension of gerrymandering. However, such correlational evidence cannot substantiate any causal claims linking gerrymandering to the racial/ethnic of segregation of schools. In particular, it cannot distinguish between affirmative and segregative gerrymandering. That gerrymandering is particularly severe in districts with low levels of segregation may indicate that gerrymandering serves to integrate, and that boundaries are drawn affirmatively in ways that reduce the racial/ethnic disparities among schools, as found by Clark (1987). Alternately, it may suggest that gerrymandering is employed as a segregative mechanism for subverting higher levels of residential integration, consistent with historical and contemporary accounts (M. Orfield & Luce, 2009; Siegel-Hawley, 2010; Vaznis, 2009). Thus, where districts are already highly residentially segregated by race, gerrymandering may not be employed to achieve racial segregation in schools.

Purpose of the Study

Prior research suggests that public school attendance zones are highly gerrymandered into irregular shapes. However, this correlational evidence does not provide direct evidence of the consequences of this gerrymandering for the racial/ethnic equity of schools. Historical evidence suggests that this gerrymandering may be segregative in nature, employed to intensify segregation and undermine integration efforts. Alternately, gerrymandering may be an affirmative legacy of the desegregation era, serving to enhance integration in districts that are residentially segregated. In this study, I seek to disentangle these effects, providing initial evidence regarding whether and in what contexts gerrymandering serves to segregate or integrate students by race and ethnicity. Toward that end, this study addresses the following primary research questions, assessing the effects of gerrymandering at the school and district levels:

Research Question 1. How does school attendance zone gerrymandering affect the racial/ethnic diversity of schools?

Research Question 2. How does school attendance zone gerrymandering affect the racial/ethnic segregation of school districts?

Prior evidence suggests that the severity of attendance zone gerrymandering varies widely across geographic and demographic contexts. As such, in addition to overall effects, I examine how the impact of gerrymandering on racial/ethnic segregation differs across contexts, paying particular attention to the dimensions of variability identified in prior research. I attend to differences in the impact of gerrymandering by school district locality (i.e., urban, suburban, town, rural), by state history of de jure segregation, and by school district desegregation status (i.e., under active desegregation order, dismissed desegregation order, never under order). In addition, I examine how the effects of gerrymandering vary depending on the level of racial/ethnic and socioeconomic change of the school district.

Gerrymandering as Student Exchange

In considering the issue of educational gerrymandering, this study is guided by a framework of "student exchange" adapted from the political realm. Previous research on educational boundaries has focused on the role that boundaries play in the residential choices of individuals; by contrast, the student exchange framework adopted in this study focuses on how schools choose students through irregular boundaries that include certain students at the expense of others. According to the student exchange framework, the delineation of attendance zone and district boundaries provides a mechanism for segregating schools beyond existing patterns of

residential segregation. In addition, the student exchange framework also acknowledges the potentially affirmative role that irregular attendance zones may play in increasing diversity and maintaining integration by weakening the link between residency and schools. Below, I formalize the framework of student exchange, situating it in the literature on electoral gerrymandering.

As Fischel (2009) has noted, the gerrymandering of educational boundaries may be viewed not as an "accident of geography," but as the manifestation of an intentional process engineered to include certain students at the expense of others. In this vein, Angel and Parent (2011) have conceptualized electoral gerrymandering as the spatial manifestation of a process of "voter exchange," which creates irregular boundaries by including voters in certain geographic areas and excluding voters in others. Gerrymandering may be defined from a voter exchange perspective as follows:

> The distortion of an election district shape from a more compact to a less compact one by exchanging voters of one party (or minority group) *living close by* for voters of another party (or minority group) *living further away*. (Angel & Parent, 2011, p. 96).

In a process of voter exchange through electoral gerrymandering, the boundaries of an otherwise geographically cohesive and efficient voting district are manipulated to achieve a more advantageous composition of voters, in terms of political affiliation or race, by excluding some nearby and replacing them with voters living farther away (*League of United Latin American Citizens v. Perry*, 2006). Boundary distortion and irregularity is therefore an artifact of the process of "foraging" for desirable voters and "expelling" undesirable voters (Angel & Parent, 2011). As Justice Stevens argued in his dissenting opinion in *Vieth v. Jubelirer* (2004), the shape of a district ipso facto is evidence of the process of electoral gerrymandering, in that "a district's peculiar shape might be a symptom of an illicit process in the line drawing purpose." Of course, district shapes may diverge from optimality for a variety of reasons, including congruence with geographic boundaries, such as irregular coastlines or islands, and coterminity with other jurisdictional boundaries. However, it may be argued that the extent to which a district diverges from regularity, after accounting for these effects, may be interpreted as evidence of a process of voter exchange.

Mirroring the "voter exchange" perspective on electoral gerrymandering, I adopt a "student exchange" perspective to understanding school attendance zone gerrymandering. Figure 1 illustrates how the process of student exchange is manifested in the gerrymandering of attendance zone boundaries. According to this perspective, the irregularity of attendance zones reflects a process of student exchange wherein certain students nearby are excluded in lieu of other students residing farther away. The construction of attendance zones is therefore an exclusionary and inclusionary process

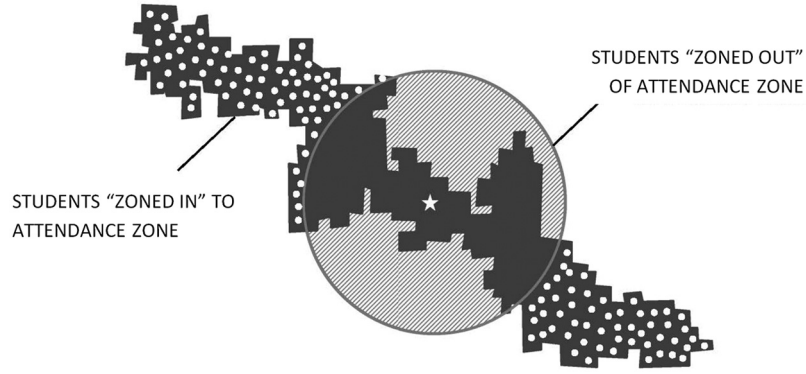

Figure 1. **Student exchange process as a function of school attendance zone gerrymandering. The white star depicts location of the attendance zone's school. The dark gray figure depicts the existing, gerrymandered attendance zone. The circle depicts the "natural," compact attendance zone that would be expected in the absence of gerrymandering. The hatched area indicates students "zoned out" by gerrymandered district. The dotted area indicates students "zoned in" by gerrymandered district. The solid gray area indicates students in the "core zone."**

Source. Figure adapted from Angel and Parent (2011).

that "zones in" certain students and "zones out" others. Where gerrymandering is segregative, it would zone out more racially/ethnically dissimilar student in favor of more similar students. However, gerrymandering may also be affirmative, zoning out more racially/ethnically similar students in favor or more dissimilar students.

Method

Analytic Technique

As Figure 1 demonstrates, the student exchange framework is premised on the assumption that we can compare an attendance zone's actual boundary to the "natural" boundary that an attendance zone would be expected to take in the absence of gerrymandering. This boundary may then be compared to the current boundaries to determine the extent to which the attendance zone has been gerrymandered to exchange students. In this study, I exploit this framework to assess the effect of school attendance zone gerrymandering on the racial/ethnic diversity of schools (Research Question 1) and the segregation among schools within districts (Research

Question 2). I employ geospatial techniques to compare the racial/ethnic characteristics of students residing in existing school attendance zones to those residing in natural zones that would be expected in the absence of gerrymandering.

In illustrating the student exchange framework above, I operationalize the natural zone of a school as a circle equal in land area to the actual attendance zone, centered on the geographic location of the focal school. Circles are theoretically instructive because they represent the most compact possible geometric shapes (Angel & Parent, 2011), in that (a) they maximize the area contained within a perimeter of given length and (b) they minimize the perimeter for an area of given size. In considering the natural attendance zone for a given school, the circle is ideal because it does not perpetrate any exchange of students—all residents living in the circular zone are closer to the school than all residents not in the circular zone. Thus, the equal land area circle may be interpreted as the natural zone that would exist if its boundaries had not been intentionally manipulated to exchange students.

The equal land area circle provides a theoretical ideal to which existing attendance zones may be compared to assess the effects of gerrymandering on an *individual* attendance zone. However, circular attendance zones do not constitute a feasible districting solution. While it is possible for a single school attendance zone to be circular, it is impracticable for all attendance zones in a district to be circular. Indeed, drawing circular attendance zones of equal land area around each school location would result in a pattern of attendance zones that would overlap in certain areas and exclude other areas. Thus, it would result in a set of attendance zones that fail to serve many students in the district, while providing several school options to other students.

Voronoi Polygonal Attendance Zones

Given the limitations of circles as a feasible redistricting solution, I adopt an alternative method of constructing the natural attendance zones of each school in the sample. Drawing on computational geometry, I define the natural attendance zone for each school as the Voronoi polygon that corresponds to that school. At a basic level, a Voronoi diagram partitions the space around a set of focal points, such that each point is contained in a single polygonal zone. The boundaries of each Voronoi polygon are defined such that all areas within a given focal point's polygon are closer to that focal point than to any other focal point (Aurenhammer, 1991; Miles & Maillardet, 1982; Okabe, Boots, Sugihara, & Chiu, 2000). Applied to the context of schools, a Voronoi diagram for each school district is constructed around all of the schools in the district that serve students of the same grade level. The Voronoi polygonal attendance zone for each school is defined such that all areas served by a given school's polygonal attendance zone are closer to

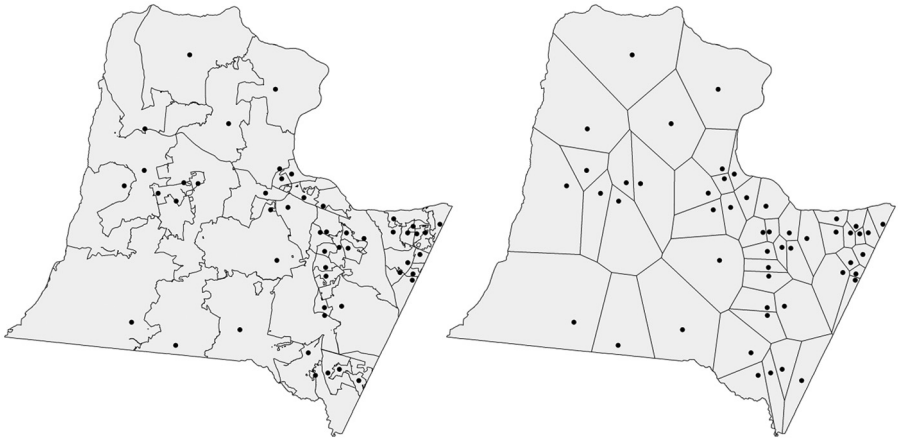

Figure 2. **School attendance zones. Left panel shows actual school attendance zones for schools in Loudoun County Public Schools, a suburban district outside Washington, D.C. Right panel shows Voronoi zones constructed around each school. School locations are marked with black dots.**

that school than to any other school. Figure 2 provide an illustration of Voronoi polygonal attendance zones constructed for a suburban district in the South. The actual attendance zones for the district are also depicted for comparison purposes.

In particular, Voronoi polygons have two desirable features that make them useful for examining attendance zone gerrymandering. First, Voronoi polygons are completely convex—as such, they have no "nooks" or "crannies" that carve out certain areas. Thus, although they are not as geometrically compact as circles (i.e., there are areas in each polygon that are farther away from the focal school than areas not in the focal school), they are by definition not gerrymandered. As such, they provide a reasonable counterfactual attendance zoning scheme to examine the gerrymandering of attendance zones. Second, as noted above, Voronoi polygonal attendance zones have the property that all areas served by a given attendance zone polygon are closer to that school than to any other school. As a result, Voronoi polygonal attendance zones are optimally efficient in that they minimize the distance between each student and the school to which they are assigned.

It is important to note, however, that Voronoi polygonal attendance zones have certain limitations. First, the Voronoi algorithm is insensitive to population density of a district. As such, Voronoi attendance zones may incorporate more or fewer students than the current attendance zone. However, given that the placement of schools is generally sensitive to

population density, in that there are more schools in more densely populated areas of districts, zoning based on school location should generally respect population density of the district. Moreover, our current school system has many schools that are underenrolled (especially in urban areas such as Detroit and Chicago) and many that are overenrolled. Thus, it is not clear in all instances that the geographic area currently occupied by an attendance zone is desirable in terms of the ideal population for a school given its capacity. Relatedly, the Voronoi technique develops attendance zones around existing school locations. As such, it neglects another potentially important way in which schools may be gerrymandered: school siting, whereby school districts may choose to locate their schools in ways that hinder or promote segregation.

In addition, although they minimize the linear distance between each student's residential location and their school of attendance, Voronoi attendance zones do not necessarily minimize student travel time to school. Indeed, travel networks may be configured such that students live closer to one school, but can travel to another school more easily. Given limitations in analyzing large-scale road network data and a lack of information regarding what mode of travel students use or what forms of transportation are provided by each district, constructing zones that were sensitive to travel time was deemed prohibitive for the purpose of this study.

Relatedly, Voronoi attendance zones are insensitive to geographic boundaries that may serve as barriers to travel, such as interstates, rivers, coastlines, and mountains. Again, it is possible that a student lives close to a school, but would have to cross an interstate or body of water to reach it. It should be noted, however, that pronounced geographic boundaries often occur at school district boundaries, rather than within districts. However, it is not clear to what extent geography plays a major role in impeding travel within districts. In addition, it is difficult to assess the extent to which geographic features are truly barriers or whether they are often symbolic boundaries that maintain separation between historically distinct communities.

Finally, Voronoi attendance zones are also insensitive to political boundaries, which abound in the fragmented American metropolis (Briffault, 1996). Thus, Voronoi zones may cross the boundaries of smaller municipalities located within school districts (e.g., townships, cities). However, it is important to emphasize that many of these political boundaries (e.g., county boundaries, county subdivisions, metropolitan boundaries) are generally larger than school district boundaries. As such, they should have little effect on the boundaries of attendance zones. However, it is possible that some larger school districts contain multiple jurisdictions, which may affect attendance zone boundaries. The fragmentation of U.S. political boundaries, which often have multiple, overlapping layers, particularly in the Northeast and Midwest, coupled with limitations on spatial data for these

entities, makes adjusting for these boundaries a complex task that falls outside the purview of this study.

The Effect of Gerrymandering on Racial/Ethnic Diversity and Segregation

Using the actual school attendance boundaries and the Voronoi attendance zones for each school, I estimate the effects of gerrymandering on the racial/ethnic diversity of schools and the segregation of school districts by comparing the characteristics of students residing in actual attendance zones to those residing in their corresponding Voronoi attendance zones. First, I estimate the effect of gerrymandering on school attendance zone racial/ethnic diversity by comparing the racial/ethnic diversity of each school attendance zone to the composition of its corresponding Voronoi attendance zones. Second, I estimate the effect of gerrymandering on school district racial/ethnic segregation by comparing the racial/ethnic segregation among the actual attendance zones in each school district to the racial/ethnic segregation among the Voronoi attendance zones in each school district.

School Racial/Ethnic Diversity

Although there are a number of different indices capturing racial/ethnic diversity, this study employs Simpson's diversity index, which is particularly appealing owing to its intuitive interpretation. Simpson's index may be interpreted as the probability that two students in a given school belong to different racial/ethnic categories. Specifically, Simpson's index is calculated as follows,

$$D = 1 - \sum_{i=1}^{r} p_i^2$$

where r is the number of racial/ethnic groups in the district and p_i refers to a particular racial/ethnic group's proportion of the school or district population. Values of the Simpson index range from 0 to 1, where 0 means that all students belong to the same racial/ethnic group (i.e., perfect homogeneity) and 1 means that all students belong to different racial/ethnic groups (i.e., perfect heterogeneity; for a detailed discussion of Simpson's index, see White, 1986).

For the purpose of this study, I assess five dimensions of racial/ethnic diversity, computing each measure for each school attendance zone and its corresponding Voronoi polygon. I calculate a measure of total multiracial diversity, addressing the diversity among students of five racial/ethnic categories (i.e., Hispanic/Latino, non-Hispanic Asian, non-Hispanic Black, non-Hispanic White, and non-Hispanic Other). In addition to multiracial diversity, I calculate a measure of non-White diversity, as well as three dual-group measures capturing Black-White, Hispanic-White, and Asian-White diversity.

School District Racial/Ethnic Segregation

I calculate the racial/ethnic segregation of each school district using Theil's entropy index of segregation (*H*), which is increasingly common in the segregation literature and is preferred to other measures (such as exposure and isolation) owing to its flexibility as a measure of multigroup or dual-group segregation and its ability to distinguish segregation from racial/ethnic composition (see Logan & Oakley, 2004; Reardon & Firebaugh, 2002). Theil's index is measure of the "evenness" with which students of different racial/ethnic groups are distributed across the schools of a district. Specifically, the Theil index quantifies how racially/ethnically diverse schools are, on average, relative to the overall racial/ethnic diversity of their metropolitan area (Reardon et al., 2000). First, the entropy (or diversity) of each school in the district as well as the district as a whole is calculated as follows,

$$E = \sum_{i=1}^{r} (p_i) ln \left(\frac{1}{p_i} \right)$$

where r is the number of racial/ethnic groups in the population and p_i refers to each racial/ethnic group's proportion of the school or district population. Theil's entropy index is then calculated as a weighted average deviation in the entropy between each school and the district as a whole, as follows,

$$H = \sum_{i=1}^{n} \left[\frac{t_i(E - E_i)}{ET} \right]$$

where n is the total number of schools in the district, t_i is the total population of school i, T is the total district population, and E_i and E represent the entropy of the school and district, respectively. The Theil index varies from 0 to 1, where 0 means that all schools have the same composition as the metro area (i.e., perfect integration) and 1 means that all schools only contain students of a single, unique racial/ethnic group (i.e., perfect segregation; Iceland, 2004). Readers may refer to Reardon and Firebaugh (2002) for more detailed information regarding *H*.

I compute five dimensions of racial/ethnic segregation among each school district's actual and Voronoi attendance zones, corresponding to the five dimensions of diversity above. I compute a measure of total multiracial segregation among all five racial/ethnic categories. I also calculate a measure of segregation among non-White students and three dual-group measures capturing Black-White, Hispanic-White, and Asian-White segregation.

Contextual Covariates

In addition to examining the overall effect of gerrymandering on school diversity and school district segregation, I conduct a variety of disaggregations to examine dimensions of variability in the effect of gerrymandering. As

discussed above, prior research (Richards & Stroub, in press) has found that the severity of school attendance zone gerrymandering varies significantly across school and district contexts, finding that gerrymandering is particularly severe in districts located in the formerly de jure segregated South; in suburban, town, and rural areas (vs. cities); and in districts experiencing rapid racial, but not socioeconomic, change. However, it is unclear from this correlational evidence whether the gerrymandering in these contexts is segregative or integrative. For example, it is unclear whether the more severe gerrymandering in school districts in the formerly de jure segregated South worsens segregation, or whether it is an affirmative legacy of the busing systems of the desegregation era. Toward that end, the analysis examines variability in the effect of gerrymandering on segregation along these dimensions.

Data Sources

School Attendance Boundary Information System (SABINS)

Actual school attendance zone boundaries for the 2009–2010 school year were obtained from SABINS, a National Science Foundation–funded repository of spatial attendance zone boundaries maintained by the College of William and Mary and the Minnesota Population Center (2011). Because districts supplied their boundaries to SABINS voluntarily, the SABINS database contains a nonrandom sample of the population of U.S. attendance zones. However, SABINS contains a large sample of public school attendance zones. SABINS contains attendance zone data for all states and the District of Columbia, with the exception of Hawaii, and includes all attendance zones for the states of Delaware, Minnesota, and Oregon.

For the 2009–2010 school year, the SABINS database contains approximately 213,000 attendance zone boundaries. Because districts have different attendance zones for different grade levels (e.g., a student may be in a different attendance zone for first grade than for third grade), SABINS attendance zones are grade-level-specific. Thus, many schools have multiple attendance zone boundaries. In total, SABINS contains 2009–2010 attendance boundaries of over 38,000 schools—roughly 40% of the population of traditional U.S. public schools. Because the SABINS database has complete data for many of the largest districts in the country and complete data for several metropolitan areas, the schools in SABINS account for nearly 54% of all U.S. public school students (roughly 2.5 million of the 4.7 million enrolled in traditional public schools nationally (calculations by author using SABINS and NCES CCD data).

Census 2010 Summary File 1

To compute the racial/ethnic characteristics of each actual and Voronoi attendance zone in the sample, Census 2010 block-level demographic

estimates of the number of children under the age of 18 by race/ethnicity were spatially linked to each attendance boundary. The census block is the smallest unit of analysis at which the Census Bureau collects and tabulates decennial census data (U.S. Census Bureau, 2012). While the geographic area of a census block may vary widely, in urban areas it is typically the size of a single city block. On average, there were approximately 208 blocks in each school attendance zone in the sample.

Although not all individuals under the age of 18 are enrolled in public schools (i.e., they may attend private or charter school, be too young for school, have graduated, or have dropped out of school), it may be used as a proxy for the characteristics of public school students residing in each block. Students were classified into one of five racial/ethnic categories paralleling those collected by the National Center for Education Statistics Common Core of Data (NCES CCD): Hispanic/Latino, non-Hispanic Asian, non-Hispanic Black, non-Hispanic White, and non-Hispanic Other.

NCES CCD 2009–2010

School geographic coordinates (i.e., latitude and longitude) for each school attendance zone from the SABINS sample were obtained from the NCES CCD and used to create the Voronoi attendance zones for each district. Each school in the sample was classified by locality (i.e., city, suburb, town, rural) according to CCD designations. In addition, each school was classified according to whether it is located in one of the 17 states that were historically subject to de jure segregation (i.e., Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia). Measures of school district demographic change were calculated using free/reduced-price lunch and race/ethnicity data from the 1999–2000 and 2009–2010 NCES CCD.

School District Desegregation Order

Data on school districts' historical and current desegregation status were obtained from a database cataloging school district desegregation order information produced by Reardon and colleagues in 2011. In the database, Reardon et al. document the status of districts ever subject to court-ordered desegregation plans. Districts are classified as under active desegregation order, formerly under a desegregation order that was dismissed, or never under desegregation order. It should be noted that the Reardon et al. database is not inclusive of all districts in the United States, they collected data only for medium- to large-sized districts and does not include data on districts that voluntarily desegregated, or districts required to desegregate by the Department of Health, Education, and Welfare.

Sample

Several filters were applied to the full SABINS sample of school attendance zones to arrive at the final analytic sample for this analysis. Because the attendance zones of elementary schools are often the "building blocks" of middle and high school attendance zones, in that they generally feed into middle school and high-school attendance zones (with some exceptions), the irregularities in middle school and high school boundaries are often aggregations of the irregularities in multiple smaller elementary school boundaries. Thus, I sought to limit the analysis to focus exclusively on elementary school attendance zone boundaries. However, as noted above, because districts have different attendance zones for different grade levels, SABINS attendance zones are grade-level-specific. As such, "elementary schools" were operationalized as schools with first grade attendance zone boundaries in SABINS.

Second, the SABINS sample was filtered to include only school districts located in metropolitan statistical areas as defined by the U.S. Census. Third, only attendance zones that serve a single school were retained for analysis (thus excluding attendance zones with open enrollment patterns). Fourth, because school districts with only one attendance zone have attendance zone boundaries that are coterminous with district boundaries, these zones do not permit any boundary manipulation independent of district boundaries and are therefore not of empirical interest. Thus, school attendance zones located in districts with only one attendance zone were also excluded from analysis. Finally, because the Voronoi technique involves redrawing attendance zones for all schools in a district, and cannot be conducted on a single school in isolation, the analysis was limited to only those schools located in districts reporting all of their first grade attendance zones.

Application of these filters yielded a final analytic sample of 15,290 school attendance zones in 663 school districts, 154 metropolitan statistical areas, and 43 states. Table 1 demonstrates that the attendance zones in the sample account for 47% of the 32,371 schools in the population of interest (i.e., schools serving first grade, located in metropolitan areas with two or more schools). In addition, the student population in the sample composes 55% of the total population of students attending schools in the population of interest. Table 1 summarizes the demographic and geographic characteristics of the analytic sample of attendance zones compared to population values. The table reveals that the analytic sample is poorer (57% vs. 51%) and less White (38% vs. 48%) than the comparable population. This demographic profile may reflect, in part, the overrepresentation of urban schools in the sample versus the population (51% vs. 39%). In addition, schools in the sample were more likely to be located in the formerly de jure segregated South than schools in the population (48% vs. 36%).

Table 1
Characteristics of Analytic Sample of Attendance Zones Versus Population

	Analytic Sample of Attendance Zones		School Population[a]	
	M	*SD*	*M*	*SD*
% free/reduced-price lunch	56.7	30.2	51.4	30.2
Racial/ethnic composition				
% White	38.4	31.5	47.6	33.6
% Black	23.9	29.0	19.0	26.2
% Hispanic	30.2	29.9	26.1	28.9
% Asian	5.9	9.1	5.8	11.0
% Other	1.7	4.3	1.5	12.1
Students per school	580.6	223.4	500.6	232.8
	n	%	*n*	%
State de jure segregation history				
In de jure South	7,372	48.2	11,595	35.9
Not in de jure South	7,918	51.8	20,689	64.1
Desegregation status				
Active	38	5.7	110	3.3
Dismissed	99	14.9	202	6.0
Never	46	6.9	114	3.4
Unknown	480	72.4	2,957	87.4
Locality				
Urban	7,806	51.1	12,485	38.6
Suburban	5,389	35.2	13,162	40.7
Town	310	2.0	1,530	4.7
Rural	1,785	11.7	5,179	16.0
Total *n*				
Students	8,872,604		16,197,302	
Schools	15,290		32,371	
Districts	663		3,383	
Metropolitan areas	154		325	
States	43		51	

[a]Population of operational U.S. public schools serving first grade students located in metropolitan areas not classified as magnet or charter schools.

Results

How Does Attendance Zone Gerrymandering Affect the Racial/Ethnic Diversity of Schools?

In the first phase of analysis, I examine the effect of attendance zone gerrymandering on the racial/ethnic diversity of individual schools. Table

Table 2
Average Racial/Ethnic Diversity of Actual and Voronoi Attendance Zones

	Actual Attendance Zones		Voronoi Attendance Zones		Difference (Actual – Voronoi)	
	M	*SD*	*M*	*SD*	Percentage Point	Effect Size (*SD*)
Multiracial	0.461	0.188	0.465	0.185	−0.003	−0.018*
Non-White	0.472	0.209	0.479	0.206	−0.008	−0.037*
Black-White	0.224	0.168	0.223	0.166	0.001	0.004*
Hispanic-White	0.276	0.153	0.277	0.152	−0.002	−0.013*
Asian-White	0.174	0.153	0.176	0.151	−0.003	−0.019*

Note. Table reports average racial/ethnic diversity values for the actual and Voronoi attendance zones for each school in the sample. Effect size estimated as the standard deviation unit difference in diversity between the actual and Voronoi zones.
*Comparison significant at $p < .001$.

2 reports results of analyses comparing the racial/ethnic diversity of actual attendance zones to the racial/ethnic diversity of the Voronoi attendance zones. To provide a standardized frame of reference for interpreting the magnitude of the differences in diversity, the final column of the table presents the deviations in standard deviation units, computed by dividing the difference between the means of diversity for actual and Voronoi attendance zones by the pooled standard deviation of the two zones (Rosnow & Rosenthal, 1996).

For four of the five dimensions of racial/ethnic diversity, actual attendance zones are significantly less diverse than the Voronoi attendance zones. However, the magnitude of these effects is relatively small. In terms of multiracial diversity, attendance zones are on average 0.02 standard deviations less diverse than Voronoi zones. Gerrymandering has a more pronounced effect on non-White diversity: Attendance zones are on average 0.04 standard deviations less diverse than Voronoi zones. Gerrymandering has a somewhat less pronounced effect between Whites and Hispanics (0.01 *SD* units), and between Whites and Asians (0.02 *SD* units). Interestingly, actual attendance zones are significantly more Black-White diverse than the Voronoi zones. Again, however, the magnitude of the effect is fairly small. On average, attendance zones are 0.02 standard deviations more Black-White diverse than the Voronoi zones.

Variability in Effects

While overall gerrymandering is associated with slight decreases in the racial/ethnic diversity of schools, Table 3 reveals that there is considerable

variability in the magnitude of the effect. Across all five racial/ethnic dimensions of diversity, a slight majority of attendance zones are less diverse than their corresponding Voronoi zones, ranging from 57% for non-White diversity to 51% for Black-White diversity. Thus, although attendance zones are on average more Black-White diverse than their Voronoi zones, gerrymandering reduces Black-White diversity for a slight majority of attendance zones, suggesting that the average effect reported in Table 2 may be driven by a small number of extreme cases.

The distribution reveals that although the average difference in diversity between actual and Voronoi zones is fairly small, gerrymandering is associated with very large decreases in racial/ethnic diversity in a nontrivial number of schools. Indeed, gerrymandering is associated with a large reduction in diversity of greater than 0.3 standard deviations in 9% to 12% of attendance zones (depending on the racial/ethnic dimension of diversity). For another 15% to 19% (depending on the racial/ethnic dimension), gerrymandering is associated with moderate decreases in diversity ranging from 0.1 to 0.3 standard deviations. However, it should also be emphasized that a large minority of actual attendance zones are more diverse than corresponding Voronoi zones. Moreover, gerrymandering is associated with large increases in diversity of greater than 0.3 standard deviations in 5% to 11% of schools, and with moderate increases in diversity of 0.1 to 0.3 standard deviations in 13% to 15% of schools.

Taken together, results of the school-level analyses examining the effect of gerrymandering on school diversity suggest that attendance zones on average serve to suppress the racial/ethnic diversity of schools. However, they also underscore the wide variability across contexts, with many schools experiencing increases in diversity attributable to gerrymandering. In the second phase of analysis, I assess the net effects of these school-level changes in composition on the overall segregation of school districts and examine how these effects vary across geographic and demographic contexts.

Case Illustration

Figure 3 provides an example of an actual school attendance zone located in a suburban district in the South to illustrate how gerrymandering serves to reduce the diversity of attendance zones. Figure 3a depicts the actual attendance zone of the school in gray, overlaid by the outline of the Voronoi attendance zone that was constructed for that school. The figure reveals that the zone is moderately gerrymandered, with numerous indentations and concavities on the northeast side. In the southwest side, the attendance zone has a "hole," which has been zoned into a different school. In Figures 3b, 3c, and 3d, both attendance zones are shown layered on top of the census blocks for the area, shaded by the proportion of Hispanics, Blacks, and Whites in each block, respectively.

Table 3

Distribution of Difference in Diversity Between Actual and Voronoi Attendance Zones

	Multiracial		Non-White		Black-White		Hispanic-White		Asian-White	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Actual attendance zones less diverse than Voronoi										
0.5+ *SD*s less diverse	760	5.0	564	3.7	917	6.0	899	5.9	896	5.9
0.3 to 0.5 *SD*s less diverse	883	5.8	826	5.4	838	5.5	886	5.8	762	5.0
0.1 to 0.3 *SD*s less diverse	2,846	18.6	2,834	18.5	2,260	14.8	2,562	16.8	2,308	15.1
0 to 0.1 *SD*s less diverse	3,709	24.3	4,439	29.0	3,739	24.5	3,628	23.7	4,071	26.7
Actual attendance zones more diverse than Voronoi										
0 to 0.1 *SD*s more diverse	3,391	22.2	3,870	25.3	3,467	22.7	3,432	22.5	3,508	23.0
0.1 to 0.3 *SD*s more diverse	2,348	15.4	2,017	13.2	2,153	14.1	2,253	14.7	2,171	14.2
0.3 to 0.5 *SD*s more diverse	719	4.7	481	3.1	901	5.9	804	5.3	782	5.1
0.5+ *SD*s more diverse	631	4.1	255	1.7	1,011	6.6	823	5.4	751	4.9

Figure 3. **Example of school attendance zone boundaries gerrymandered to reduce diversity. School location indicated by star. Panel (a) shows actual school attendance zone in dark gray, overlaid with hatched gray ''natural'' Voronoi school attendance zone. Panels (b) through (d) show census blocks in actual and Voronoi zones shaded by the percentage of students in block who are Hispanic (b), Black (c), and White (d).**

Figure 3a reveals that the area of the actual attendance zone has relatively few Hispanic children. However, the areas zoned out by the attendance zone, particularly those in the northeast, tend to have higher proportions of Hispanic children. Notably, the "hole" that has been zoned out of the southwest part of the attendance zone has a particularly high proportion of Hispanic students. By contrast, the areas that have been zoned into the attendance zone generally have fewer Hispanic students, with the exception of a single block in the southwest corner of the zone. Figure 3c reveals a similar exclusionary pattern for areas with regard to Black students, as boundary irregularity in the Northeast serves to exclude areas with higher proportions of Black students. The exclusionary nature of the attendance zone is perhaps most clear when examining the proportion of White students in each block. Figure 3d demonstrates that the areas zoned into the attendance zone in the southeast are predominantly White, while the areas zoned out in the north and northeast are predominantly non-White. The shading reveals a fairly clear discontinuity in the proportion of Whites corresponding to the boundary of the school attendance zone.

As a result of the exchange of students perpetrated by this attendance zone, the zone is significantly more White, more Asian, less Black, and less Hispanic than its corresponding Voronoi zone. As a result, the diversity of the actual attendance zone is significantly lower than the diversity of its corresponding Voronoi zone (0.45 vs. 0.53). Thus, for this school, gerrymandering is associated with a large 0.43 standard deviation reduction in diversity, placing it among the 11% of attendance zones with a multiracial effect size of greater than 0.3 standard deviations.

How Does Attendance Zone Gerrymandering Affect School District Racial/Ethnic Segregation?

The prior analysis demonstrates that at the level of the individual attendance zone, gerrymandering serves to slightly suppress school diversity. However, it also underscores the wide variability in effects, with nearly as many schools experiencing decreases in diversity attributable to gerrymandering as experiencing increases. Thus, at the district level, decreases in diversity in one school may be offset by increases in diversity in another school. In the second phase of analysis, I estimate the aggregate effect of gerrymandering on the segregation of schools, computing measures of segregation among actual and Voronoi attendance zones in each district.

Table 4 compares the average level of racial/ethnic segregation among the actual attendance zones to the average level of segregation among Voronoi zones in the sample of districts. Again, to provide a standardized frame of reference for interpreting the magnitude of the differences in segregation, the final column of the table presents the differences in standard deviation units.

Table 4
Average School District Racial/Ethnic Segregation for Actual and Voronoi Attendance Zones

	Actual Attendance Zones		Voronoi Attendance Zones		Difference (Actual – Voronoi)	
	M	*SD*	*M*	*SD*	Percentage Point	Effect Size (*SD*)
Multiracial	0.070	0.073	0.068	0.070	0.002	0.025*
Non-White	0.063	0.063	0.060	0.061	0.003	0.055*
Black-White	0.109	0.125	0.107	0.121	0.002	0.018*
Hispanic-White	0.079	0.088	0.078	0.086	0.001	0.015*
Asian-White	0.066	0.070	0.060	0.065	0.006	0.088*

Note. Table reports average level of segregation among the actual and Voronoi attendance zones in each district in the sample. Segregation calculated using Theil's entropy index. Effect size estimated as the standard deviation unit difference in segregation between actual and Voronoi zoning schemes.
*Comparison significant at $p < .001$.

Across all five dimensions of racial/ethnic segregation, the segregation among actual attendance zones is significantly higher than the segregation among Voronoi attendance zones. While the magnitude of these effects is relatively small, they are comparable to or larger than the magnitude of effects for school diversity. Indeed, multiracial segregation among actual attendance zones is, on average, 0.03 standard deviations higher than multiracial segregation among Voronoi zones. The difference in segregation among non-Whites and between Whites and Asians are particularly pronounced. In terms of non-White segregation, the segregation among actual attendance zones is 0.06 standard deviations higher than segregation among Voronoi zones. In terms of Asian-White segregation, the segregation among actual attendance zones is 0.09 standard deviations higher than segregation among Voronoi zones. While the magnitude of effects were smaller for Black-White and Hispanic-White segregation (0.02 *SD* units for both), they suggest that gerrymandering also serves to worsen segregation between Blacks and Whites and between Hispanics and non-Hispanic Whites.

The relatively larger magnitude of the effects of gerrymandering on segregation suggest that the relatively small effects of gerrymandering on the diversity of individual districts are compounded, yielding a cumulative effect of gerrymandering that has a more meaningful impact on segregation. While it is difficult to articulate what a standard deviation unit increase in segregation of 0.06, for example, means in terms of students' experience of segregation, it is useful to contextualize the magnitude of these effects in terms of the magnitude of the changes in segregation over the past decades. Educators and

Table 5

Distribution of Differences in District Segregation Among Actual and Voronoi Attendance Zones

	Multiracial		Non-White		Black-White		Hispanic-White		Asian-White	
	n	%	*n*	%	*n*	%	*n*	%	*n*	%
Actual attendance zones more segregated than Voronoi										
0.3+ *SD*s more segregated	22	3.3	42	6.4	33	5.0	29	4.4	69	10.5
0.1 to 0.3 *SD*s more segregated	144	21.8	188	28.5	127	19.2	122	18.5	183	27.7
0 to 0.1 *SD*s more segregated	267	40.5	212	32.1	240	36.4	247	37.4	213	32.3
Actual attendance zones less segregated than Voronoi										
0 to 0.1 *SD*s less segregated	147	22.3	131	19.8	156	23.6	171	25.9	121	18.3
0.1 to 0.3 *SD*s less segregated	54	8.2	67	10.2	70	10.6	59	8.9	58	8.8
0.3+ *SD*s less segregated	26	3.9	20	3.0	34	5.2	32	4.8	16	2.4

researchers have expressed considerable concern regarding the resegregation of schools that occurred over the 1990s (Frankenberg et al., 2003; Frankenberg & Orfield, 2012; G. Orfield et al., 2012; Reardon et al., 2000; Reardon & Owens, 2014). In a recent study of segregation trends, Stroub and Richards (2013) found that metropolitan multiracial segregation increased by 0.07 standard deviations between 1993 and 1998 (from 0.300 to 0.307), after which it started to gradually decline. As such, the differences in segregation between actual and Voronoi attendance zones are only slightly smaller in magnitude than the increases in total segregation observed over the 1990s.

Thus, district-level findings regarding the effect of gerrymandering on segregation suggest that overall, gerrymandering has a small but significant segregative effect. In addition, while there is significant variability in effects, the segregative effect of gerrymandering on school district segregation is relatively more consistent than the effects on diversity for individual schools. Across all five racial/ethnic dimensions of segregation, segregation among actual attendance zones is higher than segregation among Voronoi attendance zones for a substantial majority of school districts. Indeed, gerrymandering is associated with increases in multiracial segregation for more than 65% of districts. Moreover, gerrymandering is associated with increases in segregation for more than 60% of districts on all other racial/ethnic dimensions of segregation. Again, the distribution reveals that although the average difference in segregation among actual and Voronoi districts is fairly modest, gerrymandering is associated with increases in segregation of more than 0.1 standard deviations for 23% to 38% of districts (depending on the racial/ethnic dimension of segregation).

Interestingly, however, there is a substantial minority of school districts for which gerrymandering is associated with relatively substantial decreases in segregation. Indeed, in 11% to 16% of districts, school district gerrymandering is associated with a decrease in segregation of greater than 0.1 standard deviations. I conducted a post hoc outlier analysis examining the desegregation status of school districts in the subset of districts for which attendance zones are more than 0.3 standard deviations less segregated than their Voronoi districts. Analysis revealed that a large proportion of the districts with integrative attendance zones are currently subject to court-ordered desegregation. Indeed, while only 6% of the analytic sample is currently under desegregation order, districts under active desegregation orders account for 23% of the districts that are more than 0.3 standard deviations less segregated than their Voronoi zones (6 of 26). Similar patterns were detected for the other racial/ethnic dimensions of segregation.

Contextual Variation

I conduct supplemental analyses examining sources of variability in the effect of gerrymandering on segregation, seeking to identify how the

segregative and integrative effect of gerrymandering varies across geographic and demographic contexts. As noted previously, recent research has found that attendance zone gerrymandering is particularly severe in districts located in the formerly de jure segregated South; in suburban, town, and rural areas (vs. cities); and in districts experiencing rapid racial, but not socioeconomic, change. In addition, historical evidence, bolstered by the outlier analysis conducted in the previous section, has suggested that gerrymandering may be used affirmatively in districts with a history of desegregation orders. As such, I structure my analyses around these factors. Table 6 reports the unadjusted mean standard deviation unit differences in segregation between district segregation among actual and Voronoi attendance zones, disaggregated by school district geographic and demographic contextual variables.

De Jure Segregation and Desegregation Status

Historical evidence suggests that gerrymandering may have been used affirmatively in the South and in districts under desegregation orders as a means of achieving integration. Although prior research has found that attendance zones in the South are substantially more gerrymandered than attendance zones outside of the South, analyses reveal that Southern attendance zones are not significantly more gerrymandered to segregate than attendance zones in the rest of the United States.

However, more targeted analyses examining the relationship between a school district's history of desegregation order and the extent to which it is segregated to gerrymander reveal an interesting pattern. Across four of the five dimensions of segregation, school districts currently under desegregation orders were generally less gerrymandered to segregate than school districts never under desegregation order or whose desegregation status is unknown, although these differences are only significant for multiracial, Black-White, and Hispanic-White segregation. The difference was particularly pronounced for Black-White segregation: school districts currently under desegregation order have attendance zones that are 0.12 standard deviations less gerrymandered to segregate Blacks and Whites than districts never under desegregation order or whose desegregation status is unknown. Moreover, on three of the five racial/ethnic dimensions of segregation, school districts currently under desegregation orders were not only less gerrymandered to segregate—they were gerrymandered to integrate. Indeed, school districts currently under court-ordered desegregation have actual attendance zones that are 0.04 standard deviations less multiracially segregated, 0.09 standard deviations less Black-White segregated, and 0.02 standard deviations less Hispanic-White segregated than their Voronoi zones.

Districts that were formerly under desegregation orders, but which have been released from court order, evince a different pattern. In terms of

Table 6

Standardized Difference in Segregation Among Actual and Voronoi Attendance Zones by District Characteristics

	Multiracial		Non-White		Black-White		Hispanic-White		Asian-White	
	Effect Size (*SD*)	*SD*	Effect Size (*SD*)	*SD*	Effect Size (*SD*)	*SD*	Effect Size (*SD*)	*SD*	Effect Size (*SD*)	*SD*
State de jure segregation history										
In de jure South	0.031	0.220	0.059	0.192	0.025	0.321	0.035	0.253	0.112	0.315
Not in de jure South	0.021	0.150	0.053	0.165	0.015	0.186	0.004	0.180	0.074	0.194
District desegregation order										
Active	−0.040[a]	0.263	0.027	0.189	−0.092[b]	0.321	−0.015[b]	0.252	0.151	0.239
Dismissed	0.049[b]	0.215	0.054	0.208	0.003[c]	0.254	0.064[a]	0.233	0.114	0.198
Unknown/never	0.025[a]	0.162	0.057	0.168	0.029[a]	0.234	0.009[b]	0.201	0.078	0.253
District locality										
Urban	0.048	0.175	0.075	0.140	0.043	0.215	0.040	0.223	0.125[a]	0.219
Suburban	0.021	0.168	0.050	0.179	0.012	0.253	0.008	0.196	0.081[b]	0.247
Town	0.005	0.053	0.016	0.079	0.034	0.069	0.008	0.055	−0.024[b]	0.094
Rural	−0.014	0.243	0.035	0.228	−0.012	0.278	−0.006	0.260	0.050[b]	0.299
District demographic change										
Δ multiracial diversity										
Decline to very low growth (<1%)	0.033[a,b]	0.142	0.063[a,b]	0.165	0.006[b]	0.124	0.010	0.181	0.073[b]	0.198
Low (2% to 9%)	−0.004[b]	0.180	0.031[b]	0.174	−0.022[b]	0.236	−0.002	0.215	0.054[b]	0.149
Moderate (10% to 16%)	0.011[b]	0.153	0.035[b]	0.137	−0.003[b]	0.186	0.008	0.179	0.057[b]	0.163
High (17% to 24%)	0.007[b]	0.246	0.037[b]	0.200	−0.019[b]	0.268	0.019	0.284	0.072[b]	0.277
Very high (>24%)	0.071[a]	0.159	0.104[a]	0.167	0.113[a]	0.329	0.036	0.178	0.182[a]	0.355

(continued)

Table 6 **(continued)**

	Multiracial		Non-White		Black-White		Hispanic-White		Asian-White	
	Effect Size (*SD*)	*SD*	Effect Size (*SD*)	*SD*	Effect Size (*SD*)	*SD*	Effect Size (*SD*)	*SD*	Effect Size (*SD*)	*SD*
Δ % free/reduced-price lunch										
Decline (<0%)	0.013	0.131	0.042	0.163	0.014	0.199	0.004	0.141	0.041	0.234
Low (0% to 0.5%)	0.042	0.213	0.086	0.180	−0.007	0.217	0.035	0.244	0.117	0.207
Moderate (0.5% to 1%)	0.034	0.161	0.046	0.154	0.021	0.190	0.017	0.183	0.089	0.201
High (1% to 2%)	0.011	0.205	0.034	0.170	0.001	0.194	−0.001	0.264	0.083	0.207
Very high (>3%)	0.018	0.180	0.046	0.188	0.047	0.388	0.014	0.208	0.126	0.382

Note. Effect sizes represent standard deviation unit differences between segregation of actual and Voronoi attendance zones. Superscripts indicate significant differences at $p < .05$. Coefficients with the same alphabetic superscript do not differ significantly from each other.

multiracial, Black-White, and Hispanic-White segregation, districts released from desegregation orders are more segregatively gerrymandered than districts currently subject to active desegregation order. Indeed, districts that have been released from desegregation orders have actual attendance zones that are 0.09 standard deviations more multiracially segregated, 0.10 standard deviations more Black-White segregated, and 0.08 standard deviations more Hispanic-White segregated than districts that remain under active desegregation order. Although attendance zones formerly under desegregation orders are more gerrymandered to segregate than districts never under desegregation order in terms of multiracial and Hispanic-White segregation, districts whose desegregation orders have been dismissed are slightly less gerrymandered to segregate Blacks from Whites than districts never under desegregation order.

District locality. Previous research has demonstrated that gerrymandering is particularly severe in suburban, town, and rural areas, whereas urban districts have relatively more regular and compact boundaries. However, that for four of the five measures of segregation, the effect of gerrymandering on segregation is not significantly related to a school district's locality. Thus, school districts on the periphery of metropolitan areas are no more gerrymandered to segregate than school districts inside urban cores. Indeed, across all five dimensions of segregation, urban school districts are more gerrymandered to segregate, although the differences are only statistically significant for Asian-White segregation.

District demographic change. Prior research has suggested that gerrymandering is particularly severe in areas experiencing rapid racial/ethnic change (Richards & Stroub, in press), and that segregative gerrymandering of boundaries may occur in response to rapid diversification (M. Orfield & Luce, 2013). Table 6 reports the average standard deviation unit difference in segregation between actual and Voronoi attendance zones for school districts as a function of their growth in racial/ethnic diversity over the past decade. Districts are classified into quintiles reflecting declines to very low growth, low growth, moderate growth, high growth, and very high growth in racial/ethnic diversity.

Analyses reveal that segregative gerrymandering is positively related to racial/ethnic change. Across four of the five racial/ethnic dimensions of segregation, districts with very high growth in their multiracial diversity have attendance zones that are more gerrymandered to segregate than districts with more stable racial/ethnic compositions. Indeed, districts experiencing very high increases in racial/ethnic diversity of greater than 24% are on average 0.06 standard deviations more gerrymandered to multiracially segregate, 0.07 standard deviations more gerrymandered to segregate non-Whites, 0.12 standard deviations more gerrymandered to segregate Blacks and Whites,

and 0.13 standard deviations more gerrymandered to segregate Asians and Whites than districts with moderate growth in diversity.

Interestingly, there is a somewhat bimodal relationship between change in school district diversity and the segregative effect of gerrymandering. In terms of multiracial segregation and segregation among non-Whites, districts experiencing very high rates of racial/ethnic change were not significantly more gerrymandered to segregate than districts experiencing declines or very low increases in diversity.

Previous research found that the severity of gerrymandering is unrelated to the level of socioeconomic change in a district. This analysis suggests that socioeconomic change is also unrelated to the segregative or integrative nature of gerrymandering. Indeed, the difference in segregation between actual and Voronoi attendance zones did not vary depending on the change in the proportion of students qualifying for free- or reduced-price lunch in a district. It should be noted that the vast majority of sampled districts experienced only small changes in their proportion of economically disadvantaged students over the past decade: the difference between the lowest and highest quintiles was less than 4 percentage points. Moreover, it should be emphasized that free- and reduced-price lunch status is generally considered a poor measure of socioeconomic status (Harwell & LeBeau, 2010), which may fail to capture broader economic shifts.

Summary and Case Illustration

In this study, I find that the irregular shapes of attendance zones generally serve to worsen segregation beyond the natural Voronoi zones that would be expected in the absence of gerrymandering. While gerrymandering has a relatively small effect on the diversity of individual schools, these are compounded into small but meaningful effects on segregation at the school district level. Interestingly, however, analysis revealed that gerrymandering has a relatively larger effect on segregation among non-Whites and between Whites and Asians, and a smaller effect on segregation between Whites and Blacks and Whites and Asians.

Findings also underscore the wide variability in the effects of gerrymandering across contexts. Indeed, gerrymandering serves to integrate in 30% to 40% of districts, depending on the racial/ethnic dimension of segregation. Gerrymandering is generally less segregative or integrative in school districts that are currently under desegregation orders and is often more segregative in districts that have been released from their desegregation orders than in districts never subject to desegregation orders. Moreover, gerrymandering is particularly segregative in districts experiencing rapid increases in diversity, although it also has a particularly strong segregative effect in some districts with relatively stable racial/ethnic compositions.

To underscore the geographic and demographic dynamics of segregative gerrymandering, consider the case of Loudoun County Public Schools (LCPS) in Virginia, shown in Figure 2. LCPS is a sprawling suburban district outside of Washington, DC. Like many school districts in Virginia, LCPS was forced to adopt a desegregation plan in the 1960s; however, it was granted unitary status in 2006 (Causey & Claypool, 2010). Over the past decades Loudoun County has experienced dramatic economic and social changes, shifting from a predominantly White, rural district to a diversifying outer-ring suburb. Indeed, over the past decade alone, the number of schools in the district nearly doubled, from 47 to 80. While the district is highly affluent, the proportion of students eligible for free- or reduced-price lunch doubled from 8% to 16% between 2001 and 2011. At the same time, the proportion of Whites in the district declined by 20 percentage points (from 78% to 58%), while the proportion of Hispanic and Asian students more than doubled (7% to 15% and 6% to 15%, respectively). As a result of these demographic shifts, LCPS's multiracial diversity increased by 23 percentage points (from 0.38 to 0.61).

Loudoun County, therefore, represents an outer-ring suburban district, which was recently released from its desegregation order, and which is experiencing rapid racial/ethnic diversification. As Figure 2 reveals, it also has attendance zones that are highly gerrymandered into irregular shapes, particularly in the more densely populated eastern portion of the district. Like other districts that have been released from their desegregation orders and have experienced rapid racial/ethnic change, the gerrymandering of LCPS's attendance zones serves to worsen the segregation of its first grade schools. Indeed, analyses suggest that, compared to its Voronoi zones, LCPS's actual attendance zones are 0.08 standard deviations more multiracially segregated, 0.09 standard deviations more non-White segregated, and 0.27 standard deviations more Asian-White segregated. Interestingly, mirroring national trends, gerrymandering has a negligible effect on Black-White segregation (0.01 *SD*s). It should be emphasized, however, that Black students account for only a relatively small share (9%) of the student population in LCPS.

Discussion

Previous research on the impact of educational boundaries on racial/ethnic equity in schools has treated boundaries as neutral, focusing on the indirect role that boundaries play in facilitating segregation by informing the residential choices of individuals. In this study, I provide initial empirical evidence regarding the direct role that the shape of boundaries plays on structuring the racial/ethnic composition and segregation of schools. 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. It should be emphasized that the geospatial methods employed by this study cannot establish the intent of gerrymandering: While gerrymandered boundaries generally serve to segregate students by race/ethnicity, they were not necessarily intentionally manipulated to be racially discriminatory. Moreover, in some districts, those under active desegregation orders, I find that attendance zones are affirmatively gerrymandered in ways that reduce segregation.

Interestingly, the gerrymandering of attendance zone boundaries has a weaker effect on Black-White and Hispanic-White segregation than on segregation among non-Whites and segregation between Whites and Asians. Thus, this suggests that mechanisms other than gerrymandering are largely responsible for the persistently high rates of segregation between Whites and Blacks and Whites and Hispanics (G. Orfield et al., 2012; Stroub & Richards, 2013). One possible explanation for the weaker segregative effect of gerrymandering on these dimensions of segregation is legal. School districts may be concerned that boundaries that are gerrymandered in ways that segregate Blacks and Whites may be more vulnerable to litigation as violations of *Keyes*, as these historically disadvantaged groups have been the subject of most desegregation litigation.

An alternate explanation regarding the relatively minor effect of gerrymandering on Black-White segregation in particular is the geographic scale of segregation among U.S. public schools. Over the past decades, segregation has shifted from a largely within-district to a between-district phenomenon. Indeed, just 37% of total metropolitan segregation is within districts, while 63% lies across district boundaries (Stroub & Richards, 2013). This is particularly true for Black-White segregation: 79% of total Black-White segregation lies across district boundaries rather than within district boundaries. Thus, as in the case of LCPS above, because few Black students tend to be enrolled in predominantly White districts, the gerrymandering of attendance zone boundaries within districts holds less potential to affect Black-White segregation.

By contrast, a much smaller proportion of segregation between Asians and Whites and among non-Whites lies across district boundaries (49% and 48%, respectively; Stroub & Richards, 2013). As a result, Asians are more likely to be enrolled in districts with Whites and non-Whites are more likely to be enrolled in districts with each other. As such, gerrymandering holds greater potential to segregate Asians from Whites and non-Whites from each other. Thus, given the scale of public school segregation, it follows that gerrymandering of attendance zones within districts is associated with particularly large increases in segregation among non-Whites and between Asians and Whites.

The finding that, on average, attendance zones are gerrymandered in ways that exacerbate racial/ethnic segregation is consistent with historical

and qualitative evidence that suggests that gerrymandering has been used segregatively (Clark, 1987; G. Orfield & Eaton, 1997; M. Orfield & Luce, 2009; Siegel-Hawley, 2013; Vaznis, 2009). However, consistent with historical accounts that gerrymandering has been used as a policy tool for achieving racial/ethnic balance in schools under court-ordered desegregation, I find that gerrymandering is less segregative and often affirmative in districts under active desegregation orders. This suggests that desegregation orders continue to be effective in increasing integration in the handful of school districts that remain under court order. Troublingly, however, results indicate that districts that have been released from desegregation orders tend to be more segregatively gerrymandered than districts still subject to oversight and are even more gerrymandered to segregate than districts never subject to court-ordered desegregation in terms of multiracial and Hispanic-White segregation.

Taken together, these findings suggest that more stringent oversight and monitoring of local zoning practices may be an important policy lever for suppressing the creation of segregatively gerrymandered attendance zone boundaries. Moreover, this finding is troubling in light of the continued legal retrenchment on desegregation in schools. Facilitated by cases such as *Board of Education of Oklahoma City v. Dowell* (1991), *Freeman v. Pitts* (1992), and *Missouri v. Jenkins* (1995), the past two decades witnessed the massive release of districts from court-ordered desegregation remedies (Holley-Walker, 2010, 2012). Thus, it is possible that we may witness an exacerbation of the segregative effect of gerrymandering as more school districts are granted unitary status and start to redraw their attendance zone boundaries.

That attendance zones are particularly gerrymandered to segregate in districts experiencing rapid racial/ethnic change is also concerning. While this analysis does not permit any inference of intent, the findings are consistent with the argument that irregular boundaries may occur in response to rapid diversification in formerly homogeneous White communities (M. Orfield & Luce, 2013; Siegel-Hawley, 2013). Given that the racial/ethnic diversity of the U.S. population is expected to climb over the next decades, we can expect the racial/ethnic diversity of school districts to continue to rise steadily. While these increases in diversity hold the potential to integrate public schools, it is also possible that districts will increasingly turn to gerrymandering in response to these increases in diversity, a practice that may be facilitated by the weak federal oversight of *Keyes* violations and the lack of legal traction for desegregation efforts.

Interestingly, districts that experienced very low growth in racial/ethnic diversity also have boundaries that are particularly gerrymandered to segregate. While this seems somewhat counterintuitive, this may be a function of the greater stability of the attendance zones in these areas. Although they may be changed for a variety of reasons, school attendance zone boundaries are generally modified when new schools are created, when old schools

close, or when population shifts cause asymmetries in the number of students enrolled in different schools across the district. In a district experiencing rapid racial/ethnic and population change, attendance zone boundaries may change frequently. In more stable districts with little racial/ethnic or population change, these boundaries may also be more stable. Over time, families may Tiebout sort by race/ethnicity across boundaries as they select a residential location, considering school of attendance in their decision. As a result of this process of sorting, attendance zone boundaries may come to resemble racial/ethnic boundaries. Thus, while the attendance zone boundary serves to segregate, it may have been integrative or race-neutral when it was originally established.

The finding that attendance zone boundaries serve to reinforce racial/ethnic disparities in schools is concerning. However, the findings of this study also offer grounds for cautious optimism. Although the courts have continued to limit the ways in which districts may voluntarily integrate students on the basis of individual race and ethnicity, attendance rezoning represents a legally viable means of integration specifically endorsed by Justice Kennedy in *Parents Involved*. Moreover, because attendance zones are relatively fluid and are by law reviewed and modified frequently (e.g., in response to demographic changes or school openings or closures), they are amenable to change. Indeed, a significant minority of districts are already gerrymandered in ways that enhance their integration, particularly those that are under desegregation order. However, the foregoing analysis demonstrates that many districts could achieve moderate to large decreases in segregation through adopting attendance zones that are less gerrymandered, and therefore more compact, than their current zones. In addition, it should be emphasized that gerrymandered attendance zones are inherently inefficient. Although districts would not be expected to adopt Voronoi zones as a zoning scheme (owing to the limitations outlined earlier), analyses suggest that many districts could achieve increases in integration while increasing efficiency and reducing travel time to school. Thus, rezoning is appealing in that it has the potential to facilitate a rare convergence between the interests of equity and efficiency.

While attendance rezoning holds promise as a legal means of efficient integration, it also raises a number of practical considerations. In the absence of stronger state and federal oversight over local control of school attendance zone boundaries, the extent to which it is practical to modify school attendance zones may depend on the commitment of district leadership to equitable boundaries. While parental pressures certainly influence the school attendance zoning process, superintendents and district staff exert considerable control over the rezoning agenda by in proposing new boundaries, which are then subject to public review, modification, and, ultimately, approval by the local school board (Richards & Stroub, 2013). As such, creation of more equitable school attendance zones may be largely a function

of the motivation and political will of district leadership, underscoring the important role that school leaders play in fostering equity in schools.

A final note is warranted regarding the reciprocal relationship between traditional school attendance zones and schools of choice. While the vast majority of public school students still attend traditional public schools (NCES CCD, 2013), a growing minority of students attend schools of choice, particularly charters, which operate outside the spatial boundaries of traditional public schools. Likewise, school districts and states, such as Minnesota, are increasingly adopting open enrollment policies that allow students to attend schools other than the school to which they are geographically zoned (Holme & Wells, 2008). In contexts with strong choice markets, the availability of plentiful and attractive choice options may suppress segregative gerrymandering, by providing alternative "escape valves" for certain families, while relegating less geographically mobile students to their neighborhood schools. More fundamentally, however, the expansion of alternatives to traditional neighborhood schools holds the potential to erode the salience of traditional geographic boundaries that delineate school attendance zones.

Note

This study was supported in part by the Institute of Education Sciences, U.S. Department of Education, through Grant R305B100013-01. The opinions expressed are those of the author and do not represent views of the U.S. Department of Education.

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Manuscript received December 17, 2012
Final revision received May 5, 2014
Accepted July 5, 2014