The Dissertation Committee for Meredith Paige Richards certifies that this is the approved version of the following dissertation:

The Gerrymandering of Educational Boundaries and the Segregation of American Schools: A Geospatial Analysis

Committee:

Jennifer Jellison Holme, Supervisor

Norma Cantu

Robert Crosnoe

Mark Gooden

Pedro Reyes

The Gerrymandering of Educational Boundaries and the Segregation of American Schools: A Geospatial Analysis

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Meredith Paige Richards, B.A.; M.A.

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The Gerrymandering of Educational Boundaries and the Segregation of American Schools: A Geospatial Analysis

Meredith Paige Richards, Ph.D.

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Supervisor: Jennifer Jellison Holme

Despite steady and substantial decreases in residential racial/ethnic segregation since the 1960s, public school segregation is increasing steadily. As a result of these trends, schools, which have historically been less segregated than their surrounding neighborhoods, are now becoming *more* segregated than neighborhoods, underscoring the need for research on the ways in which educational institutions are facilitating segregation. Adopting a "student exchange" framework from the literature on electoral gerrymandering, this study provides initial empirical evidence examining how gerrymandered educational boundaries exacerbate or ameliorate patterns of residential segregation by "zoning in" certain students and "zoning out" others.

Using a large, nationally-representative sample of 9,717 school attendance zones and 9,796 school districts, this study employs geospatial analytic techniques to investigate the effects of school attendance zone and school district gerrymandering on the racial/ethnic diversity of schools and districts. The effect of gerrymandering on diversity is assessed by comparing the characteristics of students residing in current boundaries to those residing in the "natural", compact zone or district that would be

expected in the absence of gerrymandering, operationalized as the equal land area circle of Angel and Parent (2011) and convex Voronoi polygons.

Analyses reveal that, on average, both school attendance zones and school districts are gerrymandered to "zone out" more racially/ethnically dissimilar students in favor of more racially/ethnically similar students. As a result, schools and districts are significantly more racially and ethnically homogeneous than they would be in the absence of gerrymandering. While gerrymandering serves to segregate students of all races and ethnicities, it particularly serves to exclude blacks and Hispanics from predominantly white schools and districts, reinforcing the historical divisions between these groups. Indeed, estimates suggest that, on average, school attendance zones and school districts are 15% and 14% less black-white diverse, respectively, than would be expected if their boundaries were not gerrymandered. Findings suggest that the gerrymandering of boundaries adds another pernicious layer of segregation to public education institutions, which are already highly segregated by residency.

The finding that the gerrymandering of school attendance zones and school districts serves to segregate underscores the importance of educational boundaries as a contemporary mechanism of segregation. However, findings also warrant some optimism. Because attendance zone and district boundaries are modifiable and subject to policy intervention, state standards for boundary compactness and rezoning efforts designed to create more equitable boundaries present cost-effective opportunities to achieve meaningful gains in integration. While changing school district boundaries is less politically feasible than changing school attendance zones, when such windows of opportunity arise, they have the potential to reduce school finance inequities and equalize educational opportunity while also increasing racial/ethnic equity.

Table of Contents

List of Figures

List of Maps

List of Tables

CHAPTER 1: INTRODUCTION

The Shifting Educational-Residential Segregation Gap

The landmark *Brown v. Board of Education of Topeka* (1954) decision and subsequent legal victories dealt a severe blow to the structures of institutionalized segregation in American schools, culminating in the rapid integration of public schools along racial and ethnic lines over the 1960s and 1970s, especially for blacks and in the formerly *de jure* segregated South (Coleman, Kelly & Moore, 1975; Farley, 1975; Logan & Oakley, 2004; Orfield 1983; Smock & Wilson, 1991). The promise of *Brown* proved somewhat ephemeral, however, as segregation reached its nadir in the 1980s, giving way to a period of resegregation (Frankenberg, Lee & Orfield, 2003; Orfield, Bachmeier, James & Eitle, 1997; Orfield & Monfort, 1992; Orfield, Schley, Glass & Reardon, 1993; Orfield & Yun, 1999; Reardon, Yun & Eitle, 2000). Indeed, Orfield and colleagues have argued that schools were more segregated in 2005 than in 1970 (Frankenberg, Lee & Orfield, 2003; Orfield & Lee, 2007), with resegregation generally occurring across district lines, rather than between schools (Clotfelter, 2004; Stroub & Richards, 2011). While more recent evidence suggests that the trend towards resegregation may have plateaued, and perhaps even reversed, in recent years; at best, rates of segregation have remained relatively stable over the past decades (Stroub & Richards, 2011), underscoring the intractability of the problem of segregation in American schools.

Contrastively, trends for residential segregation by race and ethnicity have been promising, with rates of segregation continuing to decline steadily and substantially since the Civil Rights era. Accelerated by the Civil Rights Act of 1964 and fair housing laws banning racial discrimination (Clark, 2002), the past half-century witnessed substantial improvements across most dimensions of segregation, especially for blacks and whites (Charles, 2003; Clark, 2002; Iceland, 2004b; Iceland, Weinberg & Steinmetz, 2002; Logan, Stults & Farley, 2004; Timberlake & Iceland, 2007). Indeed, between 1960 and 2000, overall metropolitan residential segregation declined by 32% for blacks and 31% for whites, while remaining stable for Hispanics, despite their rapidly increasing populations (Fischer, Stockmayer, Stiles & Hout, 2004). While the problem of residential segregation remains acute, preliminary evidence from the 2010 Census suggests that the trend towards residential integration has continued into the 21st century (University of Michigan Population Studies Center, 2011).

That residential segregation has continued to improve while educational segregation is worsening or, at the very least, stabilizing, is a troubling sign that the hard-fought gains of the *Brown* era are being eroded (Logan, 2002). Most accounts of this growth in school segregation over the past decades have focused on the effects of eroding legal support for desegregation (Frankenberg et al., 2003; Logan, 2002; Orfield et al., 1997; Orfield & Monfort, 1992; Orfield et al., 1993; Orfield & Yun, 1999; Reardon & Yun, 2001b; Reardon et al., 2000). Orfield and colleagues have persuasively linked increases in segregation to the escalation in legal retrenchment on issues of segregation over the 1990s, exemplified by cases such as *Board of Education of Oklahoma City v. Dowell* (1991), *Freeman v. Pitts* (1992), and *Missouri v. Jenkins* (1995), which facilitated the massive release of districts from court-ordered desegregation remedies. Moreover, the finding that segregation is an increasingly concentrated at the district level has been attributed to the legacy of *Milliken v. Bradley* (1974), in which the Supreme Court ruled that desegregation across district boundaries was impermissible in the absence of evidence that multiple districts had committed deliberate segregation. By rendering district boundaries sacrosanct and limiting inter-district desegregation remedies, researchers have implicated the *Milliken* ruling in the shift in segregation from a between-school to a between-district phenomenon (Bischoff, 2008; Clotfelter, 1998; Frankenberg et al., 2003; Orfield & Monfort, 1992; Reardon et al., 2000). Logan and colleagues have offered a slightly different interpretation of these trends, holding that the growth in segregation, while partially driven by the enervation of desegregation efforts, may be more accurately ascribed to the increasing racial/ethnic diversity driven by the rapid growth in the U.S. non-white population (Logan, 2004; Logan & Oakley, 2004; Logan, Oakley & Stowell, 2006, 2008; Logan, Stowell & Oakley, 2002).

While accounts espoused by Orfield, Logan and their colleagues linking the increase in school segregation to the demise of desegregation and the increasing diversity of the student population are compelling, they are insufficient to explain an even more troubling finding – that schools are now, in many cases, *more* segregated than their surrounding neighborhoods and metropolitan areas (Orfield, 2002; Reardon & Yun, 2001b; Saporito & Sohoni, 2006, 2007; Sohoni & Saporito, 2009) or approaching that point (Ong & Rickles, 2004). In the decades following *Brown*, rates of educational segregation were consistently lower than those of residential segregation, suggesting that schools served to increase equity by mitigating the association between patterns of residence and school attendance that characterizes the American educational system.

Although this disparity may be attributed to several factors it is likely that this may be attributed to the effectiveness of desegregation policies. By weakening the link between where students lived and where they went to school, desegregation policies served to keep schools less segregated than the neighborhoods in which they were situated (Reardon & Yun, 2001b). The historical tendency for schools to be less segregated than their neighborhoods highlights the important role schools have played in ameliorating existing social inequities.

In the absence of such desegregation policies, it would be expected that rates of school and residential segregation would converge, as the link between residence and school of attendance is tightened and educational patterns more closely mirror neighborhood patterns. However, the available evidence suggests that rates of school and residential segregation are not just converging, but widening, as schools fail to realize the gains in residential segregation. Accounts premised on the increasing diversity of the student population cannot explain the gap because it would also be reflected in residential segregation. As such, this suggests that schools, formerly champions of equity in the post-*Brown* era, are not only failing to desegregate and reproducing existing patterns of residential segregation; they are now playing an active role in segregating students beyond the existing residential patterns.

Explaining the Educational-Residential Segregation Gap

The finding that schools are now becoming more segregated than their residential patterns would suggest thus begs the question: What are schools doing to exacerbate segregation beyond existing residential segregation? One logically feasible explanation for this finding, which has received extensive empirical attention, is the expanding role of school choice. By allowing parents to exercise their preferences in determining where their children attend school, school choice programs weaken the link between residential location and school of attendance. To the extent that these preferences tend towards more homogeneous educational environments, school choice options may therefore allow schools to become more segregated than would be expected under traditional neighborhood schools.

Consistent with this perspective, a large corpus of research has documented associations between choice policies and racial/ethnic stratification, including: charter schools (e.g., Bifulco & Ladd, 2007; Cobb & Glass, 1999; Garcia, 2008a, 200b; Renzulli & Evans, 2005; Weiher & Tedin, 2002), magnet schools (Saporito, 2003), private schools (e.g., Saporito & Sohoni, 2006, 2007), voucher programs (e.g., Brunner, Imazeki & Ross, 2010), intra-district choice/open enrollment (e.g., Carlson, Lavery & Witte, 2011; Holme & Wells, 2008), and inter-district choice programs (e.g., Holme & Richards, 2009). While there is considerable evidence that school choice is having adverse effects on racial/ethnic equity in schools, it seems unlikely that school choice is the primary driver behind the gap in educational and residential segregation. Indeed, the observed increases in segregation, which began in the 1980s, antedate the emergence of school choice in the 1990s. Indeed, Milwaukee's voucher program was not established until 1990, with Cleveland following in 1995, and the first charter school was not established in St. Paul until 1992 (Friedman Foundation, 2011). Likewise, inter-district choice laws were not enacted until the 1990s (Holme & Richards, 2009). Moreover, although increases in segregation were geographically distributed across the U.S., with the strongest effects in the South (Stroub & Richards, 2011), school choice programs have been more geographically limited in their implementation, at least until recently.

In his exploration of the dynamics of residential and school segregation, Myron Orfield (2002) reverses the traditional causal structure which views residential segregation as the primary driver behind school segregation, positing an alternate mechanism by which school districts precipitate white flight and subsequent residential segregation. According to Orfield, non-white minorities tend to move into areas that are less "controversial" – generally lower-income suburban areas with aging populations and fewer families with children. As the proportion of non-white children in a neighborhood's schools increases beyond a threshold of 10 to 20 percent, it precipitates white flight and rapid racial change that results until schools and neighborhoods are highly segregated. While this perspective provides an interesting account of how school segregation may be serving to increase residential segregation over time, it does not necessarily explain why rates of school segregation would be higher than residential segregation of students at a given point in time. Indeed, at any given point in time, the characteristics of students in schools would not be expected to differ from the characteristics of children enrolled in public schools in their neighborhoods.

The Role of Educational Boundaries

The inability of the existing narratives of segregation, including the end of the desegregation era, the rapid growth in the non-white student population, and the profusion of school choice options, to account for the rates of school segregation vis-à-vis residential segregation highlights the need for alternative causal explanations. One explanation, which has received less empirical attention, 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. Educational boundaries are the fundamental determinants of who attends which schools and districts, determining who is included and who is excluded from a certain educational opportunity. By carving up a geographic area in a manner that is non-neutral with respect to the race of the student population, educational boundaries may have lasting and profound consequences for equity in American schools.

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 argue that educational boundaries facilitate segregation by serving as signals for more "efficient" residential sorting. Because individuals often choose to live near people more "similar" to them in terms of race/ethnicity, districts tend to become more homogeneous over time (Bischoff, 2008; Ong & Rickles, 2004; Weiher, 1991). While the evidence on the indirect effects of educational boundaries provides a compelling account of how educational boundaries perpetuate segregation through residential sorting. Because they view the stratification of schools as the result of residential choices, these theories predict that school segregation reproduces and approximates neighborhood segregation. As such, they cannot adequately explain why schools are becoming *more* segregated than 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 the shape of educational boundaries plays in determining the equity of schools. According to this perspective, schools may be more inequitable than neighborhoods because they have non-neutral boundaries that allow them to maintain district homogeneity in the face of neighborhood diversity. Indeed, presuming all students went to their assigned neighborhood schools, it is untenable that school segregation would be higher than residential segregation unless the attendance zones were drawn in such a way as to exclude certain students and include others. By determining which students attend which schools and districts, educational boundaries provide a pernicious mechanism of stratification that exacerbates existing patterns of residential segregation.

Historical and anecdotal evidence regarding the inequities perpetrated by educational boundaries abound. Despite the absence of *de jure* segregation, Northern school districts often achieved *de facto* segregation by drawing their boundaries to maintain racial separation (Clark, 1987; Leigh, 1997). As Gunnar Myrdal observed, "school boundaries… are usually set at the boundary of the white and Negro neighborhoods" (Sugrue, 2009, p. 187). Although such efforts were deemed unconstitutional efforts to maintain "dual" school systems 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 was common practice for school districts in the post-*Brown* era to respond to desegregation pressures by locating schools and drawing their attendance boundaries to intensify segregation and undermine integration efforts (Clark, 1987; Orfield & Eaton, 1997). Even more troubling, anecdotal evidence from current redistricting and rezoning proceedings suggests that inequitable educational boundaries that exclude certain groups of students at the expense of others have persisted, and continue to drive racial inequalities in education (League of Women Voters, 2008; Orfield & Luce, 2010; Shapiro, 2011; Siegel-Hawley, 2010, Vaznis, 2009).

It should also be noted that the intent of race-conscious boundaries may not always be malevolent. Indeed, 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 which 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; 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. 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 educational 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.

Purpose of the Study

Recent trends in educational segregation paint a disturbing picture: despite steady progress towards residential integration over the past decades, school segregation is worsening, suggesting that schools are serving to segregate students beyond existing residential patterns. Situating the inherently spatial problem of segregation in the context of its spatial antecedents, this study examines how educational boundaries has have been manipulated or "gerrymandered" to exacerbate or, in some cases, ameliorate, patterns of residential segregation. According to this perspective, as Fischel 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 exclude certain students at the expense of others. Towards that end, the study focuses on how both major types of educational boundaries – school attendance zones and school districts – have been gerrymandered and the consequences of gerrymandering for the equity of public schools and districts. Below, I outline the study's research questions as they relate to each of these types of boundaries.

School Attendance Zone Gerrymandering

Because they determine which school students attend, school attendance zones play an extremely important role in structuring student's educational opportunities, making them perhaps the most salient educational boundary. Indeed, as will be discussed at length in Chapter 2, anecdotal evidence suggests that attendance zone boundaries have historically served as a critical battleground for undermining integration efforts. Moreover, to the extent that gerrymandered educational boundaries may have been used as an instrument of integration, it is expected that they would be evident at the level of the school attendance zone, reflecting the traditionally intra-district character of desegregation remedies. Towards that end, this study addresses the following specific research questions regarding the effects of school attendance zones:

1) *How gerrymandered are U.S. public school attendance zones?*
2) *Does school attendance zone gerrymandering serve to segregate or integrate students by race/ethnicity? How much would school diversity be improved or worsened through rezoning designed to minimize gerrymandering?*

Owing to shifts in the geographic scale of segregation since *Brown*, the majority of segregation now lies between, rather than within districts. Indeed, by 2009, roughly 63% of all racial/ethnic segregation was between districts (Stroub & Richards, 2011). Because school attendance zones now account for a relatively small proportion of segregation now lies between districts, suggesting that the potential benefit of policies addressing inequities in school attendance zones is likely to be small relative to school districts. However, because attendance zones are more fluid than school districts, and are reviewed and modified frequently, they are somewhat more amenable to change than between-district segregation and may constitute a more practical avenue for achieving integration objectives. Indeed, while it may be difficult to establish consensus and political will for boundary changes at a larger-scale, it may be possible to target inequities perpetuated within single districts.

Prior anecdotal evidence, as well as the student exchange theory underlying the study, suggests that school attendance zones may exhibit heterogeneity in terms of their level of gerrymandering and the effects of gerrymandering on racial/ethnic diversity in schools. For example, as will be discussed at length in Chapter 2, segregative gerrymandering may reflect a legacy of *de facto* segregation, especially in the North. Conversely, integrative gerrymandering may reflect the history of desegregation remedies in the South or in other areas subject to court-ordered desegregation. Indeed, it is conceivable that gerrymandering varies widely across a variety of geographic dimensions, including: metropolitan or micropolitan context, locality (i.e., urban, suburban or rural), history of *de jure* segregation, state. Analysis of variation in gerrymandering across geographic contexts provides into the causal mechanisms underlying gerrymandering. In addition, it helps to identify those contexts in which policy remedies targeting school boundaries to reduce racial/ethnic segregation would be more or less successful. In addition, to illuminate the racial dynamics that are driving the process of student exchange, it is particularly important to examine how gerrymandering varies as a function of the racial/ethnic composition of boundaries. Thus, to address geographic and demographic heterogeneity in school attendance zone gerrymandering across contexts, for Research Questions 1 and 2, the following sub-questions are addressed:

1a) *How does school attendance zone gerrymandering vary across geographic and demographic contexts?*

2a) *How does the effect of school attendance zone gerrymandering on school diversity vary across geographic and demographic contexts?*

School District Gerrymandering

Because district boundaries are so strongly implicated in the perpetuation of the "new" segregation between districts, it is critically important to understand how district boundaries *ipso facto* have contributed to this segregation. Indeed, the finding that segregation would only be reduced by 37% if all students in each district were to be perfectly integrated across schools underscores the importance of continued attention to the role of district boundaries in perpetuating segregation and the potential for solutions that transcend district boundaries, even in the face of difficulties in implementing such policies. From a policy perspective, it is acknowledged that district boundaries are extremely difficult to change, requiring state intervention and the cooperation of multiple district entities that have generally been immunized against legal remedy by the legacy of *Milliken*. To the extent that new district boundaries are proposed and existing district boundaries are reviewed, it is particularly important to understand the equity effects of these boundaries. This is especially important given the role that districts play in determining the educational opportunities of relatively large numbers of students. Towards that end, this study addresses the following specific research questions regarding the effects of school districts:

3) *How gerrymandered are U.S. public school districts? How does school district gerrymandering relate to school attendance zone gerrymandering?*

4) *Does school district gerrymandering serve to segregate or integrate students by race/ethnicity? How much would school district diversity be improved or worsened through rezoning designed to minimize gerrymandering?*

As with school attendance zones, examining the extent to which school district gerrymandering varies across contexts is particularly important to help understand the dynamics of exclusion manifest in gerrymandered boundaries as well as the potential for policy remedies to enhance diversity in schools As such, to address geographic and demographic heterogeneity in school district gerrymandering across contexts, for Research Questions 3 and 4, the following sub-questions are addressed:

3a) *How does school district gerrymandering vary across geographic and demographic contexts?*

4a) *How does the effect of school district gerrymandering on district diversity vary across geographic and demographic contexts?*

Conceptual Framework

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 the 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 by manipulating their boundaries to include certain students at the expense of others. According to the student exchange framework, the distortion of attendance zone and district boundaries provides a mechanism for segregating or integrating schools beyond existing patterns of residential segregation.

This perspective offers a viable alternative to existing narratives of resegregation, which are generally inadequate to explain the current trends in segregation, providing a mechanism of stratification beyond existing residential segregation. In addition, the student exchange framework also acknowledges the potentially affirmative role that educational boundaries may play in increasing diversity and maintaining integration by weakening the link between residency and schools. In the sections that follow, I formalize this framework of student exchange, situating it in the literature on electoral gerrymandering and "voter exchange".

Electoral Gerrymandering

In the political realm, gerrymandering may be conceived of as the process of drawing district boundaries to confer an electoral advantage on one group over another, generally on the basis of political affiliation (i.e., partisan gerrymandering) or unlawfully, on the basis of race or ethnicity (i.e., racial gerrymandering). As such, the general aim of gerrymandering is to dilute the effect of "one person, one vote" by minimizing the effect of opponents' votes and maximizing the effect of supporters' votes.

Although the practice of electoral gerrymandering is a longstanding American tradition that may be traced to the election of the first Congress in 1789, when anti-Federalists in Virginia engineered district boundaries to prevent Madison from being excluded from the House of Representatives (Labunski, 2006; Martis, 2008). The popularization of the term "gerrymandering", however, may be traced to the famous 1812 political cartoon in the *Boston Gazette* (see Figure 1), a satirical portmanteau associating then-governor Elbridge Gerry with the salamander shape taken by the districts in his politically-biased redistricting schemes for Massachusetts (Labunski, 2006; Martis, 2008). Nearly 200 years later, gerrymandering continues to spark colorful language, with justices of the court describing irregular districts as “a Rorschach inkblot test” (*Shaw v. Barr*, 1992) “a bug splattered on a windshield” (*Shaw v. Reno*, 1993), “a sacred Mayan bird” (*Bush v. Vera*, 1996), and “[i]f you drove down the interstate with both car doors open, you’d kill most of the people in the district” (*Shaw v. Reno*, 1993).

Figure 1. Boston Gazette political cartoon picturing governor Gerry’s “gerrymandering” of Massachusetts.

Gerrymandering is a general term encompassing three general strategies for distorting district boundaries to achieve political gain. First, districts may incorporate discontiguous areas that disconnected from the main part of the district to achieve a certain distribution of voters. Second, district populations may be allowed to vary, undermining the “one person, one vote” principle by giving more weight to voters in smaller districts than voters in larger districts. Third, districts boundaries may be manipulated to be “irregular” or “bizarre”, to exclude certain groups and include others, thereby engineering a preferred voter composition for the district. Corresponding to these three strategies, political scientists have identified three principles for identifying gerrymandered political districts: 1) contiguity, 2) equinumerosity, or population equivalence, and 3) compactness, each of which is discussed at length in Chapter 2.

The constitutional issues surrounding the legality of gerrymandering in the political context are complex and rapidly changing. At a basic level, while partisan gerrymandering, or manipulation of boundaries along party lines for the sole purpose of achieving political gain, has been deemed constitutional, the courts have generally concluded that racial gerrymandering runs counter to the intent of electoral democracy and have sought to limit its effects. Although affirmative racial gerrymandering, notably through the creation of majority-minority districts designed to redress historic discrimination, was employed after the adoption of the Voting Rights Act of 1965. However, gerrymandering solely on the basis of race, regardless of affirmative intent, was subsequently ruled unconstitutional in *Shaw v. Reno* (1993) and *Miller v. Johnson* (1995), although the use of race has been upheld when used in conjunction with partisan considerations (*Hunt v. Cromartie*, 1999). The courts have generally repudiated gerrymandering on the grounds that it violates the Equal Protection principle of the 14th amendment, by excluding closer voters in favor of voters farther away, a gerrymandered district exhibits an impermissible preference for certain voters over others (*Davis v. Bandemer*, 1986).

As a result, all 50 states prohibit “inequinumerous” redistricting strategies, which violate the spirit of “one person, one vote”, while 49 states have clear statutes prohibiting “discontiguous” boundaries for either legislative or congressional districts (Levitt, 2011). While the practice of creating irregular or non-compact boundaries has been outlawed by 37 states, concerns regarding the valid and reliable measurement of boundary “irregularity” have rendered it more difficult to prosecute successfully (Levitt, 2011).

Electoral Gerrymandering as “Voter Exchange”

Angel and Parent (2011) have conceptualized electoral gerrymandering as the spatial manifestation of a process of aggressive “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, p. 96).

In a process of voter exchange through gerrymandering, the composition of voters in what would be a cohesive and efficient district is deemed unsatisfactory. As such, boundaries are manipulated to achieve a more advantageous composition of voters by excluding some nearby and replacing them with voters living farther away (*LULAC v. Perr*y, 2006). Boundary distortion and irregularity is therefore the direct evidence of this process of “foraging” for desirable voters and “expelling” undesirable voters.

Consistent with this interpretation, in discussing cases political gerrymandering, justices of the Supreme Court have consistently depicted gerrymandering as an act of voter exchange, whether on the basis of voter party affiliation (i.e., political gerrymandering) or race/ethnicity (i.e., racial gerrymandering). As Justice Kennedy wrote in the opinion of the Court in *LULAC v. Perry* (2006), "a district that reaches out to grab… isolated minority communities is not reasonably compact." Likewise, Souter argued in his dissent in *Vieth v. Jubelirer* (2004), districts with "specific protuberances on the draconian shape that reach out to include Democrats, or fissures in it that squirm away from Republicans" may be considered gerrymandered. In the opinion of the court in *Bush v. Vera* (2006), Justice O'Connor contended that Texas' electoral districts used "narrow corridors, wings, or finders… [to] reach out to enclose black voters while excluding nearby Hispanic residents."

According to the voter exchange framework, irregularities in political boundaries may be viewed as the direct result of deliberate boundary manipulation designed to include and exclude certain voter populations. Indeed, 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 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 non-exchange reasons, including congruence with geographic boundaries, such as irregular coastlines or islands, and coterminity with other jurisdictional boundaries. However, it is argued that the extent to which a district shape diverges from its "natural", compact shape, after controlling for these effects, may be interpreted as evidence of a process of voter exchange.

Educational Gerrymandering as “Student Exchange”

Mirroring the “voter exchange” perspective on electoral gerrymandering, I adopt a “student exchange” perspective to understanding school attendance zone and school district gerrymandering. According to this perspective, the irregularity of educational boundaries reflects a process of student exchange wherein “less desirable” students nearby are excluded in lieu of “more desirable” students residing farther away. As with political gerrymandering, which may be motivated to exchange voters on the basis of party affiliation or race, student “desirability” may be based on a number of factors, including student race/ethnicity, student socioeconomic status, or tax capacity. The construction of educational districts is therefore an exclusionary and inclusionary process that “zones in” certain students and “zones out” others. Figure 2 illustrates how the process of student exchange results in district boundary gerrymandering.

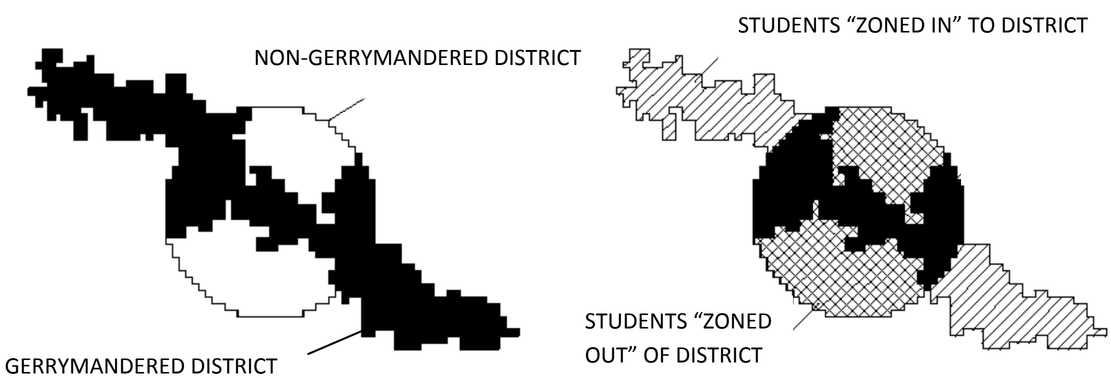


Figure 2. Student exchange as a function of educational district gerrymandering.
Note: Figure adapted from Angel & Parent (2011).

The conceptualization of gerrymandering as student exchange is premised on the notion that current educational boundaries may be compared to the boundaries of “natural” school attendance zones or districts that would be expected in the absence of gerrymandering to determine how irregularities to boundaries serves to exchange students. For the purposes of the current illustration, the “natural” district is considered a circle of equal land area to the original district having its center on the center of gravity of the original district (Angel & Parent, 2011). Generally, the larger the area exchanged by the district (i.e., the lower the ratio of the district’s area enclosed by the circle representing the ideal district to the area of the actual district), the more “aggressive” and egregious the gerrymander.

As the figure above illustrates, the area of overlap between the “natural”, non-gerrymandered district and the actual, gerrymandered district represents those students that are neither “zoned in” nor “zoned out” by the process of student exchange. These students, therefore, comprise the “core” student population for the district, while the area of overlap may be considered the “core” of each attendance zone or district. To the extent that school attendance zone and, to a lesser extent, district boundaries are created and modified in response to public demand, it may be inferred that the process of exchange is driven, at least in part, by the parents and stakeholders in the “core”. This suggests that the preferences and characteristics of parents and students in “core” zones and districts may drive the process of exclusion and inclusion manifested by gerrymandered boundaries. For example, the aggressiveness of a student exchange process and, therefore, the severity of gerrymandering, may be related to the homogeneity of the “core”, with more homogeneous cores seeking to consolidate their homogeneity by exchanging racially and ethnically dissimilar students for more similar students.

School attendance zone gerrymandering. At the school level, the construction of school boundaries "zones in" certain students who would reasonably expect to go to another school and "zones out" students who would reasonably expect to go to the focal school. Because school attendance zoning decisions are participatory in nature, and subject to parental and community involvement, gerrymandering at the attendance zone level may be guided by the preferences of parents in the "core" zone to maintain homogeneous schools in the face of district diversity. As Myron Orfield (2002) has argued, attendance zones may be manipulated to satisfy parental demands, which often intensify when districts experience significant racial change that threatens to change the racial composition of schools. However, as noted previously, the impetus for student exchange via school attendance zone gerrymandering may also be benign, reflecting the affirmative intent to integrate across segregated schools.

School district gerrymandering. At the school district level, district boundaries "zone in" more desirable students who would reasonably expect to attend school in another district in exchange for less desirable students. Whereas the impetus for student exchange through attendance zone boundaries reflects a school district's effort to manipulate the racial and ethnic distribution of students across schools, either in response to "core" parental preferences or in the interests of integration, the impetus of student exchange may be conceptualized as a school district's effort to engineer the homogeneity, or heterogeneity, of its overall racial and ethnic composition.

While school attendance zone and school district gerrymandering are independent exchange processes, they may in practice interact with each other. For example, if a district's boundaries result in a relatively homogeneous student population, districts may be less inclined to exchange students within their boundaries using attendance zones. However, a more diverse district may use gerrymandered attendance zones as a mechanism for segregating students in response to parental demands. Although it is theoretically possible that school districts, like attendance zones, could be designed to maximize heterogeneity, there is little anecdotal evidence to suggest that this is the case.

Another important exchange process that may underlie educational boundary gerrymandering warrants consideration. At the school district level, gerrymandering may also reflect a process better characterized as "land exchange" than "student exchange". This exchange, colloquially referred to as "tax grabbing", is motivated by the financial goal of enhancing the district's taxation capacity for property wealth. Because the issue of taxation is not relevant at the school level, this is not likely to be a motivating factor for the distortion of school attendance zone boundaries. Because the study is concerned with the consequences, rather than the intent, of educational gerrymandering, the issue of gerrymandering as "tax grabbing" is not peripheral to its objective.

Affirmative vs. Discriminatory Intent of Gerrymandering

While the term "gerrymandering" generally has a pejorative connotation, the impetus for student exchange via educational boundary gerrymandering, as with voter exchange, may theoretically be either discriminatory or affirmative in nature. Consider the case of gerrymandering perpetrated for the purpose of engineering the racial/ethnic composition of a school attendance zone or school district. As discussed previously, it is theoretically possible that such race-conscious boundary manipulation may be motivated by a discriminatory intent, designed to preserve the racial/ethnic homogeneity of the student population and to segregate students across schools or districts in a post-*Milliken* context. As with electoral boundaries, the establishment of discriminatory educational boundaries is patently unconstitutional; as noted previously, however, efforts to prosecute such cases are plagued by difficulties inherent in establishing the discriminatory intent of boundaries (Douglas, 1995). However, as discussed previously, the distortion of educational boundaries may also be motivated by an affirmative intent, a vestige of the desegregation era designed to weaken the link between residential segregation and school segregation. While such affirmative gerrymandering has been outlawed in the context of electoral districts (*Shaw v. Reno*, 1993), it has been expressly endorsed in the educational context (*Parents Involved in Community Schools v. Seattle School District No. 1*, 2007).

It is important to distinguish between the initial impetus for voter exchange and the consequences of boundary gerrymandering for equity. Indeed, even if the intent of gerrymandering was initially affirmative, boundaries may have the effect of segregating. By contrast, even if boundaries were originally intended to be discriminatory, they may have an integrative effect. For example, while a school district's boundaries may have been manipulated for the purpose of increasing property tax revenue, the effect of the boundary manipulation may have been to segregate students by race/ethnicity, owing to the strong association between race/ethnicity and property tax wealth. By contrast, it is possible that a school's attendance boundaries were originally designed to increase the diversity of the school; however, owing to residential migration patterns, they may currently have a segregative, rather than integrative, effect. Because of difficulties inherent in assessing intent (discussed at length in the Limitations section below), the current study seeks to avoid conflating the intent of gerrymandering with its consequences, focusing exclusively on the effects of educational boundary gerrymandering on equity in schools.

Gerrymandering Inefficiency

One fundamental aspect of boundary gerrymandering that is of particular practical importance in the educational context is its inherent inefficiency. As is discussed at length in Chapter 2, district gerrymandering necessarily results in a less efficient district shape than would be expected in the absence of gerrymandering. Indeed, the "natural", compact district that would be expected in the absence of gerrymandering would, by definition, minimize the travel time between each student in a school attendance zone and their school. To the extent that a district is gerrymandered, therefore, it also diverges from optimal efficiency, resulting in increases in travel time and costs. When gerrymandering promotes the objectives of integration, educational entities must weigh the costs may associated with these inefficiencies against the benefits to the district in terms of increased equity. However, when gerrymandering adversely impacts equity, the additional costs imposed by the district's inefficiency merely provide an additional burden; as such, the objectives of equity and cost-savings may both be realized through more efficient districting schemes that minimize gerrymandering.

Overview of Methodology

In this study, I investigate the gerrymandering of educational boundaries using a variety of sources of spatial and aspatial data analyzed via complementary geospatial and traditional regression analytic techniques. As discussed above, the study has two primary objectives: 1) to document the prevalence and severity of educational boundary gerrymandering, and 2) to analyze how the gerrymandering of educational boundaries serves to perpetuate, or ameliorate, racial and ethnic inequities in American schools. Mirroring these objectives, the study has two primary phases.

In the first phase of analysis, I draw on the rich methodological literature on the measurement of electoral gerrymandering to quantify the irregularity of school attendance zone and school district boundaries. Two complementary measures of compactness were computed quantifying gerrymandering for a large sample of school attendance zones and the full population of school districts. Boundaries of 9,717 elementary school attendance zones were obtained from the School Attendance Boundary Information System (SABINS), a novel repository for national school boundary data. Boundaries of all 9,621 school districts in U.S. metropolitan areas, which are reported biennially to the U.S. Census Bureau, were obtained from the Topologically Integrated Geographic Encoding and Referencing (TIGER)/Line® system.

To determine how gerrymandering varies across school and district contexts, measures of gerrymandering were regressed on a variety of geographic and demographic covariates, including core-based statistical area type (i.e., metropolitan or micropolitan), locality type (i.e., city, suburban, town, rural) , history of *de jure* segregation, history of desegregation order, etc.

In the second phase of analysis, I examine the effects of educational boundary gerrymandering on the racial/ethnic diversity of schools and districts. Building on the study's student exchange framework, I estimate the "effect" of gerrymandering on diversity for each of the schools and districts in the sample by comparing the diversity of existing boundaries to the diversity of the "natural" boundaries would be expected in the absence of gerrymandering. These natural, non-gerrymandered school attendance zones and districts are operationalized through two different types of compact shapes: 1) the perfectly-compact equal land area circle of Angel and Parent (2011), and 2) an optimally-efficient convex Voronoi polygon minimizing student distance to school. Each actual and "natural" attendance zones and school districts is spatially merged with Census 2010 Summary File 1 block-level data via ArcGIS. Based on these demographic data, the racial/ethnic diversity of each current school attendance zone and district is compared to the racial/ethnic diversity of its "natural" attendance zone to estimate the effect of gerrymandering on diversity.

As in the first phase of analysis, regression models were estimated to determine how the effects of gerrymandering on diversity vary across geographic and demographic contexts. Particular attention is paid to how the demographics of student in the "core" attendance zone or district are related to the segregative or integrative effect of gerrymandering on racial/ethnic diversity.

Contribution of Study

This study contributes to the emerging field of geographic research in education, testing the extent to which educational boundaries may be directly implicated in the segregation, or integration, of schools beyond their residential areas. Adapting a framework from the political science literature, the study develops a "student exchange" perspective on segregation focusing on how educational entities promote or ameliorate segregation by choosing to include certain students and exclude others. Recent research on segregation has generally focused on the declining role of districts in matters of integration and the growing role of individual decisions in the context of permissive choice policies. This framework, however, refocuses attention to the direct effects that educational institutions play in the resegregation of American schools.

Despite the logical association between educational boundaries and segregation and anecdotal evidence corroborating this link, no empirical research has examined how the configurations of educational boundaries have directly contributed to the equity and inequities of schools. Moreover, despite its implications for the equity of American schools, the concept of gerrymandering has been almost entirely neglected in the educational domain. Evidence on gerrymandering in education has remained entirely anecdotal, generally restricted to noting "irregularities" in districts undergoing legal scrutiny (e.g., Clark, 1987; Leigh, 1997). Using a large-scale national sample of attendance boundaries and the entire population of school district boundaries, this study provides the first empirical evidence of the prevalence and severity of educational gerrymandering and its impact on the equity of American schools.

Even more importantly, to the extent that gerrymandering has been addressed in the education literature, discussions have lacked any theoretical or methodological clarity. While the term "gerrymandering" is often bandied about, authors have generally failed to provide an adequate definition of the term (or any definition) (e.g., Douglas, 1995; Orfield & Eaton, 1997). By focusing on the definition of gerrymandering and situating gerrymandering in the process of “student exchange”, this study attempts to provide a stronger theoretical basis for defining the phenomenon. Moreover, this study leverages the robust methodological literature in the political sciences addressing the definition and measurement of gerrymandering, offering a more nuanced multidimensional perspective on the different manifestations of gerrymandering.

In addition to its theoretical contribution, this study has significant implications for policy. Because attendance zone and district boundaries are mutable and subject to policy intervention, redistricting and rezoning presents a viable and cost-effective, if politically arduous, opportunity to achieve integration. Indeed, despite eroding judicial support for integration remedies, the establishment of affirmative race-conscious school district and attendance zone boundaries has been reaffirmed as an acceptable integration strategy (*Parents Involved*, 2007). By estimating how much segregation might be reduced through more equitable districts, this study provides actionable information for policy. Moreover, the study assesses the potential for redistricting designed to reduce the affirmative gerrymandering of the desegregation era, as exhorted by the “neighborhood schools” movement, to hinder the objectives of integration.

Although the equity implications of district boundaries and redistricting policies are of paramount concern to this study, the study also has important financial implications for districts. Because gerrymandered boundaries are inherently inefficient, in that they increase student travel time and costs beyond what would be expected in a compact district, school districts could expect to achieve cost savings through redistricting designed to reduce gerrymandering. As such, where educational gerrymandering serves to segregate, creating more regular districts will realize gains in equity as well as cost savings for districts. Where gerrymandering integrates, however, districts must weigh the benefits for equity against the additional travel costs imposed by inefficient districts. This study assists in this cost-benefit calculus by directly estimating the magnitude of the effect of gerrymandering on segregation as well as quantifying the increases in travel time associated with the district's deviations from regularity.

In addition to these theoretical and practical contributions, this study makes several methodological contributions to the literature. First, because this study constitutes the first empirical assessment of gerrymandering in education, it adapts measures of electoral gerrymandering to the educational context and develops an additional measure, embeddedness, which is unique to the educational context. Drawing on the student exchange framework of Angel and Parent (2011), I will develop geospatial measures assessing the effects of gerrymandering on the diversity and segregation of schools. Finally, to assess the potential effects of redistricting on segregation, I will use geospatial analytic software to develop alternative redistricting algorithms derived from Voronoi-type polygons.

CHAPTER 2: REVIEW OF THE LITERATURE

In this chapter, I review the literature on current trends in educational and residential segregation and the emergence of the educational-residential segregation gap. I review and weigh the evidence for the dominant explanations for segregation trends, including the retreat from desegregation and the growth in school choice, concluding that additional attention to the direct effects of educational boundaries is warranted. I present the scant anecdotal evidence on gerrymandering in education, highlighting the necessity of additional theoretical and methodological attention to the concept. Drawing on the literature on gerrymandering in political science and adapting it to the educational context, I then provide a comprehensive discussion of the definition and measurement of educational gerrymandering.

Segregation Trends

The Retreat from School Integration and Rising Educational Segregation

In the decades following the *Brown* (1954), American schools experienced dramatic gains in racial and ethnic integration. Although progress was initially stalled by dilatory tactics on the part of Southern school districts, ultimately, continued legal victories resulted in the dismantling of the structures of *de jure* segregation. Accordingly, gains in integration were particularly pronounced in the South. Given the legal emphasis on redressing the historical discrimination against blacks, declines in the segregation of blacks were particularly pronounced. Gains were also achieved in the North, as the courts turned their attention to remedies for *de facto* segregation in the late 1960s and early 1970s (Coleman, Kelly & Moore, 1975; Farley, 1975; Logan & Oakley, 2004; Orfield

1983; Smock & Wilson, 1991). It should be emphasized that trends in segregation were not universally positive; despite the Court's ruling in *Keyes* (1973) affording Hispanic students the same desegregation rights as black students, the segregation of Hispanics continued to increase steadily over this period (Wells, 1989).

By the 1970s, judicial activism for integration had waned, exemplified by the *Milliken* decision barring metropolitan-wide desegregation plans that crossed district boundaries, even when meaningful integration could not be achieved within existing boundaries. By limiting integration efforts to district boundaries, Milliken severely hamstrung integration efforts, especially for racially isolated urban districts. Subsequent rulings in the 1990s, including *Board of Education of Oklahoma City v. Dowell* (1991), *Freeman v. Pitts* (1992), and *Missouri v. Jenkins* (1995), cemented the courts' legal retrenchment and resulted in the release of hundreds of districts from court-ordered desegregation (Holley-Walker, 2010, 2011). Indeed, between 2004 and 2009, 89 school districts were granted unitary status in the formerly *de jure* segregated states of Alabama, Florida, Georgia, Louisiana, Mississippi, North Carolina, and South Carolina alone (Holley-Walker, 2010). Indeed, by 2010, only 200 of the nearly 16,000 districts in the U.S. remained under desegregation orders (Holley-Walker, 2011). In addition to the steady decline in mandatory desegregation orders over the past decade, the courts have recently handicapped districts' ability to *voluntarily* integrate by prohibiting the use of individual student race/ethnicity when assigning students to schools (*Parents Involved in Community Schools v. Seattle School District No. 1*, 2007).

Mirroring this legal trajectory, by the 1980s, the integration of public schools had stalled, giving way to a period of modest resegregation for blacks and whites, as well as continued increases in the segregation of Hispanics. Much of the evidence for the resegregation of public schools comes from a series of studies conducted by Orfield and colleagues (Frankenberg et al., 2003; Orfield et al., 1997; Orfield & Monfort, 1992; Orfield et al., 1993; Orfield & Yun, 1999; Reardon et al., 2000). This body of work generally finds that the segregation of black students reached its nadir in the late 1980s, and increased steadily thereafter. Indeed, Orfield and colleagues have argued that by the mid-1990s, black students were *more* segregated than they were in 1973. Orfield and colleagues have found that the level of Hispanic segregation has consistently increased since the late 1960s, surpassing that of blacks by the early 1990s. Moreover, Orfield and colleagues have found that the South, which experienced the largest declines in segregation in the post-*Brown* era, also experienced the largest increases in black segregation over the 1990s, while the largest increases in Hispanic segregation were found in the West.

Subsequent research employing more nationally-representative samples and more sophisticated measures of segregation, which are less sensitive to overall racial/ethnic composition than exposure and isolation, has found somewhat more equivocal effects than Orfield and colleagues. Using a multiracial entropy index of segregation (discussed at length below), Reardon, Yun and Eitle (2000) find that the total level of metropolitan school segregation remained stable over the first half of the decade. Decomposing total segregation into its unique racial/ethnic components, however, they find that whites have become increasingly segregated from non-whites, while segregation among minority groups has declined. Although they use whites as their focal racial/ethnic group, unlike Orfield and colleagues, who focus on the segregation of minorities from whites, Reardon et al.'s dual-group findings are generally consistent with Orfield's work.

In addition, work by Logan and colleagues, employing a dissimilarity index of segregation on NCES CCD data, which avoids many of the problems of isolation and exposure used by previous research, generally corroborates the finding that the segregation of black and Hispanic students increased slightly over the 1990s. Contrary to the work of Orfield and colleagues, who have attributed growth in school segregation to the erosion of desegregation, Logan and colleagues conclude that growth in segregation was largely a function of the decline in the white population and the increase in minority populations, rather than an increase in the separation of students by race. As such, they argue that the slight increases in segregation over the 1990s do not constitute a process of resegregation precipitated by the legal retrenchment of desegregation orders, but rather are a natural result of an increasingly diverse student population.

In addition to the overall increases in metropolitan racial/ethnic segregation, recent research has documented an important shift in the geographic scale of segregation. While the segregation of public schools in the *Brown* era was primarily *within* districts (i.e., between schools), the recent resegregation has been driven by dramatic increases in segregation *between* districts. Indeed, Clotfelter (2004) finds that, in the decades following the *Brown* decision, decreases in within-district segregation were outpaced by increases in between-district segregation, yielding net increases in metropolitan segregation over time. Likewise, Reardon et al. (2000) find that the growth in segregation over the 1990s was attributable to growth in between-district segregation, and public school segregation continued to shift from a between-school phenomenon to a between-district phenomenon. The finding that segregation is an increasingly concentrated at the district level has been attributed to the legacy of *Milliken v. Bradley* (1974), in which the Supreme Court ruled that desegregation across district boundaries was impermissible in the absence of evidence that multiple districts had committed deliberate segregation. By rendering district boundaries sacrosanct and limiting inter-district desegregation remedies, researchers have argued that the *Milliken* ruling has facilitated the resegregation of American schools across district boundaries (Bischoff, 2008; Clotfelter, 1998; Frankenberg et al., 2003; Orfield & Monfort, 1992; Reardon et al., 2000).

Contrary to the dominant narrative of resegregation, more recent evidence suggests that the trend towards increasing segregation in schools may have plateaued, and perhaps even reversed, in recent years. Indeed, in the only study of school segregation extending beyond the year 2000, Stroub and Richards (2011) found that the increases in segregation of the 1980s and 1990s have given way to a period of slight integration, especially for blacks, with rates of segregation slightly lower in 2009 than in 1992. While overall segregation decreased slightly over the study period, Hispanic segregation continued to increase. Although such trends are promising, and suggest that American schools may have made incremental progress towards integration over the past decade, counteracting some of the losses of the previous decade, they still fall far short of an equitable realization of the goals of *Brown*. As such, the problem of segregation in American schools remains.

Steady Gains in Residential Integration

While residential segregation certainly remains a serious problem, the past decades have witnessed steady and substantial growth in integration since the adoption of the landmark antidiscrimination legislation of the Civil Rights Act of 1964 and the Fair Housing Act of 1968 (Charles, 2003; Clark 2002). Indeed, data on residential segregation reveals that levels of multiracial, black, and white segregation all declined significantly over the past five decades across most dimensions of segregation (for a review see Massey & Denton, 1988), in most metropolitan areas (Charles, 2003; Clark, 2002; Iceland, Weinberg & Steinmetz, 2002; Logan, Stults & Farley, 2004; Timberlake & Iceland, 2007).

Specifically, using Theil's entropy index of segregation, Fischer et al. (2004) found that between 1960 and 2000, metropolitan residential segregation between Census tracts declined by 32% for blacks and 31% for whites. Using a smaller sample of the 21 largest cities with over 50,000 blacks, Clark (2002) found that overall segregation decreased by 24% over the same period. Analyzing change in segregation between 1980 and 2000 for the 50 largest metropolitan areas, Charles (2003) found that black segregation, as measured via dissimilarity and isolation, declined by 10 and 12 percentage points, respectively, while exposure was relatively stable (increasing by 1 percentage point). Computing entropy indices of segregation on all U.S. metropolitan areas over the same period, Iceland (2004b) found that multiracial segregation declined by 26%, black segregation declined by 25%, and white segregation declined by 24%. These overall trends, however, mask considerable geographic heterogeneity in effects. While gains in residential integration were highest in the Midwest and South, they were lower in the Northeast and West. Moreover, gains in segregation were largest in the most populous metropolitan areas.

It should be emphasized, however, that trends for Hispanics and Asians are much less promising than trends overall and for blacks, underscoring the increasingly complex and multiethnic nature of segregation. Fischer et al. (2004) found that Hispanic segregation was virtually unchanged between 1970 and 2000 (data were not available for the 1960 Census). In her analysis of the 50 largest metropolitan areas from 1980 to 2000, Charles (2003) found that Hispanic dissimilarity and isolation increased by 6 and 10 percentage points, respectively. Hispanic exposure, however, decreased by 16 percentage points. Likewise, for Asians, dissimilarity and isolation increased by 3 and 6 percentage points, while exposure decreased by 16 percentage points. Using data on all U.S. metropolitan areas, Iceland (2004b), however, found that Hispanic segregation *declined* by 2% between 1980 and 2000, although Asian segregation increased by 14% over the same period. In addition, although a complete discussion falls outside the purview of this study, it should be noted that residential segregation by socioeconomic status has continued to increase steadily over time, suggesting that class is becoming an increasingly important mechanism of residential stratification (Fischer, 2003; Fischer et al., 2004).

Although evidence from the 2010 Census is still preliminary, early evidence provides equivocal support for the assertion that these residential trends towards improving black and white segregation and stable or worsening segregation of Asians and Hispanics have continued into the 21st century. Using dissimilarity indices of segregation on the 100 most populous metropolitan areas, Frey (calculations provided by University of Michigan Population Studies Center, 2011) found that the segregation of blacks has continued to decline, albeit slightly. At worst, black segregation has not increased since 2000. During this period, however, the segregation of Asians and Hispanics seems to have increased substantially, highlighting the need for research extending segregation beyond traditional and black-white dichotomy.

The Educational-Residential Segregation Gap

As discussed in Chapter 1, the increases in educational segregation, while concerning *ipso facto*, are particularly troubling in light of evidence that residential segregation has continued to improve. Moreover, as a result of these trends, emerging evidence suggests that schools are becoming more segregated than the neighborhoods in which they are situated. (Orfield, 2002; Reardon & Yun, 2001b; Saporito & Sohoni, 2006, 2007; Sohoni & Saporito, 2009) or approaching that point (Ong & Rickles, 2004). This represents a significant departure from the desegregation era, where rates of educational segregation were consistently lower than those of residential segregation.

In a series of studies using school attendance zones boundaries for the 21 largest U.S. school districts, using Census 2000 data, Saporito and Sohoni (2006, 2007, 2009) compared the characteristics of students enrolled in public schools to the characteristics of students living in their corresponding attendance zones. Saporito and Sohoni conclude that the schools are substantially more homogeneous than the characteristics of students living in their boundaries, a finding they attribute to school choice, especially private, charter and magnet school enrollments. Specifically, they find that, on average, black-white segregation in schools is 3 percentage points higher than in their corresponding attendance zone, while Hispanic-white segregation is 6 percentage points higher in schools than in their attendance zone. The largest difference was Dade County, Florida, where schools were a staggering 21 percentage points higher than their attendance zones. Only one district, San Diego, had school racial/ethnic segregation values *lower* than residential segregation. Results were even more staggering for the segregation of students by socioeconomic status; on average, schools have a socioeconomic exposure rate 24 percentage points lower than their attendance zones. Using interesting an innovative methodological techniques, Saporito and Sohoni provide strong evidence implicating schools in the exacerbation of patterns of residential segregation.

In another study comparing school and residential segregation at the metropolitan level, Ong and Rickles found somewhat more equivocal results. Using data on all U.S. metropolitan areas from 1990 to 2000, Ong and Rickles found that, consistent with the historical enforcement of desegregation policies for blacks, school segregation remains slightly lower than residential segregation (a dissimilarity index of 0.54 vs. 0.58). For Asians and Hispanics, however, school segregation was consistently higher than residential segregation (ranging from roughly 2 to 6 percent). However, while growth in school segregation steadily outpaced growth in residential segregation for blacks, the residential segregation outpaced school segregation for Asians and Hispanics. Unlike the work of Saporito and Sohoni, which directly compares the segregation of students in schools to the residential segregation of students in school attendance zone boundaries, Ong and Rickles approach is somewhat problematic, however, in that it uses different geographic scales of analysis for school segregation and residential segregation (i.e., the school and the Census tract).

Explaining the Educational-Residential Segregation Gap

Previous research has suggested that the retreat from school desegregation has played a role in resegregating schools by race and ethnicity; however, this research does not provide insight into why schools are becoming more segregated than their corresponding residential areas or how schools are serving to exacerbate segregation beyond the effects of individual residential decisions.

One possible explanation that has been studied extensively in recent years concerns the expanding role of school choice as a unique educational mechanism of stratification. Although early proponents argued that school choice presented the opportunity to improve educational equity by attenuating the persistent links between residential segregation and school attendance (Kahlenberg, 2008). Consistent with evidence that parental preferences tend towards more homogeneous educational environments, others have argued that school choice has the potential to make schools even more segregated than would be expected under traditional neighborhood schools (Denessen, Driessena & Sleegers, 2005; Garcia, 2008b; Hanushek, Kain, Rivkin &

Branch, 2006; Kahlenberg, 2008; Kleitz, Weiher, Tedin & Matland, 2000; Weiher & Tedin, 2002).

Consistent with the latter perspective, on the whole, evidence suggests that school choice options have in practice served to stratify students by race and ethnicity. The preponderance of research attention has focused on the effects of charter schools. At the student level, research has found that students tend to transfer from more diverse schools to less diverse schools where their racial/ethnic group is more heavily represented (Bifulco & Ladd, 2007; Booker et al., 2005; Weiher & Tedin, 2002). At the school level, evidence suggests that charter schools are less diverse than public schools (Frankenberg & Lee, 2003). Specifically, Cobb and Glass found that both urban and rural charter schools in Arizona tended to dramatically over-represent whites. Miron and Nelson (2002) found that the racial/ethnic composition of charter schools differed significantly from the population of nearby public schools, with charter schools alternately under-representing and over-representing minorities.

Empirical evidence on other forms of school choice also corroborates the segregative preferences and consequences of choice programs. In a study of the magnet program in Philadelphia, Saporito (2003) demonstrated that whites and more socioeconomically disadvantaged students exhibited "outgroup avoidance", by transferring out of schools with higher rates of poverty and non-white children. In practice, Saporito (2003) found that the magnet program had the effect of increasing segregation between whites and nonwhites substantially, from 0.68 based on neighborhood schools to 0.76 with magnet schools. Likewise, in their examination of private schools, Saporito and Sohoni found that the presence of private schools exerts a strong negative effect on the percentage of white students enrolled in public schools. In a survey analysis of perceptions of universal voucher programs in California designed to assess the potential effect of a charter initiative on segregation, Brunner and colleagues (2010) found that white households are more likely to support vouchers when their children attend schools with higher concentrations of nonwhite children.

Studies of public school choice, including intra- and inter-district open enrollment, also generally support the conclusion that policies allowing students to transfer out of their neighborhood schools have a stratifying effect. In studying intra-district open enrollment in North Carolina, Hastings and colleagues (2009) found that parents of all racial groups tended to prefer schools where their race is the clear majority. In their study of school-level inter-district open enrollment flows in Colorado, Holme and Richards (2008) found that inter-district choice contributed to stratification by race and ethnicity (albeit to a lesser extent than by socioeconomic status), with white students tending to transfer from more racially diverse districts into districts with higher proportions of White students. In a student-level study tracking open enrollment flows in Minnesota and Colorado, Carlson and colleagues (2011) found that while enrollment flows were driven primarily by student achievement and structural characteristics of districts, they may also have the effect of segregating by race and ethnicity, particularly in Colorado.

As discussed in Chapter 1, the inconsistent temporal and spatial relationship between the emergence of school choice policies and the resegregation of schools suggests that while school choice certainly holds the potential to greatly exacerbate school segregation, it is unlikely that choice is primarily to blame for the growth in segregation or the primary impetus for the educational-residential segregation gap. Indeed, while school segregation increased steadily from the mid-1980s through the 1990s before beginning to decline slightly in the 2000s, school choice did not emerge in its modern incarnation until the establishment of Milwaukee's voucher program in 1990 and Minnesota's charter program in 1992 (Friedman Foundation, 2011), with open enrollment policies emerging in various states throughout the 1990s (Holme & Richards, 2009). Moreover, school choice programs have been historically concentrated in certain metropolitan areas in certain states, such as Arizona, Minnesota, Ohio, Wisconsin, and Washington, DC (although the number of states with some form of choice legislation has increased dramatically over the past decades). However, increases in segregation have been more evenly geographically distributed across the U.S., with the strongest effects in the South (Stroub & Richards, 2011).

The Role of Educational Boundaries

Another potential explanation for the resegregation of schools vis-à-vis neighborhoods, which has received less empirical attention than school choice, concerns the effects of educational boundaries on segregation. As discussed in Chapter 1, prior research on boundaries has almost exclusively focused on the effects of boundaries on residential sorting, addressing how the information contained in boundaries serves to inform individual decisions. According to this general perspective, because individuals tend to prefer to live near people more "similar" to them in terms of race/ethnicity, boundaries facilitate segregation over time through private choices (Bischoff, 2008; Ong & Rickles, 2004; Weiher, 1991). Such accounts of the indirect effects of educational boundaries on segregation, however, cannot adequately explain why schools are becoming *more* segregated than neighborhoods, predicting instead that school segregation would reproduce and approximate neighborhood segregation.

While empirical attention has been paid to the indirect effect of educational boundaries on residential decisions, no prior empirical evidence has examined the how the shape of boundaries themselves helps perpetuate inequities. Ample anecdotal and historical evidence on isolated districts suggests that the gerrymandering of school districts may have been a common practice for school districts to achieve greater homogeneity or for schools to respond to racial diversity or change. Sugrue describes how many Northern districts responded to the skyrocketing black population in the 1940s and 1950s by gerrymandering their attendance zone and district boundaries to maintain *de facto* segregation. Jacobs (1998) describes how Columbus, Ohio used school siting, as well as gerrymandered and non-contiguous district boundaries, to maintain a "dual system" in the 1970s. Douglas describes how the gerrymandering of school attendance zones in Charlotte, North Carolina, despite clearly demarcating black and white neighborhoods, failed to meet the standard of intent required by the federal district court judge. 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.

The anecdotal and historical nature of prior evidence on gerrymandering in education highlights the necessity of more recent empirical evidence examining the direct role of educational boundaries in perpetuating inequities. Equally important, however, is the necessity for theoretical and methodological advancement in the study of gerrymandering. While the previous literature has occasionally alluded to the concept of "gerrymandering" in general terms, it has failed to provide an adequate definition of the term or how it is measured. As such, it is important that the study of gerrymandering in education proceed from a stronger theoretical understanding of the concept and more sophisticated means of its assessment. Towards this end, the current study has posited a "student exchange" framework, outlined in Chapter 1, as a lens to focus the concept of gerrymandering. In addition, using principles of gerrymandering derived from the political sciences, the study provides a more specific and nuanced definition of the multidimensional concept of gerrymandering. Moreover, it identifies specific statistical and geospatial measures that may be used to measure each dimension of gerrymandering. Below, I outline each of the principles of gerrymandering, as well as its associated measures, in greater detail.

Principles of Gerrymandering

The literature on electoral gerrymandering has identified three central principles for identifying and quantifying gerrymanders: 1) contiguity, 2) equinumerosity, and 3) compactness (Fryer & Holden, 2007). In addition to these traditional principles of gerrymandering used in the political sciences, I posit a fourth principle, embeddedness, which is particularly relevant to the educational context. Below, I discuss each of these four principles, outlining their definition, measurement, legal standards, and application to the educational context. A summary of each of measure, including definitions and computation procedures, is featured in Table 1. Chapter 3 contains more detailed information on each of the measures used in this study. Note that because both school attendance zones and school districts are types of “districts” to which the principles of gerrymandering may be applied, I hereafter use the general term “district” to collectively refer to both of these types of educational boundaries.

Contiguity

Contiguity is perhaps the most straightforward standard for assessing gerrymandering. According to the principle of contiguity, each district should be a single, unbroken shape (Azavea, 2006, 2010). As such, all parts of a district must be physically connected such that each district has no portion that is “completely separated from any other part of the same district” (Thompson, 2002, p. 103). In practical terms, “a contiguous district is one in which a person can go from any point within the district to any other point [within the district] without leaving the district” (Note, 1966, p. 1284, as cited in Engstrom, 2003). Although it is theoretically possible to imagine a continuous measure of contiguity (i.e., the number of disconnected parts of a district, the proportion of a district contained within a single polygon), contiguity is generally considered a dichotomous concept. As such, a district is classified as either contiguous or non-contiguous.

Because it may be measured fairly unambiguously, with violations readily apparent, contiguity is the most common and longstanding standard for protecting against gerrymandering. Indeed, Congress enacted rules requiring contiguity in congressional districts as early as 1842 (*Matter of Sherrill v. O'Brien*, 1907), and courts have reaffirmed the principle as a *de facto* requirement for all electoral districts (*Reynolds v. Sims*, 1964; *Shaw v. Reno*, 1993). In practice, 49 states currently have statutes expressly requiring at least one chamber of their state legislative districts to be contiguous, while 23 require contiguous congressional districts (Levitt, 2011). These numbers obfuscate the emphasis on contiguity in practice. Indeed, it is expected that for the current legislative redistricting cycle, all districts will be drawn to be contiguous (Levitt, 2011).

While deviations from contiguity are generally considered detrimental to electoral fairness, it is conceivable that they may be either detrimental or instrumental to achieving the equity goals of educators. While non-contiguous districts or attendance zones may serve to segregate by annexing students in non-adjacent areas in an effort to maintain more homogeneous student bodies. However, non-contiguity may also be used to integrate by incorporating students that increase the diversity of the school's student body. Thus, while an absolute standard of contiguity may not be necessary or even desirable for schools, it is important to understand how deviations from contiguity have affected the equity of schools.

Accordingly, although states often give "consideration" to contiguity in school attendance zone and school district boundaries (e.g., California), in practice, many states have non-contiguous school districts, such as Fulton County School System in Georgia, the northern and southern portions of which are separated 17 miles by the Atlanta Public Schools (Fulton County Schools, 2011). Likewise, at the attendance zone level, while contiguity is often considered in school districting deliberations, it is not usually mandatory. Moreover "satellite" districts have historically been used as a means of gerrymandering for desegregation, as in Greensboro, North Carolina and Natchez, Mississippi (Rossell, 2006).

Despite the conceptual simplicity of the concept of contiguity, several considerations arise in the application of the absolute theoretical standard. First, the question of whether water may be used in the determination of contiguity presents several problems (Rush & Engstrom, 2001). On the grounds that the contiguity standard applies to both land and water, in some cases districts have used bodies of water, such as rivers, to connect two discrete land areas, even when it is not possible to traverse through the water from one part of the land area to another (Rush & Engstrom, 2001). While critics have expressed concern about the legitimacy of such districts, they have been legally upheld in some areas (e.g., Florida Supreme Court, SJR 2G 1992). In addition, on the assumption that the contiguity standard does not apply to water, many states, especially coastal states, have special exemptions for districts containing islands, on the grounds that land-area contiguity is not feasible.

Second, under the technical definition of contiguity, two areas may be considered contiguous if they exhibit "point contiguity", in that they are connected at a single point (Engstrom, 2003). See Figure 3 for an example of a district satisfying a criterion of point contiguity. However, in practice, such configurations are generally deemed suspect, as they violate the spirit of the standard of contiguity (Thompson, 2002). As such, while a few states, such as North Carolina, permit point contiguity for legislative redistricting, the practice is rejected by most redistricting authorities (Engstrom, 2003).

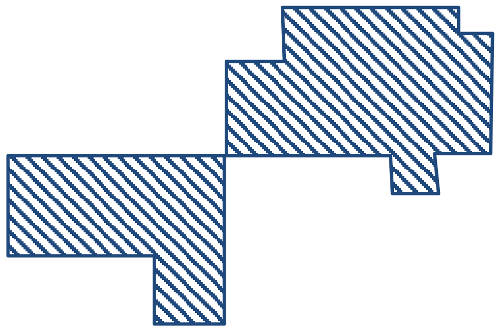


Figure 3. District exhibiting point contiguity.

Similarly, districts often employ narrow corridors to connect two discrete parts of a district, a practice which, while satisfying the technical standard for contiguity, also violates the spirit of the principle (Engstrom, 2003). Indeed, such districts have been criticized by federal justices as "tokenism that mocks the traditional criterion of contiguity" (*Hays v. State of Louisiana,* 1993, p. 1200). However, while such districts may superficially meet the standard for contiguity, they often violate standards of compactness, which is discussed at length later, underscoring the importance of using multiple, complementary principles when assessing gerrymandering. However, it should also be noted that while contiguity is a conceptually distinct principle, it may also be captured by other measures of gerrymandering. Specifically, as is discussed at length below, measures of compactness may also capture the effects of violations of contiguity, inasmuch as non-contiguous districts are necessarily less compact than contiguous districts.

Equinumerosity

Like contiguity, the principle of equinumerosity, or population equality, is conceptually straightforward. According to this principle, all districts in a set of districts (i.e., in a state) should have roughly equivalent populations. As such, while traditional principles of contiguity and compactness are measured at the level of a single district, with a few exceptions, equinumerosity is measured globally, assessing the evenness of the distribution of populations across districts. In electoral redistricting, the principle of equinumerosity is paramount to assuring the "one-person, one-vote" rule established by Article I, Section 2 of the constitution, as held by the Supreme Court in *Reynolds v. Sims* (1964) for legislative districts and reaffirmed in *Karcher v. Daggett* (1983) for congressional districts. All 50 states have laws designed to ensure that electoral districts have equivalent populations, "as nearly as practicable one man's vote in a congressional election is to be worth as much as another's" (*Wesberry v. Sanders*, 1964).

Despite the intuitive simplicity of the principle of equinumerosity, its operationalization is somewhat more complex. In applying the standard to electoral redistricting, the courts use a handful of measures which estimate the extent to which actual district populations deviate from the "ideal" district population. For any given area, the ideal population for each district is equal to the total area population divided by the number of districts. The extent to which each district differs from this ideal is then assessed via an absolute or relative deviation. To obtain the absolute deviation, the population of the ideal district is subtracted from the population of the actual district. To obtain a relative deviation, the district's absolute deviation is divided by the ideal population, yielding the proportion by which the district's population deviates from the ideal population. Because it is less sensitive to population size, the relative deviation is generally preferred to the absolute deviation (Brickner, 2010).

These district-level absolute or relative deviations are then aggregated at the district level in one of two ways. First, the absolute or relative deviations may be averaged across all districts in the area to obtain a mean absolute or mean relative deviation for the area. Second, the minimum and maximum may be used to establish an "overall range" of absolute or relative deviations. The courts have generally adopted range measures in assessing equinumerosity in legislative redistricting cases, which have generally deemed an absolute range of relative deviations of 10% to be acceptable (Brickner, 2010).

It should be noted that, unlike contiguity, which has a clear dichotomous measure that may be easily applied by the courts to determine gerrymandering, equinumerosity is a continuous measure (i.e., the population equivalence of legislative districts in a state may range from high to low). As such, equinumerosity requires a more subjective legal standard than contiguity. In applying the principle of population equivalence to electoral cases, the Supreme Court requires that all districts in a state be as equinumerous "as practicable", which it has operationalized through a 10% standard. According to this standard, legislative plans may be valid so long as the range of relative deviations is within 10%.

In the educational context, it may be argued that no reasonable expectation of equinumerosity exists, especially for school districts, which vary considerably in terms of the number of students they serve. The principle of equinumerosity may be more applicable to the case of school attendance zones, however, to the extent that schools of a given level within a district may be expected to serve roughly equivalent populations. Although radical differences in the number of students served by schools in a district may be indicative of real differences in school capacity, they may often reflect a process of gerrymandering, especially when the demographic profiles of schools differ significantly. Thus, while there may be no clear legal standard for objecting to population inequality among districts and, to a lesser extent schools, it may be a critical symptom of gerrymandering with strong theoretical and practical implications for segregation and which is not captured by other measures.

For example, consider Figure 4A, which depicts a school district consisting of two schools and their corresponding attendance zones. Both school attendance zones are contiguous, both are compact (as will be discussed later), and neither are embedded (discussed later). Thus, both satisfy all other criteria for gerrymandering. However, the green school has a population that is a fifth of the population of the purple school. Moreover, the green school is 90% white, while the purple school is 40% white, suggesting that the district is relatively segregated. Now consider Figure 4B, which depicts the same district, but with an alternate school attendance zoning arrangement. Again, both school attendance zones are contiguous, compact, and non-embedded; however, the school populations are much more equivalent. Under the new zoning scheme, the green school is 48% white and the purple school is 49% white and is substantially less segregated than the original districting scheme. This scenario illustrates how the lack of equinumerosity among schools constitutes an important form of gerrymandering that may serve to increase racial segregation.

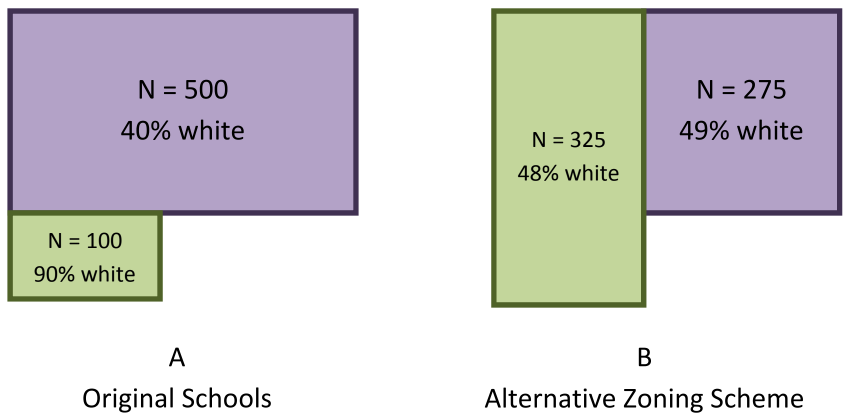


Figure 4. Example of inequinumerosity using two zoning scenarios in a district with 500 students.

The potential role of population inequality on segregation among districts is particularly important given the growing concern over the "fragmentation" or proliferation of school districts (e.g., Bischoff, 2008; Clotfelter, 2001; Frankenberg, 2009). Indeed, many have argued that the trend towards school district consolidation that characterized the past century has begun to reverse, with the number of districts now increasing steadily. While fragmentation is often associated with the outward expansion of metropolitan areas, incorporating ever more remote suburban and exurban areas, it is also attributable to the subdivision or "splintering" of existing districts (e.g., Frankenberg, 2009). In their study of the effects of school district fragmentation on segregation, Richards & Stroub (2011) found that the fragmentation of districts within metropolitan areas were associated with increases in segregation. Because the study held metropolitan boundaries constant for the study period and controlled for population growth, it captured the unique effect of fragmentation attributable to the subdivision of metropolitan areas into smaller, more homogeneous districts. Thus, I argue that the phenomenon of fragmentation constitutes a form of educational boundary gerrymandering which is not reflected in measures of contiguity, compactness, or embeddedness, but may be manifested in inequinumerosity.

Compactness

Compactness is perhaps the single most important and well-studied principle of gerrymandering in modern electoral politics, with 37 states requiring their legislative districts to be "reasonably compact" and another 18 states requiring compactness of their congressional districts. It is also the most controversial. Unlike contiguity and equinumerosity, which have clear definitions and, therefore, relatively clear measurement and legal standards, compactness is notoriously difficult to define. It has been likened to "political pornography" (Scheidegger, 2004; Windlow, 2011), applying a similar maxim to that famously applied to obscenity by Justice Stewart: "I know it when I see it" (Jacobellis v. Ohio, 378 U.S. 184, 197, 1964).

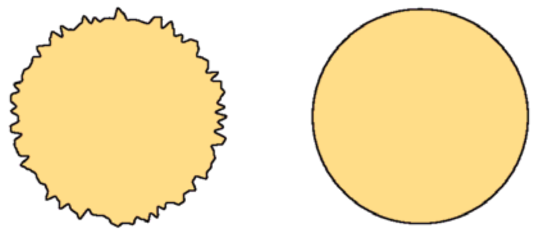
Simply put, compactness refers to the extent to which a district's boundaries are "bizarre" (e.g., Chambers & Miller, 2010; Pildes & Niemi, 1993) or, according to the seminal work of Polsby and Popper (1993), "ugly". Mathematically, compactness quantifies how much a district differs from a perfectly compact shape. Geometrically, the circle is considered the most compact shape. Specifically, according to the isoperimetric theorem, a circle is optimally compact because it 1) maximizes the area contained within a perimeter of given length and 2) minimizes the perimeter for an area of given size (Weisstein, 2011). Because the circle is the most compact geometric shape, the goal of most measures of compactness is to determine the extent to which the district's shape differs from perfect circularity (although a few compare the district to a hexagon or square).

A number of different measures of compactness have been culled from the fields of geography, law, mathematics, and political science. Because compactness measures how much a district deviates the shape of a circle, which minimizes the perimeter for its area and maximizes the area for its perimeter, measures of compactness generally fall into one of two complementary classes: 1) measures of indentation, or perimeter-based measures of the smoothness or efficiency of a district's boundary, and 2) measures of dispersion, or areal-based measures of the extent to which a district's polygon is spread out or elongated from its center. Below I discuss each of these measures and their subtypes in detail, addressing the advantages and disadvantages of each. Where relevant, Table 1 contains more detailed computation formulas.

Indentation. Gerrymandering is most frequently assessed using measures of indentations. Two subtypes of measures of indentation have been developed to quantify how convoluted a district's boundaries are: 1) perimeter-area ratios, and 2) convexity measures.

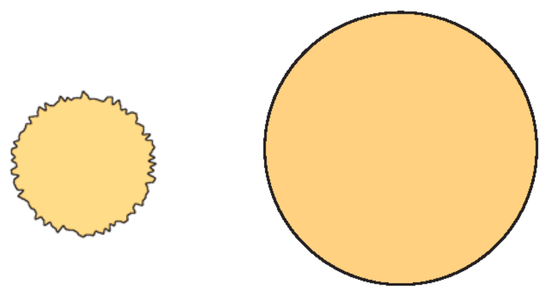
Perimeter-area. The most common measures of indentation are perimeter-area ratios. The Schwartzberg (1966) index, originally outlined in Attneave and Arnoult (1956), compares the perimeter of the district to the perimeter of a circle with equal area

(See Figure 5.1). Conversely, the Polsby-Popper index, originally developed by Cox as a measure of the roundness of grains of sand, compares the area of the district to the area of a circle with equal perimeter (See Figure 5.2).



A B

Figure 5.1. The Schwartzberg index compares perimeter of district A to perimeter of district B, which has area equal to that of circular district A.



A B

Figure 5.2. The Polsby-Popper index compares area of circular district A to area of district B, which has perimeter equal to that of district A.

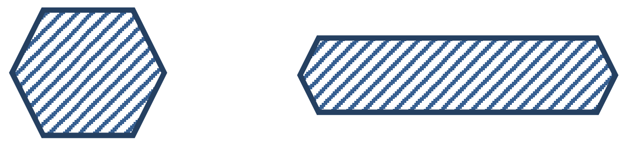
The Schwartzberg index has been criticized for being too sensitive to perimeter length and insufficiently sensitive to shape (Young, 1988). For example, using a Schwartzberg index, Figure 6B below is considered more gerrymandered than the L-shaped figure in 6A, despite being much less spread out about its center.

Figure 6. Using the Schwartzberg index, district B is more gerrymandered than district A.

While the Polsby-Popper measure is less biased by perimeter length than the Schwartzberg index, critics have noted that Polsby-Popper is sensitive to shape irregularities that may not be attributable to gerrymandering, including adherence to geographic and other geopolitical boundaries. For example, districts that border bodies of water and have extremely indented coastlines often score very poorly on the Polsby-Popper index, despite the lack of intent to gerrymander. Likewise, if a school district is contiguous with a county boundary, and the county itself is highly gerrymandered, the gerrymandering of the school district may not be intentional ipso facto. This problem may be mitigated, however, through a variety of techniques such as excluding non-coastal perimeter length in calculations or adjusting the measure to account for compactness of larger boundaries, allowing the researcher to isolate the extent to which non-compactness is a result of intentional gerrymandering.

Convexity. Another class of measures of indentation, which have received increased attention in recent years, are measures are measures of district convexity (Chambers & Miller, 2010). Geometrically, a polygon is convex if all of its angles are non-reflexive (i.e., less than 180 degrees), and are concave if they have one or more reflexive angles (i.e., more than 180 degrees, but less than 360 degrees). As a measure of indentation, convexity is primarily a measure of exclusion. Because concavities or indentations in a district's perimeter are viewed as evidence of boundaries changing direction to exclude certain areas, non-convex districts exhibit an exclusionary bias, while perfectly convex districts are non-exclusionary (although, as dicussed below, it may reflect an *inclusionary* bias through elongation). As a consequence, a perfectly convex district has the property that the shortest line distance between any two points lies within the district polygon. Convexity may be measured dichotomously, as whether a district polygon has any reflexive angles or not; however, because so few districts are actually convex, however, in practice it is better measured via a continuous variable measuring the degree of convexity.

Two primary continuous measures of convexity have been adopted. The "simple convexity" index developed by Taylor (1973) measures the proportion of angles in a district that are convex. Specifically, Taylor's measure computes ratio of the number of angles in a district polygon that are non-reflexive relative to the number of angles in the district polygon that are reflexive. While Taylor's formula is an excellent measure of indentation, is is somewhat problematic in that it views all convex polygons as equally compact (e.g., hexagons, circles, squares, rectangles, and triangles are all perfectly compact) (Chambers & Miller, 2010; Young, 1988). Moreover, it fails to provide any safeguard against elongation. As such the two districts in Figure 7 below would receive identical scores on Taylor's convexity measure, despite the fact that Figure 7B appears to be less compact than 7A.



A B

Figure 7. Using Taylor's simple convexity measure, hexagon A and hexagon B are equally compact (i.e., perfectly convex).

In addition to Taylor's measure of simple convexity, Chambers and Miller (2010) have recently proposed a new "path-based" measure of convexity, which estimates the probability that a district contains the shortest path between a randomly-selected pair of points lies within the district. As noted above, in a maximally-compact shape, such as a hexagon or circle, the shortest line distance between all pairs of points lies within the shape. As with Taylor's simple convexity measure, however, Chambers and Miller's path-based convexity index deems a wide variety of polygons as "perfectly compact" and is insensitive to differences in elongation, also failing to discriminate between shapes such as those in Figure 7 above.

Dispersion. As noted previously, measures of indentation may be criticized failing to discriminate cases of gerrymandering via elongation (i.e., they are unable to discriminate between Figures 7A and 7B. The second class of compactness measures, dispersion measures, seeks to address that very phenomenon, by quantifying how tightly packed or spread out a district is (Niemi et al., 1990). Three basic subtypes of dispersion measures have been developed: 1) length-width displacement indices; 2) comparisons of district area to area of compact figure; and 3) moment of inertia measures.

Length-width displacement. Perhaps the simplest and most intuitive measures of dispersion are those that compare the length of the district to the width of the district (Polsby & Popper, 1991). As Table 1 reveals, a variety of length-width comparisons are possible, I will discuss two in detail. Perhaps the most prevalent length-width displacement measure is Harris' measure of the ratio of the length of the longest axis to the maximum length perpindicular to that axis (Harris, 1964). The closer the ratio is to 1, the more compact the figure (illustrated in Figure 8 below).

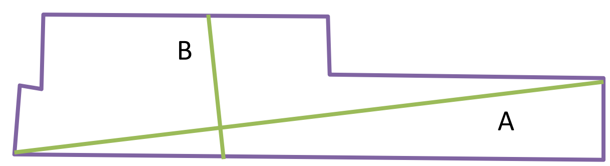


Figure 8. Length-width displacement comparing longest axis (A) to maximum perpendicular axis (B).

A slightly different type of length-width displacement is the measure reported by Niemi et al. (1990), which compares the length and width of the minimum enclosing rectangle about the district polygon, as shown in Figure 9 below. As with Harris' measure, the closer the ratio is to 1, the more compact the figure.

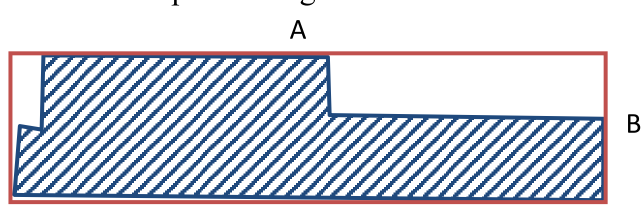


Figure 9. Length-width displacement comparing length (A) and width (B) of minimum enclosing rectangle about district polygon (hatched).

Unfortunately, however, length-width displacement measures are problematic in that they are poor at discriminating among different shapes. For example, it gives equivalent scores to a square and a cross in Figure 10A and 10B. Even more troubling, it may assign a near perfect score to "devious" shapes, such as the serpentine shape in Figure 10C.

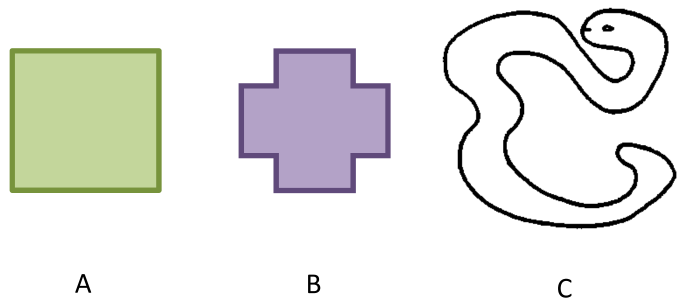


Figure 10. Length-width displacement measures consider both A and B perfectly compact, C extremely compact. Figure 10.C adapted from Young (1988).

Comparison of district area to area of compact figure. Another class of dispersion measures seek to compare the area of a given district polygon to the area of a compact shape. Most measures of this type compare the area of the district to the area of a minimum spanning figure that contains the entire district. In the earliest exemplar of this type of measure, the Reock index compares the area of a district to the area of the smallest circle that contains the entire district (i.e., the minimum circumscribing circle, see Figure 11).

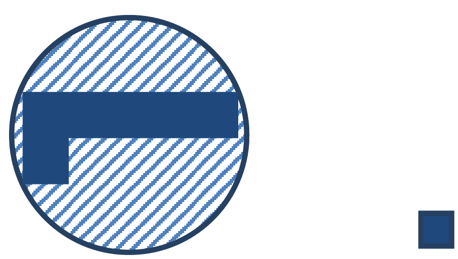


Figure 11. The Reock index compares the area in the district (solid blue) to the area in the minimum circumscribing circle (hatched blue).

Another index comparable to Reock can be computed using a minimum circumscribing hexagon. Likewise, a “convex hull” measure can be computed using the minimum convex bounding polygon. Perhaps the simplest way of conceptualizing a convex hull is imagining the polygon that would result if one stretched a rubber band around the district shape (Azavea, 2006, 2010). A slight variation on the Reock index, proposed by Horton (1932) and Gibbs (1961), compares the area of a district to the area of the circle with diameter equal to the longest axis of the district. Taken together, each of these measures essentially captures the extent to which certain areas are excluded by a district, as such, the areas inside the compact figure but outside the district may be viewed as areas “zoned out” of a district.

Despite their intuitive appeal, such measures based on minimum spanning figures exhibit several limitations. First, such shapes lack discriminatory power in that they often yield counterintuitive results. For example, as Figure 12 illustrates, according to the Reock measure, a star (Figure 12A), which has several concavities, is more compact than the convex triangle (Figure 12B). Moreover, because of its emphasis on the most extreme points of a district’s perimeter, a highly convoluted figure such as the serpent-shaped district (Figure 12C) may be deemed more compact than a perfectly convex square (Figure 12D).

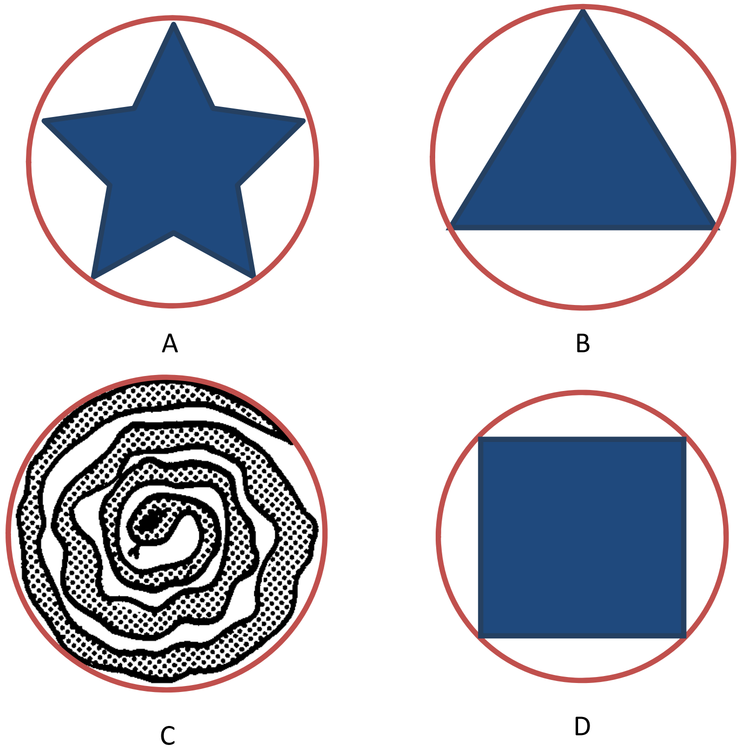


Figure 12. Using the Reock index (minimum circumscribing circle in red), the concave star (A) is more compact than the convex triangle (B). In addition, the serpentine shape (C) is deemed more compact than a square (D). Figure 12C adapted from Young (1988).

In addition, as Figure 11 above illustrates, the Reock and circumscribing hexagon measure are highly sensitive to district elongation, which is especially problematic in coastal areas with long, narrow districts. Moreover, all circumscribing measures may be strongly biased by non-contiguity. For example, if the small square to the right of Figure 11 above is an island that is part of the district, the area of the enclosing figure would be greatly magnified, thus dramatically skewing the estimate of compactness. This problem may be mitigated somewhat by computing separate enclosing figures for each non-contiguous part of the district.

In addition to measures using a minimum enclosing figure, dispersion may also be assessed using a maximum inscribed figure, by compare the area of the district to the area of the largest enclosed feature that may contained by the district. In a corollary to Reock, Ehrenberg (1892, as cited in Frolov, 1974), proposed a measure that compared the area of the maximum inscribed circle to the area of the district (See Figure 13 below). Whereas each of the measures using an enclosing figure outlined above essentially captures the extent to which certain areas are *excluded* by a district, the measure of inscription captures the extent to which certain areas are *included* by a district. As such, the areas outside the inscribing circle but inside the district may be viewed as areas "zoned into" a district.

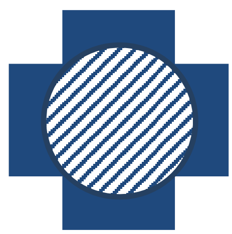


Figure 13. Ehrenberg's index compares the area in the district (solid blue) to the area in the maximum inscribed circle (hatched blue).

Flaherty and Crumplin (1992) have proposed a unique measure incorporating both the minimum circumscribing circle used in Reock's index and the maximum inscribed circle used in Ehrenberg's index. Flaherty and Crumplin's measure essentially measures the proportion of the area in a district's minimum circumscribing circle that is inside the district's maximum inscribed circle (see Figure 14). Although this measure is has not been widely used to assess gerrymandering, it is a promising measure that is intuitively appealing. By comparing the size of the area “zoned into” a district to the size of the area “zoned out” of a district, it provides an elegant measure of the extent to which boundaries have been manipulated to include or exclude certain areas.

Figure 14. Flaherty and Crumplin’s maximum-minimum circle index compares the district area of the maximum inscribed circle (hatched blue) to the area of the minimum circumscribing circle.

The equal land area circle of Angel and Parent (2011) upon which the student exchange framework for this study is premised may also be used as a measure of dispersion. In this method, an “equal land area circle” equivalent in size to the land area currently occupied by the district is created about the geographic center of the district (See Figure 15 below). This circle represents the natural, compact shape that the district would have taken in the absence of a process of student exchange, expelling certain students and replacing them with others. As a standard for assessing gerrymandering, Angel and Parent propose that districts should be required to have less than 50% of their land area outside the equal land area circle (noting that only 44 of the 435 U.S. congressional districts meet this standard). No states or courts have yet adopted this standard; more time is necessary to determine whether it will gain any traction.

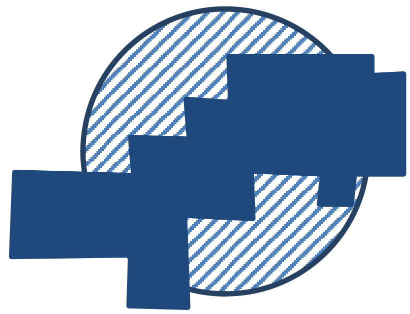


Figure 15. Angel and Parent's (2011) index compares the area of the district enclosed by the equal land area circle to the total area of the district.

Angel and Parent's measure is appealing for several reasons. First, because it situates the measurement of gerrymandering in terms of the underlying cause of gerrymandering – voter exchange – it serves not just as a measure of the appearance of bizarre shape, but as a proxy for the exchange process underlying the drawing of irregular boundaries. In addition, by quantifying gerrymandering in terms of who is "expelled" from a district, it conceives of gerrymandering, especially electoral gerrymandering, as a Constitutional "harm" because it excludes voters from districts that they should rightfully be included in.

In addition, Angel and Parent's measure exhibits several specific methodological advantages. First, unlike other measures of compactness, the equal land area circle excludes water area and area in neighboring states. As such, it is less sensitive to coastal geographies and state boundaries than other measures of contiguity and compactness. Second, Angel and Parent's experimental findings suggest that the equal land area circle is highly correlated with people's intuitive perceptions of gerrymandering (r = 0.91), which suggests a high degree of face validity. This stands in contrast to some of the other measures above, which often yield counterintuitive results, deeming figures perceived to be compact as non-compact and vice versa.

While Angel and Parent's measure exhibits a number of advantages over other measures of dispersion, like any other measure, it also has certain limitations. In particular, the equal area circle is relatively poor at identifying the gerrymandering of districts with narrow protuberances (i.e., "kite" districts) or districts with deep gauges, despite clear evidence of aggressive voter exchange (see Figure 16).

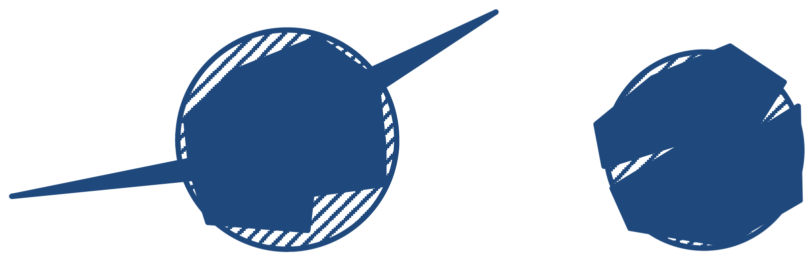


Figure 16. Angel and Parent's (2011) equal land area circle index fails to detect the aggressive gerrymandering in the districts above.

Moment of Inertia. Moment of inertia measures offer a more sophisticated alternative to simple length-width displacement measures, by including a large number of points in a district rather than just extreme points (Boyce & Clark, 1964; Kaiser, 1966; Niemi et al., 1990). Indeed, as Polsby and Popper (1991) have noted, moment of inertia measures "renders literal what Reock's measure only approximates", compactness as the relationship between every point in a shape to the shape's center (p. 345). Specifically, moment of inertia measures estimate the sum of squared distance between every point in the district and the center of gravity, or geographic center, of the district. Because the computational demands of such measures are often prohibitive, a somewhat simpler measure, originally proposed by Boyce and Clark (1964), may also be employed, measuring the average distance from the district's center of gravity to a set of points on the district perimeter reached by a set of equally spaced lines (Niemi et al., 1990).

Moment of inertia measures have considerable conceptual advantages over other measures. As noted previously, the moment of inertia uses a large sample of points within a polygon or on the edge of a polygon, providing a more sensitive measure of dispersion than those based exclusively on extremes (Niemi et al., 1990). Moreover, although extreme points are considered, they are weighted by their frequency, meaning that measures are less biased by extreme points (Niemi et al, 1990).

Despite these conceptual advantages, moment of inertia measures have several important limitations. First, moment of inertia measures may be insensitive to certain deviations from compactness, giving exceedingly high scores to non-compact, tortuous shapes such as the serpent district in Figure 12 above (Young, 1988). Second, basic moment of inertia measures lack size invariance (Young, 1988). Thus, a circle with a diameter of 15 is deemed "more compact" than a circle of diameter of 60. However, moment of inertia measures may be adjusted to provide a "relative" measure that is size invariant (Kaiser, 1966). As with other measures of compactness, a circle minimizes the moment of inertia for a given area, and is thus the most compact possible shape. Thus, the size variant moment of inertia may be adjusted to control for district size by comparing the moment of inertia to that of a circle of equal area (Kaiser, 1966).

Embeddedness

In addition to the three traditional principles of gerrymandering, I offer one additional dimension that is unique to the educational context. In educational settings, it is common for a school district to be “embedded” in another district, such that it is bordered on all sides by another, larger district (See Figure 17 below, Census 2010 TIGER/Line shapefiles). These “floating” or “island” districts are particularly common in the South, where smaller city-level districts are embedded in larger county-level districts. Such districts do not necessarily violate any of the traditional principles of gerrymandering. They are technically contiguous, in that one could travel from any point in each district to any other point in the district without leaving the district (although the most direct path may require you to leave the district). They may be equinumerous, so long as the area in district A, often the urban core, is more densely populated than the surrounding district B, often the surrounding suburb. Moreover, they may be relatively compact, exhibiting a relatively circular shape with low indentation and dispersion. While such pairs of districts satisfy the principles of contiguity, equinumerosity and compactness, by carving out a district within another district, they are decidedly gerrymandered. As such, assessment of educational gerrymandering requires attention to this unique type of boundary configuration.

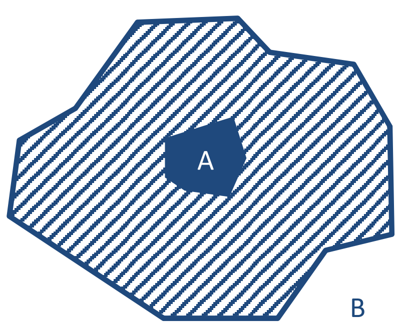


Figure 17. School district A is embedded in school district B.

Because embeddedness is a multi-district problem, as with equinumerosity, the embeddedness cannot be measured at the local, district level. Instead, the effect of embeddedness must be estimated at the level of the set of affected districts. As with contiguity, embeddedness is assessed as a categorical variable. As such, a set of districts are deemed embedded or non-embedded.

Selecting the Appropriate Measure of Gerrymandering

As the foregoing illustrates, the past half-century has witnessed a profusion of methodological work on the measurement of gerrymandering, resulting in a variety of measures of district "bizarreness." Facilitated by the availability of sophisticated geographic information systems, recent scholarship has further refined these measures and rendered compactness even more tractable. Indeed, as Justice Kennedy prophesized "new technologies may produce new methods of analysis that make more evident the precise nature of the burdens gerrymanders impose" (concurring, Vieth v. Jubelirer, 2004, 541 U.S. 8). Despite these advances, gerrymandering is still a complex phenomenon, and each principle of gerrymandering outlined above is merely a mathematical proxy that captures a unique aspect of district shape. As such, while each is useful for identifying potential gerrymanders; no one measure is sufficient to determine whether a district has been gerrymandered or to quantify the severity of the gerrymander.

Because of the array of measures available to researchers in studying gerrymandering, it is important to select the measure of gerrymandering that captures the dimension of boundary irregularity that is most relevant to the context being studied. In addition, because each measure detects some aspects of gerrymandering, but is insensitive to others, it is important that research acknowledge the strengths and limitations of the measures employed. Moreover, because there are multiple measures designed to capture each dimension, accurate diagnosis of gerrymandering should employ convergent evidence from multiple, complementary measures along each of these dimensions.

It should be emphasized that while all dimensions of gerrymandering are important and unique, above all else, gerrymanders are characterized by violations of compactness. Indeed, research has demonstrated that compactness is the most "face valid" dimension of gerrymandering, in that it comports well with individual perceptions of gerrymandering (Angel & Parent, 2011). Even more importantly, compactness is a much more ecumenical and flexible concept than contiguity and embeddedness, capturing various forms of boundary irregularity. Non-contiguous and embedded shapes are necessarily non-compact; as such, measures of compactness are also sensitive to violations of these principles. However, the reverse is not true – non-compact shapes are not necessarily non-contiguous or embedded. Thus, it may be argued that compactness constitutes the single most important aspect of boundary irregularity. Of course, like the other spatial measures, compactness is insensitive to the aspatial dimension of inequinumerosity. However, this is less relevant in the school context, since there is no reasonable expectation of population equivalence in the case of school districts, and only a weak expectation of population equivalence in the case of schools. For these reasons, discussed at length in the methodology, the current study focuses on the compactness of educational boundaries.

CHAPTER 3: METHODOLOGY

This study employs complementary geospatial techniques and regression models to analyze how the process of student exchange manifested in the gerrymandering of educational boundaries serves to ameliorate or perpetuate racial and ethnic inequities in American schools. For both school attendance zones and school districts, a two-phase analytic approach is employed. The first phase of analysis addresses Research Questions 1 and 3, which are reiterated below:

1) *How gerrymandered are U.S. public school attendance zones?*
3) *How gerrymandered are U.S. public school districts? How does school district gerrymandering relate to school attendance zone gerrymandering?*

In addition to descriptive analyses documenting the prevalence and severity of gerrymandering, regression models are estimated to address subquestions 1a and 3a, regarding variation in the gerrymandering of educational boundaries across geographic and demographic contexts. The analytic technique for the first phase of analysis is discussed at length below, while results for school attendance zones and school districts are reported in the first part of Chapters 4 and 5, respectively.

The second phase of analysis addresses Research Questions 2 and 4, which are reiterated below:

2) *Does school attendance zone gerrymandering serve to segregate or integrate students by race/ethnicity? How much would school diversity be improved or worsened through rezoning designed to minimize gerrymandering?*

4) *Does school district gerrymandering serve to segregate or integrate students by race/ethnicity? How much would school district diversity be improved or worsened through rezoning designed to minimize gerrymandering?*

In addition to these omnibus questions, regression models are estimated to address subquestions 2a and 4a, regarding variation in the segregative effects of gerrymandering of educational boundaries on school and district diversity across geographic and demographic contexts. In particular, the analyses attend to how the racial and ethnic characteristics of students residing in school attendance zones and school districts drive the process of student exchange. Results of the second phase of analysis for school attendance zones and school districts are reported in the second part of Chapters 4 and 5, respectively.

In the following sections, I outline the analytic strategy for each phase of analysis, outline all sources of data, describe the sample of school attendance zones and school districts, identify and operationalize all dependent and independent variables, and discuss the specific analytic models used in the study.

Analytic Technique

Phase I: How Gerrymandered are U.S. Public School Attendance Zones and Districts?

Because this study constitutes the first empirical work on educational boundary gerrymandering, the first phase of analysis is descriptive, documenting the severity and prevalence of educational boundary gerrymandering in U.S. public schools and school districts. As noted previously, because schools and school districts do not have a clear expectation of equinumerosity, like electoral districts, this study focuses exclusively on spatial aspects of gerrymandering manifested in boundary “bizarreness”. In addition, because of the singular importance of compactness as an indicator of gerrymandering, which is sensitive to violations of contiguity and embeddedness, this study focuses on the extent to which educational boundaries are gerrymandered into non-compact shapes. Moreover, as will be discussed at length below, the analysis in the second phase assesses the effect of gerrymandering on school and school district diversity by comparing actual boundaries to maximally-compact boundaries. Thus, using measures of compactness ensures alignment between the first and second phases of analysis.

Specifically, gerrymandering is quantified using two complementary measures of compactness. I employ a perimeter-based measure of compactness, the classic Schwartzberg index, which quantifies compactness in terms of the ratio of the perimeter of a district to the perimeter of a district with equal area. Because the Schwartzberg index, as a perimeter-based measure of compactness, is often overly sensitive to perimeter length and insufficiently sensitive to shape, I supplement the index with an areal measure of compactness. Specifically, I use the more recently-developed Polsby-Popper index, which quantifies compactness in terms of the ratio of the area of a district to the area of a district with equal perimeter. Although the Polsby-Popper index, as an area-based measure of compactness, is often overly sensitive to shape irregularity, and insufficiently sensitive to perimeter, when coupled with the Schwartzberg index, the two measures provide a fairly comprehensive assessment of shape irregularity – in terms of both perimeter and area.

To assess contextual variation in gerrymandering, measures of compactness are regressed on a variety of school and school district covariates to determine the extent to which gerrymandering varies across geographic and demographic contexts, including: core-based statistical area type (e.g., metropolitan or micropolitan), locality (i.e., urban, suburban, rural, town), history of de jure segregation, proportion of students that qualify for free- and reduced-price lunch, student race/ethnicity, and student population.

Phase II: Effect of Gerrymandering on School Attendance Zone and District Diversity

In the second phase of analysis, I examine the consequences of educational boundary gerrymandering for school and school district equity, investigating whether the gerrymandering of school attendance zone and school district boundaries serves to segregate or integrate students by race/ethnicity. This is accomplished by comparing the characteristics of students residing in existing school attendance zones and school districts to those residing in ideal, maximally-compact zones and districts representing the "natural" shape each zone and district would be expected to assume in the absence of gerrymandering. The racial/ethnic composition of all boundaries in the study was determined by spatially mapping the boundaries of each district to U.S. Census blocks and aggregating block-level demographic data on the racial/ethnic characteristics of children from the Census 2010 Summary File 1.

For both school attendance zones and school districts, the effect of gerrymandering on diversity is estimated by comparing the diversity of students in actual school attendance zones and districts to students in the equal land area circle of Angel and Parent (2011) corresponding to each zone and district. As discussed previously, because a circle is the most compact possible figure, the equal land area circle, which is equivalent in size to the land area currently occupied by the district, may be interpreted as the “natural” district that would exist if the district boundaries had not been intentionally manipulated into irregularity by expelling certain students in the original district and replacing them with students in outlying areas.

Figure 18 provides an illustration of sample “natural” equal land area school attendance zones that would be expected in the absence of gerrymandering (red circles) for a given district, overlaid on the actual school attendance zones from the SABINS sample (blue). For school attendance zones, the equal land area circle zones were created around the geographic location of each school. Comparable equal land area circle districts were conducted for school districts. However, for school districts, equal land area circles were created around the geographic centroid of the district, rather than a specific school location.

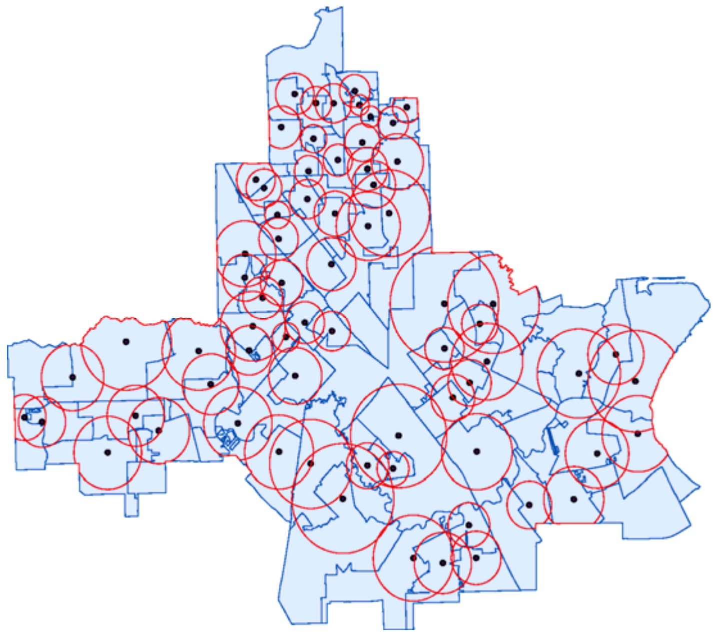


Figure 18. Example of equal land area circle school attendance zoning in Pasadena ISD, Texas. School locations are indicated by black dots, school attendance zones are demarcated in blue, and "natural" equal land area zones are demarcated by red

As the figure above illustrates, while it is feasible for a single school attendance zone or district to be circular, in practice, it is not feasible to assume that all districts to be circular, as they would overlap and/or exclude certain areas. As such, an additional analysis was conducted comparing the diversity of students residing in actual attendance zones to those residing in the Voronoi polygonal attendance zone corresponding to each attendance zone. While Voronoi polygons do not maximize compactness to the extent of the circular district, these zones are ideal in that they are fully convex, with no perimeter concavities. Moreover, they are maximally efficient, in that they minimize student travel distance to school.

Because the Voronoi algorithm presumes that schools attract roughly equivalent numbers of students—a presumption of equinumerosity that is not applicable to school districts—a parallel analysis was not conducted school districts. As such, the analysis of the effects of gerrymandering on school district diversity was limited to models using equal land area circles as the districts' "natural" zones. Figure 19 below provides an illustration of a sample district featuring actual school attendance zones as well as "natural" Voronoi districts that would be expected in the absence of gerrymandering.

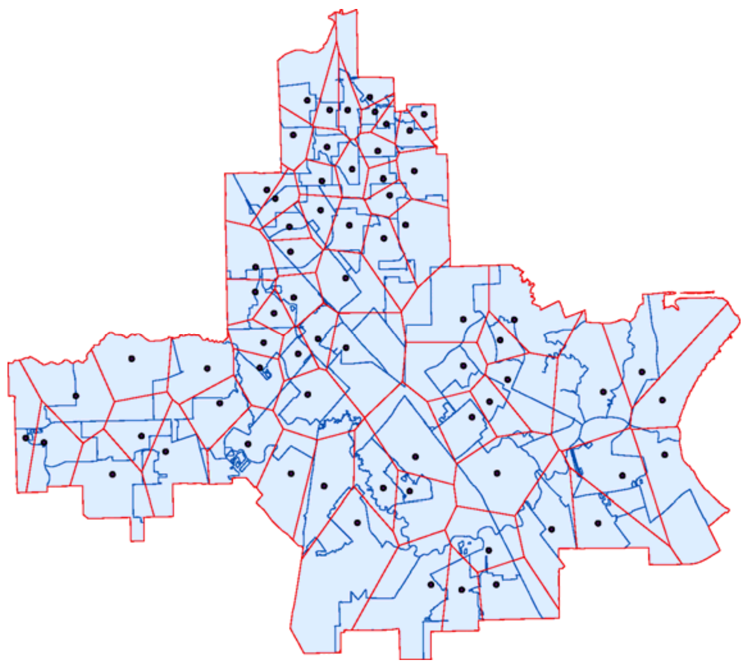


Figure 19. Example of Voronoi school attendance zoning in Pasadena ISD, Texas. School locations are indicated by black dots, school attendance zones are demarcated in blue, and Voronoi polygonal zones are demarcated with red lines.

For both the equal land area circle analyses and the Voronoi analyses, the effect of gerrymandering on diversity is quantified as the percentage increase in diversity that would be expected if boundaries were not gerrymandered. To determine the extent to which gerrymandering varies across geographic and demographic contexts, the percentage change in diversity associated with elimination of gerrymandering is regressed on a variety of school and school district covariates, including: core-based statistical area type (e.g., metropolitan or micropolitan), locality (i.e., urban, suburban, rural, town), history of *de jure* segregation, proportion of students that qualify for free- and reduced-price lunch, student race/ethnicity, and student population.

Particular attention is paid to the relationship between the segregative effect of gerrymandering and the racial/ethnic characteristics of students residing in the "core" of each attendance zone and school district. The "core" zone or district refers to the portion of the natural, non-gerrymandered attendance zone or district that is also located in the gerrymandered, actual attendance zone or district. Because students in the "core" zone or district are neither "zoned in" nor "zoned out" in the student exchange process, they may be viewed as the drivers behind the student exchange process. As such, it is of particular importance to examine how the racial and ethnic characteristics of students in this core zone drive the process of student exchange.

Effect vs. intent of gerrymandering. The methodology employed in this study provides direct evidence of the current *effect* of boundary gerrymandering on the racial/ethnic composition of school attendance zones and school districts. However, the cross-sectional methodology employed by the study does not provide a strong basis for inferring the *intent* of educational boundary gerrymandering, because it is possible that the racial/ethnic composition of students residing in an educational boundary has changed since the boundary was originally established, meaning that the segregative effect of gerrymandering may be the result of individual residential decisions since boundaries were established. Thus, while deviations from regularity suggest that boundaries were intentionally manipulated, and the current effect of that manipulation may be deemed segregative or integrative, the study cannot definitively determine whether boundaries were originally manipulated with a discriminatory intent of segregating students or an affirmative intent of integrating students.

While it is impossible to definitively establish intent using such a cross-sectional methodology, it should be noted that the basis for causal inference differs somewhat for school attendance zones and school districts, with a somewhat sounder basis for causal inference regarding the intent of school attendance zone gerrymandering than for school district gerrymandering. Because attendance zones are reviewed and modified regularly to accommodate changes in district population as well as changes in the supply of schools (e.g., facility openings and closures and expansions), it is likely that the characteristics of students in their current boundaries fairly accurately represent the characteristics of students in the boundaries at the time of boundary adoption. Thus, the analysis provides a fairly strong basis for inferences about the discriminatory or affirmative intent of school attendance zone boundaries to segregate or integrate.

While school district boundaries certainly change over time, overall, they are much more stable than school attendance zone boundaries, reflecting their coterminity with other more permanent political boundaries (e.g., counties) as well as additional political and legal barriers to their modification. Given that district boundaries may have been established decades ago, the demographic characteristics of students residing in and around school districts may have changed substantially since the boundaries were adopted. In particular, given the important role that school districts play in residential decisions, individuals may have sorted across boundaries, making them more segregated than they were when established. As a result, although the presence of irregular boundaries provides direct evidence that boundaries were originally gerrymandered to exchange students for some reason, it cannot be inferred from the characteristics of current residents whether the boundaries were intentionally manipulated to segregate students by race/ethnicity without comparing boundaries to the racial/ethnic characteristics of students contemporaneous to the establishment of the district boundary. Thus, there is a weaker basis for inferring the discriminatory or affirmative intent of school district boundaries on the basis of whether they currently segregate or integrate.

Data Sources

This study leverages multiple sources of publicly-available spatial data coupled with geographic and demographic data to examine the severity of educational gerrymandering and its effects on the diversity of schools and school districts. Below, I outline each data source and the information obtained from each source. Table 2 provides a crosswalk between each data source and each of the study variables.

Spatial Boundary Data

School attendance zone and school district boundaries were obtained from two different data sources. To facilitate spatial analysis in geographic information systems software, all educational boundaries were downloaded and analyzed as Esri "shapefiles", a proprietary file format containing geospatial vector data for use in ArcGIS®.

School attendance zone boundaries. School attendance zone boundary shapefiles for the 2009-10 school year were obtained from the School Attendance Boundary Information System (SABINS). The SABINS database is a novel, National

Science Foundation-funded repository for digital GIS national school attendance zone data. Because the SABINS project is still in its early stages, the database currently only contains shapefiles for the 2009-10 school year. SABINS shapefiles were obtained via the National Historical Geographic Information Systems (NHGIS) website.

Elementary school attendance zones are 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). Thus, irregularities in middle school and high school boundaries are often just aggregations of the irregularities in multiple smaller elementary school boundaries. Thus, the analysis focused exclusively on elementary school attendance zone boundaries, operationalized as those school attendance zones in the SABINS sample which served students in first grade.

In addition, only school attendance zones located in U.S. Census “core-based statistical areas” were selected for further analysis. Under U.S. Census definitions, urban areas, or “core-based statistical areas”, may be classified into two types: metropolitan statistical areas and micropolitan statistical areas. To be classified as a metropolitan statistical area, a core-based statistical area must have an urbanized area of more than 50,000, while a micropolitan area must have an urbanized area with a population of more than 10,000 but less than 50,000.

School district boundaries. School district boundary shapefiles were obtained from the U.S. Census Topologically Integrated Geographic Encoding and Referencing (TIGER)/Line® system. Although the vast majority of U.S. school districts are “unified” districts, serving both elementary and secondary students, the TIGER/Line system also contains spatial data on those districts serving only elementary students and secondary students. For temporal comparability with school attendance zones, school district shapefiles for 2010 were used in the study. As with school attendance zones, only school districts located in U.S. Census "core-based statistical areas" were selected for further analysis.

Sources of Geographic and Demographic Data

Census 2010 Summary File 1. Census 2010 block-level demographic estimates of the number of students enrolled in school by student race/ethnicity were obtained via the NHGIS site. These data were used to compute measures of racial/ethnic diversity for each attendance zone and district by spatially linking Census data on student race/ethnicity at the block level to the spatial boundaries discussed above. In addition, measures were used to provide demographic covariates for each school attendance zone and district.

The Census block is the smallest unit of analysis at which the Census Bureau collects and tabulates decennial census data (U.S. Census Bureau, 2011). Because of confidentiality concerns associated with reporting data at such a granular level, data available at this level is somewhat limited. As such, while data on resident race/ethnicity is available at the block level, data on poverty and socioeconomic status are not available at this level. While the geographic area of a Census block may vary widely, in urban areas it is typically the size of a single city block. In 2010, there were approximately 11,078,297 blocks in the U.S. and 308.7 million residents, 74.2 million of whom were under the age of 18. Thus, in terms of population, each block contains an average of 28 residents, 7 of whom are children under the age of 18.

Census data on the race/ethnicity of children residing in each block were spatially linked to attendance zone and district boundaries to determine the characteristics of students residing in each boundary. Because the Census does not directly report the number of children in each block disaggregated by race/ethnicity, the information was computed indirectly by comparing the total population of each block to the population of individuals over the age of 18. Subtracting the number of individuals above the age of 18 from the total population for each racial/ethnic category yielded the number of children in each block by race/ethnicity. Although not all individuals under the age of 18 are enrolled in public schools (i.e., they may attend private school, be too young for school, have graduated, or have dropped out of school), it provides a proxy for the characteristics of students residing in each block.

Student race/ethnicity data was obtained via the data field capturing "Hispanic or Latino, and not Hispanic or Latino by Race" (P9), which classifies students as either Hispanic or Latino or as a member of one of eight racial categories: American Indian/Alaska Native, Asian, non-Hispanic Black, Hispanic, Native Hawaiian/Pacific Islander, non-Hispanic White, Other, or two or more races. Although such a system conflates race and ethnicity (i.e., a student must be classified as either Hispanic *or* white, not both), it is desirable because it provides findings that are comparable to previous research on school segregation, which has almost exclusively relied on NCES CCD data. For analytical purposes, all calculations of diversity and segregation computed on Census block data used a slightly more parsimonious seven-category system combining students of Other race with students of two or more races.

NCES CCD 2009-10. School- and district-level geographic covariates were obtained from the National Center for Education Statistics (NCES) Common Core of Data (CCD). Schools and districts were classified according to the type of core-based statistical area in which they are located (i.e., metropolitan or micropolitan), which is available in the Local Education Agency (School District) Universe Survey Data file. In addition, school attendance zone and school district locality type (e.g., city, suburb, town, rural) was obtained from the NCES CCD (data field: ULOCAL). Data on student race/ethnicity for each school and district in the samples (data fields: AM, ASIAN, BLACK, HISP, PACIFIC, TR, and WHITE) used in the first phase of analysis were also drawn from the NCES CCD. All data from the NCES CCD was linked to school attendance zone and school district boundaries via common geographic identifiers with SABINS and Census TIGER/Line. For temporal comparability with SABINS and Tiger/LINE shapefiles, NCES data for the 2009-10 school year were used for analysis.

U.S. Commission on Civil Rights 2008. Information on school district desegregation status was obtained from a comprehensive 2008 report issued by the U.S. Commission on Civil Rights, which classifies school districts as: 1) in unitary status, and no longer under federal court oversight, 2) currently under federal court order, or 3) never subject to federal school desegregation litigation. The report contains data on 90% of all school districts currently under federal desegregation order (238 of 266), including all districts in the states of Alabama, Florida, Georgia, Louisiana, Mississippi, North

Carolina, and South Carolina, and Tennessee. This list does not include other desegregation orders to which the United States is not a legal party; however, there is no reliable or comprehensive on evidence on these cases (U.S. Commission on Civil Rights, 2008).

Sample

Below I describe the samples of school attendance zones and school districts used in the study analysis. It should be noted that these samples apply to the analysis as a whole; however, each of the regression models used in the analysis may use slightly different subsamples and levels of aggregation.

Sample of School Attendance Zones

The SABINS data set contains boundary data on nearly 21,000 school attendance zones in 47 states, excluding Hawaii, Louisiana, and Nevada, and the District of Columbia. Complete attendance zone data are available for the states of Delaware, Minnesota, and Oregon. It is somewhat unclear what proportion of the population of school attendance zones this sample constitutes. Although it is not known how many attendance zones exist in the U.S., Saporito and Warren (SABINS, 2011) have estimated that they number roughly 70,000 to 80,000. As such, it is estimated that the SABINS sample contains 26% to 30% of the total population of school attendance zones.

Several filters were applied to the SABINS sample of school attendance zones to arrive at the final analytic sample. First, as discussed previously, only the 13,412 elementary school attendance zones in the SABINS sample were selected for analysis. Map 1 shows the geographic distribution of all elementary school attendance zones in the

SABINS sample. This sample accounts for 25.1% of all 53,460 elementary schools in the U.S. Second, as discussed previously, the SABINS sample was filtered to include only those 11,013 school attendance zones located in core-based statistical areas as defined by the U.S. Census, including both metropolitan and micropolitan statistical areas. Map 2 shows the geographic distribution of all school attendance zones in the SABINS sample located in metropolitan and micropolitan statistical areas. Finally, because school districts with only one attendance zone have attendance zone boundaries that are coterminous with district boundaries, these zones are do not permit any boundary manipulation independent of district boundaries and are therefore not of empirical concern. Thus, the 4,704 school attendance zones located in districts with only one attendance zone were also excluded from analysis.

Application of these filters yielded a final analytic sample of 9,717 school attendance zones in 3,139 school districts. Map 3 shows the geographic distribution of the school attendance zones in the final study sample. As the map illustrates, the attendance zones in the final sample are concentrated in the 19 states of Arizona, California, Connecticut, Delaware, the District of Columbia, Florida, Georgia, Kansas, Maryland, Massachusetts, Minnesota, Missouri, Oregon, Pennsylvania, Rhode Island, Texas, Virginia, Wisconsin and Wyoming. Although the attendance zones in the sample do not cover a large proportion of the land area of the U.S., they account for 22.7% of the 47,953 schools in the population of interest (i.e., elementary schools located in metropolitan and micropolitan districts with two or more schools).

As discussed above, separate analyses were conducted to assess the effects of gerrymandering on school attendance zone diversity, one comparing attendance zones to equal land area circle zones and another comparing attendance zones to Voronoi polygonal zones. Because the equal land area circle creates ideal attendance zones for each individual school attendance zone independent of other attendance zones, it employs the full SABINS sample of attendance zones described above. However, the creation of convex polygonal zones according to the Voronoi algorithm necessitates analysis of a set of attendance zones in a school district. By definition, a Voronoi attendance zone for a school is defined as the area within which all students are closer to that school than to any other school. Thus, the creation of Voronoi attendance zones must be computed on a set of attendance zones within a district. As such, it was only possible to construct Voronoi attendance zones on the sample of attendance zones in districts reporting all elementary school attendance zone data. This yielded a subsample for the Voronoi analysis of 3,204 schools in 282 districts. Map 4 shows the geographic distribution of the school attendance zones in the Voronoi subsample.

Table 3 summarizes the demographic and geographic characteristics of the full SABINS sample of school attendance zones and the Voronoi sample compared to population values. As Table 3 reveals, schools in the full SABINS sample are slightly larger, on average, than schools in the population (519 students vs. 464 students), while those in the Voronoi subsample are larger still (576). Demographically, both the full and Voronoi samples slightly underestimate the proportion of whites and blacks in comparable schools, and slightly overestimate the population of Asians and Hispanics.

While the full SABINS sample slightly overestimates the proportion of students eligible for free and reduced-price lunch status (50.4% vs. 49.8%), the Voronoi subsample slightly underestimates the population (44.4% vs. 49.8%).

In terms of geography, the full SABINS sample was fairly equivalent to the population in terms of the proportion of schools located in metropolitan vs. micropolitan areas (86.0% metropolitan for sample vs. 86.3% for population). The Voronoi sample, however, was considerably more concentrated in metropolitan areas than the population, with only 3.3% of schools located in micropolitan areas. In terms of locality, the schools in the full sample are slightly less likely to be located in urban areas (27.3% vs. 31.5%) or towns (8.8% vs. 11.3%), and slightly more likely to be located in suburban (36.1% vs. 33.2%) and rural areas (27.8% vs. 23.9%). Likewise, schools in the Voronoi sample are less likely to be located in urban areas (25.1% vs. 31.5%), towns (5.7% vs. 11.3%), and rural areas (16.5% vs. 23.9%), and considerably more likely to be located in suburbs (52.7% vs. 33.2%). Schools in both the full and Voronoi samples are also slightly more likely to be located in the formerly *de jure* segregated South than the population as a whole (42.2% for the full sample and 43.1% for the Voronoi sample vs. 35.5% for the population). On the whole, however, the full SABINS sample is fairly comparable to the population in terms of demographics and geography, while the Voronoi sample is slightly more affluent and more suburban, although less white, than the population.

Sample of School Districts

Unlike school attendance zones, for which there are no national reporting requirements, school districts are required to provide spatial boundary data to the U.S.

Census biennially. As such, the Census TIGER/Line data contains shapefiles for the entire population of U.S. regular public school districts with a defined spatial extent. While there are over 18,000 school districts in the U.S. according to the NCES CCD, there are roughly 13,760 spatial school districts in the Census TIGER/Line sample. This discrepancy is attributable to the fact that many districts, including charter-only districts (n = 2,236) and administrative or regional education agencies (n = 1,521), do not have clearly delineated boundaries and were thus not available for spatial analysis. Map 5 shows all spatial U.S. public school districts. As with the sample of school attendance zones, the sample of school districts was restricted to those districts located in core-based statistical areas. Thus, the final sample contained 9,796 school districts, accounting for 72.3% of all U.S. school districts and more than four-fifths of all students. Map 6 shows the geographic distribution of all public school districts located in core-based statistical areas.

Table 4 summarizes the demographic and geographic characteristics of the school district sample. Because the sample comprises the full population of school districts located in core-based statistical areas, no population comparison is necessary.

Sample of Census blocks. As discussed previously, the characteristics of school attendance zones and school districts are derived by spatially merging these boundaries with Census blocks to identify the blocks comprising each school attendance zone and district. The characteristics of each school attendance zone and district are then calculated by aggregating Census block characteristics at the appropriate geographic level. School attendance zones in the sample contained a total of 4,646,375 Census blocks (accounting for 41.9% of all U.S. Census blocks), meaning that there are approximately 478 Census blocks per district in the sample. Districts in the sample contained a total of 9,590,066 Census blocks (accounting for 86.6% of all U.S. Census blocks), meaning that there are approximately 982 Census blocks per district in the sample. These aggregate figures likely underestimate the number of block groups in non-rural districts, especially those in more densely populated metropolitan and micropolitan areas.

Phase I: Study Variables

Tables 2 and 3 outline each of the dependent and independent variables used in the first phase of the study, documenting the severity of school attendance zone and school district gerrymandering and the extent to which gerrymandering varies across geographic and demographic contexts. Below I discuss these variables in detail, addressing the computation method, level of analysis, and interpretation of each.

Dependent Variable - School Attendance Zone and School District Compactness

The gerrymandering of each school attendance zone and school district was quantified using two complementary measures of compactness: the Schwartzberg and Polsby-Popper indices. As discussed in Chapter 2, the Schwartzberg index is more sensitive to perimeter length, while the Polsby-Popper index is more sensitive to irregular shape. Thus, taken together, these indices provide convergent evidence of violations of compactness, accounting for irregularities in both the perimeter and shape of the district polygon. Moreover, because the second phase of the study assesses the effects of gerrymandering on school diversity by comparing actual attendance zones and districts to the equal land area circle (deemed the most compact possible shape according to both

Schwartzberg and Polsby-Popper indices), these measures ensure alignment between the first and second phases of analysis. The computation procedure for each measure is discussed in detail below.

Schwartzberg. The Schwartzberg index measures the indentation of a polygon by comparing its perimeter to the perimeter of a circle with equal area. Mathematically, the Schwartzberg measure may be represented as follows:

$$C = \frac{p}{2\sqrt{\pi a}}$$

where p is the perimeter of the polygon and a is the area of the polygon. The Schwartzberg index ranges from 0 to 1, where 1 represents a perfectly compact shape (i.e., a circle). Because any polygon must necessarily have a non-zero perimeter and area, it is impossible for the Schwartzberg index to reach 0; as such, it asymptotically approaches 0.

Polsby-Popper. The Polsby-Popper index measures the indentation of a polygon by comparing its area to the area of a circle with equal perimeter. Mathematically, the Polsby-Popper measure may be represented as follows:

$$C = \frac{4\pi a}{p^2}$$

where a is the area of the polygon and p is the perimeter of the polygon. As with the Schwartzberg index, the Polsby-Popper index ranges from 0 to 1, where 1 represents a perfectly compact shape (i.e., a circle). Again, because any polygon must necessarily have non-zero perimeter and area, it is impossible for the Polsby-Popper index to reach 0; as such, it asymptotically approaches 0.

Independent Variables

An array of contextual covariates were added to the regression models predicting school attendance zone and school district gerrymandering to assess heterogeneity in the effects of gerrymandering across geographic and demographic contexts.

Core-Based Statistical Area type. For both school attendance zones and school districts, regression models predicting gerrymandering contained a dichotomous variable capturing whether the school or district is located in a metropolitan statistical area or micropolitan statistical area, with micropolitan as the reference category. Core-based statistical area type was obtained via the NCES CCD Local Education Agency Universe data.

Locality. School attendance zone and school district locality was obtained via the NCES CCD. The NCES CCD classifies localities according to four main locality types: city, suburb, town, and rural. Each type of locality has three subtypes representing the size of the locality – large, midsize and small for city and suburb localities and fringe, distant, and remote for town and rural localities. For the purpose of this analysis, districts were be categorized according to their primary locality type, aggregating across locality subtype, with rural locality type as the reference category.

Free- and reduced-price lunch. A measure of the proportion of students in a school that qualify for either free- or reduced-price lunch, computed from NCES CCD data, was added to models predicting both school attendance zone and school district gerrymandering.

Student race/ethnicity. Three measures of student race/ethnicity derived from NCES CCD data were incorporated into the models predicting school attendance zone and school district gerrymandering: percent white, percent black, and percent Hispanic.

Student population. For both school attendance zones and school districts, a log-transformed measure of student population, obtained via the NCES CCD, was added to regression models as a control variable.

History of *de jure* segregation. For school attendance zones, a dichotomous variable capturing whether the state in which the metropolitan area is located was historically subject to *de jure* segregation is added to the regression models. School attendance zones located in Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia were coded as located in the formerly *de jure* segregated South (and Border states). School attendance zones located in states not subject to *de jure* segregation were coded as the reference category for regression analyses.

Whereas school attendance zones in the formerly *de* jure segregated South may be expected to differ from those in the rest of the U.S. owing to the legacy of desegregation efforts, which often utilized irregular boundaries and busing patterns to achieve integration, there is no theoretical reason to expect district boundaries in the formerly *de jure* segregated South to differ from those in the rest of the U.S. in terms of their gerrymandering, because district boundaries were generally left intact by desegregation policies. As such, this variable was not included in models predicting school district gerrymandering.

History of desegregation order. In addition, for the subsample of 1,286 school attendance zones located in districts for which data on federal desegregation orders are available in the U.S. Commission on Civil Rights report, a dichotomous variable representing the status of court-ordered desegregation in the district was created. School attendance zones were coded as being in districts either 1) subject to desegregation orders, either granted unitary status or currently under federal court ordered desegregation, or 2) never subject to federal school desegregation litigation, with the latter coded as the reference category.

Although desegregation orders are generally issued at the district level, this variable is only relevant to gerrymandering at the school attendance zone level, because district desegregation orders often necessitated the manipulation of school attendance zone boundaries, but did not dictate the boundaries of school districts themselves.

District compactness. Because school attendance zone gerrymandering may reflect school district gerrymandering where school attendance zone boundaries are coterminous with school district boundaries, it is essential to disentangle the effects of gerrymandered attendance zones from gerrymandered districts. As such, the Schwartzberg and Polsby-Popper indices for the districts containing each school attendance zone were added to regression models as a control variable.

Phase II: Study Variables

Tables 2 and 3 outline each of the dependent and independent variables used in the second phase of the study, examining the effects of school attendance zone and school district gerrymandering on diversity and contextual variation in these effects across geographic and demographic contexts. Below I discuss these variables in detail, addressing the computation method, level of analysis, and interpretation of each.

Dependent Variable – Effect of Gerrymandering on Diversity

As discussed above, school attendance zones and school districts were compared to their "natural" districts to obtain the effect of gerrymandering on school attendance zone and district diversity. For school attendance zones, the diversity of each actual attendance zone was compared to the diversity of its corresponding equal land area circle zone, and its corresponding Voronoi polygon zone. For school districts, the diversity of each actual district was compared to the diversity of its corresponding equal land area circle zone. Indices capturing the effect of gerrymandering on each of these measures of diversity were used as the dependent variables in the ordinary least squares regression models estimating contextual variation in the effects of gerrymandering on school attendance zone and district racial/ethnic equity.

Creation of the equal land area circle. As discussed previously, the equal area circle proposed by Angel and Parent (2011) represents the natural shape that a school attendance zone or school district would be expected to take in the absence of any "student exchange" through boundary gerrymandering. As such, this is used as the standard against which individual school attendance zones and districts are measured to determine the extent to which the irregular manipulation of boundaries has affected the racial and ethnic diversity of schools and districts.

For each school attendance zone and school district in the sample, the equal land area circle was created in ArcGIS using the following procedure. First, the land area of each polygon (i.e., school attendance zone or district boundary) was calculated. Second, for school districts, the geographic center or center of gravity of each district polygon was located and mapped. For school attendance zones, the latitude and longitude of the school were used as the “centroid” of the zone. Finally, the equal land area circle was created around each school district’s geographic center and each school attendance zone’s school location, by creating a “circular buffer” with the area equal to the polygon area computed in the first step. Because it is not feasible for attendance zones to cross current school district boundaries, the area outside each attendance zone’s school district boundary was excluded from the land area circle. An example of equal land area circle zones created according to this procedure is depicted in Figure 18.

Once the equal area circle for each school attendance zone and school district were created, the boundaries of current zones and districts as well as the equal land area zones and districts were spatially merged to block-level Census data on student race/ethnicity. These data were then aggregated at the school attendance zone and district level and used to calculate measures of diversity.

Creation of the Voronoi polygonal attendance zones. Computational geometric techniques were used to create alternative zoning schemes for the school attendance zones in the Voronoi sample. Specifically, the study uses a Voronoi algorithm to create sets of school attendance zones within districts that are contiguous, non-embedded, relatively compact, and convex.

Voronoi diagrams, alternately known as Dirichlet tessellations, have been frequently applied in a broad range of disciplines to assist in decisions regarding the location of retail stores (e.g., Boots & South, 1997), hospitals (e.g., Schuurman et al., 2006), and transportation routes (Abellanas et al., 2003). Although they have not yet been widely applied to the realm of education, a handful of international studies have utilized Voronoi techniques. Notably, Pearce (2000) assessed the validity of Voronoi polygons as proxies for school catchment areas in the U.K., while Karimi, Delavar and Mostafavi (2009) used the technique to inform the location of educational centers in Israel. While the bulk of prior applied research has applied the Voronoi diagram technique to determine where facilities should be located, this study applies Voronoi diagrams to address the corollary problem: given the location of facilities (i.e., schools), where should boundaries be drawn?

Before I describe the process for creating Voronoi-type educational districts, a brief discussion of the geometric properties of Voronoi polygons is warranted. At the most basic level, a Voronoi diagram partitions the space around a set of points, such that each point is contained in a single polygon. As shown in Figure 20, a Voronoi diagram consists of a set of polygons around a set of points, each having the property that all locations in the polygon are closer to their "central point" than to any other point (Aurenhammer, 1991; Miles & Maillardet, 1982; Okabe et al., 2000). The area of the polygon containing each point is defined by starting at the central point and expanding outward at identical rates for all points in the set. This results in a set of tessellated polygons, which may be formally represented as follows:

$$V_i = \{x \mid \| x - x_i \| = \| x - x_j \|\}$$

for $i \neq j$, where x_i and x_j are location vectors and V_i is the Voronoi region for point i. As Figure 20 illustrates, all polygons in a Voronoi diagram have the property of being convex, contiguous, and non-embedded (Karimi et al, 2009). Because they are characterized by straight-line edges, and are thus necessarily non-circular, Voronoi polygons must necessarily diverge from perfect compactness according to the measures discussed in Chapter 2. While they may not be perfectly compact, Voronoi polygons are optimally compact, in that they maximize the compactness of the boundaries for the set of schools in a given district, given the predetermined location of schools.

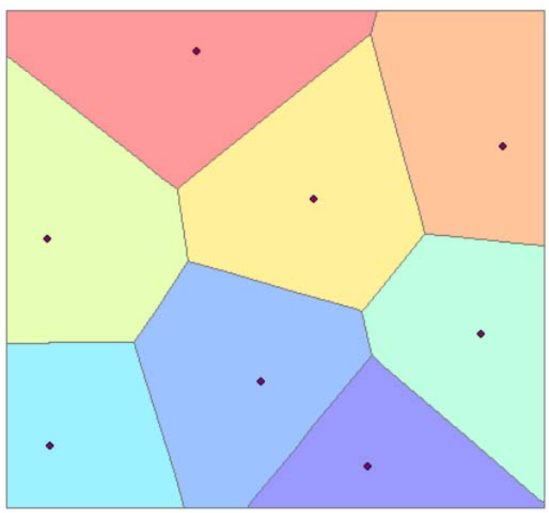


Figure 20. Ordinary Voronoi diagram of polygons around random points in space.
Note: Figure adapted from Karimi et al. (2009).

Applying the Voronoi algorithm to the realm of school attendance rezoning, each school may be viewed as a "central point" of the Voronoi polygon. As such, in a Voronoi school attendance re-zoning algorithm, all attendance zones have the property that each student in each attendance zone lives closer to that school than to any other school in the district. An example of actual Voronoi polygonal attendance zones created according to this procedure is depicted in Figure 19. Once the Voronoi polygonal attendance zones have been created, they were spatially merged with block-level Census data on student race/ethnicity. These data were then aggregated at the school attendance zone level and used to calculate measures of diversity.

Calculating diversity. Several measures of racial/ethnic diversity were calculated for each school attendance zone and school district and their corresponding equal land area circles and Voronoi polygons. For each of the school attendance zones and school districts in the study, three measures of racial/ethnic diversity were computed: 1) multiracial diversity, 2) black-white diversity, and 3) Hispanic-white diversity.

Diversity is quantified using Simpson's diversity index as a function of the number of different subgroups in a given area relative to the proportion of the population that belongs to each subgroup. Holding the number of subgroups constant, areas in which all groups are evenly represented have high rates of diversity, while areas where one group is significantly over- or under-represented have low diversity. Likewise, holding the proportion of the population in each group constant, areas with more groups have higher diversity while areas with fewer groups have lower diversity. Specifically, diversity was calculated as follows:

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

where r is the number of racial ethnic groups in a population and p_i refers to a particular racial/ethnic group's proportion of the school population. For measures of multiracial diversity, because students are classified according to seven racial/ethnic groups outlined above (i.e., American Indian/Alaska Native, Asian, non-Hispanic Black, Hispanic, Native Hawaiian/Pacific Islander, non-Hispanic White, Other, or two or more races), r is seven. For dual-group measures of black-white and Hispanic-white diversity, r is two.

Simpson's diversity index may be interpreted as the probability that two students in a given school or district belong to different racial/ethnic categories. 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). In the context of this study, Simpson's index may be interpreted as the probability that two students at a given school or district belong to different racial/ethnic categories. Although a number of alternative measures of diversity are available, such as the Shannon index, the Simpson index is particularly appealing because of its intuitive interpretation.

Effect of gerrymandering on diversity. For each school attendance zone and school district in the sample, the effect of gerrymandering on diversity is quantified as the percent by which "natural" or ideal school attendance zones are more or less diverse than their corresponding actual attendance zones. This is equivalent to the amount by which school attendance zone or school district diversity would increase or decrease if gerrymandering were eliminated.

For example, if a school attendance zone's has a multiracial diversity index of 0.6 (i.e., a 60% chance that two randomly selected students belong to different racial/ethnic groups), but its equal land area circle zone (or Voronoi polygonal zone) has a multiracial diversity index of 0.7 (i.e., a 70% chance that two randomly selected students belong to different racial/ethnic groups), the effect of gerrymandering on the diversity of this school is calculated as follows:

$$\Delta Div = \frac{Div_{Natural} - Div_{Actual}}{Div_{Actual}} = \frac{0.7 - 0.6}{0.6} = +16.667\%$$

In this example, the actual attendance zone of this school is 16.7% less multiracially diverse than its corresponding non-gerrymandered equal land area zone (or Voronoi polygonal zone) – meaning that two randomly selected students are 16.7% more likely to belong to different racial/ethnic groups in the natural attendance zone than in the actual attendance zone. Moreover, this school would be expected to achieve a 16.7% increase in diversity among students of all racial/ethnic groups if the gerrymandering of its attendance zone boundaries was eliminated.

Positive values of the index indicate that the non-gerrymandered attendance zone is more diverse than its corresponding actual attendance zone and that diversity would be increased by eliminating gerrymandering. As such, a positive value indicates that gerrymandering serves to segregate. Negative values indicate that the non-gerrymandered attendance zone is less diverse than its corresponding actual attendance zone and that diversity would be decreased by eliminating gerrymandering. As such, a negative value indicates that gerrymandering serves to integrate. Thus, the index may be alternately interpreted as the percentage change in diversity associated with elimination of gerrymandering, the amount by which a school attendance zone or district is gerrymandered to segregate or integrate or, more informally, the magnitude of the effect of gerrymandering on diversity.

Independent Variables

To assess heterogeneity in the effects of gerrymandering across geographic and demographic contexts, an array of contextual covariates were added to the regression models predicting the effects of school attendance zone and school district gerrymandering on diversity. Mirroring the analyses in the first phase, regression models for both school attendance zones and school districts included variables capturing core-based statistical area type (i.e., metropolitan or micropolitan), locality (i.e., city, suburban, town, or rural), and school population. Likewise, models for school attendance zones contained variable capturing history of *de jure* segregation and history of federal desegregation order (i.e., unitary status, currently under desegregation order, or never subject to litigation).

In addition, several demographic predictors were incorporated in the models predicting the effects of school attendance zone and school district gerrymandering on diversity. However, these predictors differ slightly from those used in the analyses above. Analyses in the first phase documented the association between school attendance zone and school district gerrymandering and actual school demographics as reported by the NCES CCD, in terms of the percent of students that are white, black, and Hispanic. The analysis in the second phase, however, was concerned with how students residing in the "core" of an attendance zone or school district (i.e., the area in a school's "natural" zone or district that is also inside a schools actual zone or district) drive the process of student exchange. As such, measures of core racial/ethnic composition were created using aggregated Census block data. This was accomplished by identifying the area of intersection between the natural and actual polygons in ArcGIS (i.e., the “core”) and spatially merging to shapefiles of all U.S. Census blocks. Once the blocks in each core were identified, the racial/ethnic characteristics of children under the age of 18 (used to operationalize students) for each block were aggregated to obtain the characteristics of each core.

Paralleling the analysis above, for each core, the percentage of students that are white, black, and Hispanic were calculated and added to the regression models. In addition, measures of core student racial/ethnic diversity were included to provide insight into how the homogeneity of school attendance zone and school district cores drives the student exchange process, beyond the effects of a particular student race/ethnicity.

Three different measures of racial/ethnic diversity were computed using Simpson’s index, outlined in the preceding section: an index of multiracial diversity among all seven racial/ethnic groups employed by the study, an index of black-white diversity, and an index of Hispanic-white diversity.

Analytic Models

To answer each of the study research questions, 41 ordinary least squares (OLS) regression models were estimated. Below, I outline the models estimated for the first and second phases of analysis.

Phase I Regression Models

To address contextual variation in gerrymandering of school attendance zones and districts, the first phase of analysis involved estimation of 14 separate regression models regressing measures of gerrymandering on geographic and demographic covariates. Eight models assessed variation in school attendance zone gerrymandering, while six assessed variation in school district gerrymandering.

School attendance zone gerrymandering. Six models were estimated regressing school attendance zone gerrymandering on the school geographic and demographic characteristics described above. Three of these models used a Schwartzberg perimeter-based measure of compactness as the dependent variable in the regression (Models 1, 2, and 3), while three used the Polsby-Popper area-based measure as the dependent variable (Models 4, 5, and 6). As is discussed at length in Chapters 4 and 5, owing to multicollinearity among the racial/ethnic predictors, separate models were estimated to examine the independent association between gerrymandering and each racial/ethnic dimension. Thus, for both the Schwartzberg and Polsby-Popper models, three separate models were estimated to capture the effects of each focal racial/ethnic dimension, including: percent white (Models 1 and 4), percent black (Models 2 and 5), and percent Hispanic (Models 3 and 6).

In addition to these six models, two separate models comparable to those above were estimated to assess the relationship between history of desegregation order and school attendance zone gerrymandering. Separate analyses were required because Office of Civil Rights data on school desegregation status were only available for 1,286 school attendance zones in the sample. Separate models were estimated with the Schwartzberg (Model 7) and Polsby-Popper (Model 8) indices of compactness as model dependent variables. Because these models were designed to isolate the effects of desegregation orders on gerrymandering, separate models were not estimated for each racial/ethnic dimension. Thus, only the percent white predictor was included in these models.

School district gerrymandering. Paralleling the models for school attendance zones above, six models were estimated regressing school district gerrymandering/compactness on district geographic and demographic characteristics described above. As with the attendance zone analysis, the dependent variable in three of these models is the Schwartzberg perimeter-based measure of compactness (Models 1, 2, and 3), while the dependent variable in the other three is the Polsby-Popper area-based measure of compactness (Models 4, 5, and 6). Again, separate models were estimated to examine the independent association between gerrymandering and each racial/ethnic dimension. Thus, for both the Schwartzberg and Polsby-Popper models, three separate models were estimated to capture the effects of each focal racial/ethnic dimension, including: percent white (Models 1 and 4), percent black (Models 2 and 5), and percent Hispanic (Models 3 and 6).

Phase II Regression Models

The second phase of analysis, assessing contextual variation in the effects of gerrymandering on school attendance zone and school district diversity, involved estimation of 27 separate OLS regression models. Fifteen models assessed variation in the effects of school attendance zone gerrymandering on diversity, while twelve assessed variation in the effects of school district gerrymandering on diversity.

Effect of school attendance zone gerrymandering on diversity. Twelve models were estimated on the full SABINS sample examining contextual variation in the effects of school attendance zone gerrymandering on diversity, as measured in terms of the percent difference in diversity between actual school attendance zones and their natural equal land area circle zones. It should be noted that comparable regression analyses were not conducted for the Voronoi polygonal attendance zones. As is discussed at length in Chapter 4, the rationale for this omission is two-fold: 1) the overall results for the Voronoi sample generally validate those of the equal land area circle analysis, but the latter analysis has a substantially larger sample size, and 2) the Voronoi sample is less representative of the population of school attendance zones than the full SABINS sample; as such, it is likely to yield more biased estimators.

For each school attendance zone, the effect of gerrymandering on three different measures of diversity was calculated: 1) multiracial diversity, 2) black-white diversity, and 3) Hispanic-white diversity). For each of these dependent variables, four separate models were estimated. Each model contained a comparable array of geographic covariates as presented above. However, owing to multicollinearity between the demographic measures of core diversity, core percent white, core percent black, and core percent Hispanic, separate models were estimated to examine the unique effect of these four variables. For the models containing the diversity predictor, the core diversity measure corresponding with the dependent variable was included in each model. Thus, the model predicting the effects of school attendance zone gerrymandering on multiracial diversity included core multiracial diversity as a predictor (Model 1), while the models predicting the effects of school attendance zone gerrymandering on black-white and Hispanic-white diversity included black-white and Hispanic-white diversity as predictors, respectively (Models 4 and 8). Equivalent measures of core percent white, core percent black, and core percent Hispanic were added to the models predicting the effects of school attendance zone gerrymandering on multiracial diversity (Models 2, 6, and 10), black-white diversity (Models 3, 7, and 11), and Hispanic-white diversity (Models 4, 8, and 12).

In addition to these twelve models, three separate models comparable to those above were estimated to assess how the effect of school attendance zone gerrymandering on diversity varied between schools subject to desegregation orders and those never subject to litigation. As with Phase I, separate analyses were required because Office of Civil Rights data on school desegregation status were only available for 1,286 school attendance zones in the sample. Three separate models were estimated examining the effects of gerrymandering on multiracial diversity (Model 13), black-white diversity (Model 14), and Hispanic-white diversity (Model 15). Again, because these models were designed to isolate the effects of desegregation orders on gerrymandering, separate models were not estimated for each racial/ethnic dimension. Thus, only the core diversity measure corresponding with the dependent variable were included in each model (i.e., core multiracial diversity for Model 13, core black-white diversity for Model 14, and core Hispanic-white diversity for Model 15).

Effect of school district gerrymandering on diversity. Paralleling the models for school attendance zones above, twelve models were estimated to assess contextual variation in the effects of school district gerrymandering on diversity. For each of the three types of diversity in the analysis (i.e., multiracial diversity, black-white diversity, and Hispanic-white diversity), four separate models were estimated. Each model contained the array of geographic covariates presented above. However, owing to multicollinearity between the demographic measures of core diversity, core percent white, core percent black, and core percent Hispanic, separate models were estimated to examine the unique effect of these four variables. For the models containing the diversity predictor, the core diversity measure corresponding with the dependent variable was included in each model. Thus, the model predicting the effects of school district gerrymandering on multiracial diversity included core multiracial diversity as a predictor (Model 1), while the models predicting the effects of school district gerrymandering on black-white and Hispanic-white diversity included black-white and Hispanic-white diversity as a predictor, respectively (Models 4 and 8). Equivalent measures of core percent white, core percent black, and core percent Hispanic were added to the models predicting the effects of school district gerrymandering on multiracial diversity (Models 2, 6, and 10), black-white diversity (Models 3, 7, and 11), and Hispanic-white diversity (Models 4, 8, and 12).

Regression Assumptions

Each of the regression models discussed above was fitted using ordinary least squares regression. All data were examined prior to regression analysis to ensure that assumptions of OLS regression were met. To ensure that the OLS estimators are unbiased, the study samples were compared to the general population to ensure their representativeness. As Table 4 demonstrates, the SABINS sample and the sample of districts used in the regression analyses were quite representative of their population of interest. In addition, all independent variables were tested for violations of assumptions of normality and transformed if necessary to minimize skewness and kurtosis. Measures of student population were found to be strongly positively skewed and were transformed using a natural log transformation (Cleveland, 1984).

To ensure that multicollinearity of predictors did not compromise the interpretation of regression coefficients, full regression models containing all predictors of interest were estimated and variance inflation factors (VIFs) were examined to ensure that models do not inflate the variance of the coefficient estimates for each predictors. Rules of thumb for interpreting VIF values vary; this study used a VIF standard of 5, according to the procedure of Rogerson (2001), to identify multicollinear predictors. When predictors were found to be multicollinear, as was the case with demographic predictors (e.g., percent white and percent black), separate models were estimated assessing the unique effects of each of the variables.

Interpretation of Results

As noted previously, all categorical variables were dummy coded, while all continuous variables were centered about their mean. As a result, the intercept of the regression model predicting school attendance zone gerrymandering in phase one may be interpreted as the mean level of gerrymandering for a school of average population, located in a rural locality in a micropolitan area outside the formerly *de jure* segregated South, with an average proportion of students eligible for free- and reduced-price lunch, and an average proportion of students that are white, black, and/or Hispanic. Likewise, the intercept of the regression model predicting school district gerrymandering in phase one represent the mean level of gerrymandering for a district of average population, located in a rural locality in a micropolitan area, with an average proportion of students eligible for free- and reduced-price lunch, and an average proportion of students that are white, black, and/or Hispanic.

In interpreting the results of the regression analyses, unstandardized regression coefficients were used to interpret the magnitude and direction of the relationship between each of the contextual predictors and dependent variables. Although the primary objective of the study is not to causally link predictors with the dependent variable, but merely to examine contextual variability in gerrymandering and the effect of gerrymandering on diversity, the model R2 is reported for each model. This value represents the extent to which the set of geographic and demographic predictors explain variability in gerrymandering or the segregative effect of gerrymandering.

CHAPTER 4: SCHOOL ATTENDANCE ZONE GERRYMANDERING

In this chapter, I address the first and second research questions of the study, reporting the results of two phases of analysis on school attendance zone gerrymandering. In the first phase of analysis, I address the first research question, employing complementary measures of areal and perimeter compactness to document the severity and prevalence of the gerrymandering of U.S. public school attendance zones. In addition, I analyze how attendance zone boundary gerrymandering varies across school geographic and demographic contexts.

In the second phase of analysis, I address the second research question, comparing the diversity of current school attendance zone boundaries to the diversity of "natural", non-gerrymandered school attendance zones to estimate the segregative or integrative effect of attendance zone gerrymandering on the racial/ethnic diversity of public schools. Based on this analysis, I estimate how much school diversity would be enhanced or reduced via rezoning to minimize gerrymandering. In addition, I examine how the effect of gerrymandering on school diversity varies across school geographic and demographic contexts. In particular, I attend to how the racial and ethnic characteristics of students in a school attendance zone's "core" (i.e., students residing in the portion of the actual school attendance zone that were not "zoned in" via gerrymandering) drive the process of student exchange. The results of both phases of analysis are presented below.

Phase I: How Gerrymandered are Public School Attendance Zones?

To address the first research question, regarding the severity and prevalence of public school attendance zone gerrymandering, measures of compactness were calculated for all 9,717 school attendance zones in the analytic sample identified in Chapter 3. To ensure that examination of gerrymandering attended to irregularities in both perimeter and area, the analysis employed the complementary Schwartzberg and Polsby-Popper indices, which quantify compactness in terms of irregularity of perimeter and area, respectively, which are discussed in detail in Chapter 3.

The mean Schwartzberg index for school attendance zones 0.587 (SD = 0.136), meaning that on average the perimeter of a school attendance zone is 58.7% of the perimeter of a circular zone with equal area. The mean Polsby-Popper index for school attendance zones in the sample is 0.363 (SD = 0.165), meaning that on average the area of a school attendance zone is 36.3% of the area of a circular zone with equal perimeter. As expected, given that they are complementary measures of indentation, the Polsby-Popper and Schwartzberg indices were highly correlated with each other ($R = 0.989$, $p < .001$).

Because values of these spatial summary indices are not intuitive with regards to the severity of student exchange resulting from boundary irregularity, Figure 21 below provides a frame of reference for interpretation, with examples of school attendance zones with very low, low, average, high, and very high levels of compactness. Low and high compactness attendance zones were selected at approximately one standard deviation below and above the mean in terms of both areal and perimeter compactness, while very low and very high compactness attendance zones were selected at approximately two standard deviations below and above the mean. Because areal and perimeter compactness were so highly correlated, only one attendance zone was selected to illustrate each level of compactness.

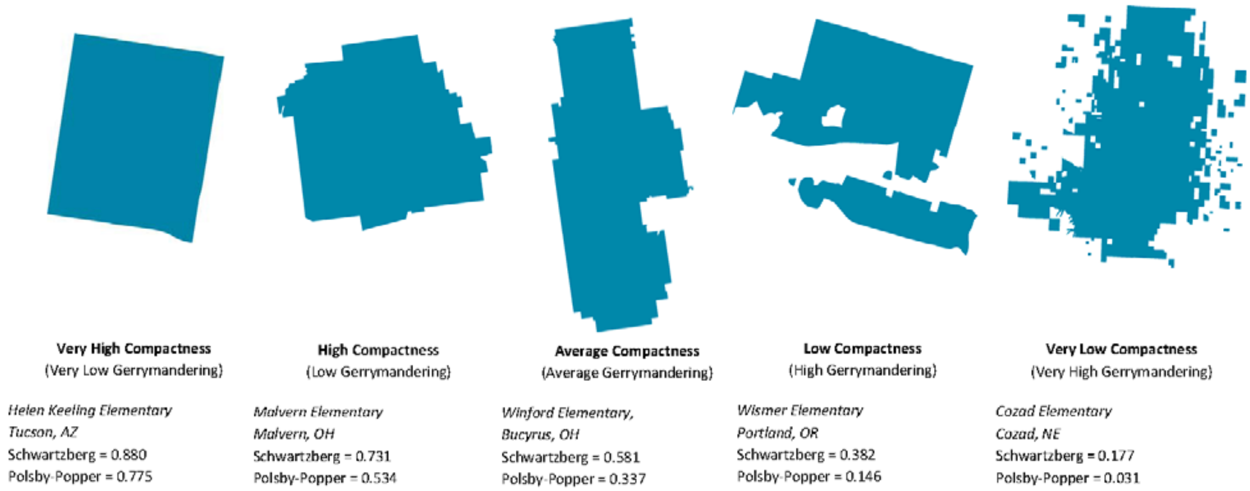


Figure 21. Examples of school attendance zones of very high, high, average, low, and very low compactness and their corresponding compactness values.

The attendance zone of Winford Elementary in Bucyrus, Ohio (center) represents an "average" attendance zone, in terms of both its areal and perimeter compactness. As the Figure 21 reveals, Winford's attendance zone is fairly regular, but is somewhat elongated, with some boundary indentations and protuberances. The Schwartzberg index for Winford Elementary is 0.581, slightly lower than the national average of 0.587, meaning that the perimeter of its attendance zone is 58.1% of the perimeter of a circular zone with equal area. Likewise, the Polsby-Popper index for Winford is 0.337, slightly lower than the national average of 0.363, meaning that the area of its attendance zone is 33.7% of the area of a circular zone with equal perimeter.

The attendance zone of Malvern Elementary in Malvern, Ohio (second from left) represents a "high compactness" attendance zone. While Malvern's boundaries have a number of protuberances and concavities, they are relatively small, and the district shape is much less elongated than Winford's. The Schwartzberg index for Malvern is 0.731, while its Polsby-Popper index is 0.534. Thus, Malvern Elementary is 15 percentage points more compact in terms of perimeter and 19.7 percentage points more compact in terms of area than an average school attendance zone, as represented by Winford Elementary.

The attendance zone of Helen Keeling Elementary in Tucson, Arizona (left) represents a "very high compactness" attendance zone. Helen Keeling's attendance zone is almost perfectly rectangular, with little elongation, no concavities, and only one small protuberance. The Schwartzberg index for Helen Keeling Elementary is 0.880, while its Polsby-Popper index is 0.775. Thus, Helen Keeling Elementary is 29.9 percentage points more compact in terms of perimeter and 43.8 percentage points more compact in terms of area than an average school attendance zone, as represented by Winford Elementary.

The attendance zone of Wismer Elementary in Portland, Oregon (second from right) represents a "low compactness" attendance zone. Wismer's attendance zone boundary, while regular on the north and east, has concavities and protuberances on the south and west. Moreover, Wismer's attendance zone is highly discontiguous, comprised of two major disconnected areas and two smaller "islands" and one major void. The Schwartzberg index for Wismer is 0.382, while its Polsby-Popper index is 0.146. Thus, Wismer Elementary is 19.9 percentage points less compact in terms of perimeter and 19.1 percentage points less compact in terms of area than an average school attendance zone, as represented by Winford Elementary.

The attendance zone of Cozad Elementary in Cozad, Nebraska (right) represents a "very low compactness" attendance zone. Cozad's attendance zone boundary has a highly irregular shape, with numerous protuberances, concavities, voids, and discontiguous "island" areas. Accordingly, the Schwartzberg index for Cozad is 0.177, while its Polsby-Popper index is 0.31. Thus, Cozad Elementary is 40.4 percentage points less compact in terms of perimeter and 30.6 percentage points less compact in terms of area than an average school attendance zone, as represented by Winford Elementary.

Readers may find it helpful to refer to this figure and the percentage-point differences in compactness between each of the example school attendance zones to assist in visualization and interpretation of the magnitude of each of the contextual effects discussed below.

How Does School Attendance Zone Gerrymandering Vary Across Geographic and Demographic Contexts?

To assess how school attendance zone gerrymandering varies across school geographic and demographic contexts, compactness indices were regressed on a variety of school characteristics. Six ordinary least squares regression models were estimated regressing the Schwartzberg (Models 1 through 3) and Polsby-Popper (Models 4 through 6) indices on a variety of explanatory variables capturing school geographic and demographic characteristics. A separate model, discussed at length below, was estimated to assess the effects of desegregation orders on gerrymandering for the subset of districts for which information on federal desegregation status was available from the U.S. Commission on Civil Rights.

Each model contained several categorical geographic variables, including: core-based statistical area type, locality, and *de jure* segregation status. In addition, each model contained demographic predictors capturing the proportion of students eligible for free- and reduced-price lunch and student race/ethnicity. Because the proportion of whites at a school is a strong predictor of the proportion of students that are Hispanic (R = -0.655) and, to a lesser extent, black (R = -0.549), demographic predictors were multicollinear when added to regression models simultaneously. Indeed, regression analysis yielded variance inflation factor (VIF) values greater than 7.0 for all racial/ethnic predictors, exceeding the recommended VIF value of 5.0 suggested by Rogerson (2001) and well above the suggested maximum of 4.0 suggested offered by Pan and Jackson (2008) (i.e., White VIF = 10.07, Black VIF = 7.68, Hispanic VIF = 9.05). As such, the effects of each racial/ethnic predictor were estimated via separate models to avoid statistical problems associated with multicollinearity. Models 1 and 4 included the proportion of students that are white, while Models 2 and 5 included the proportion of students that are black, and Models 3 and 6 included the proportion of students that are Hispanic.

Each model also contained control variables, including a measure of school district boundary compactness corresponding with the dependent variable (i.e., Schwartzberg or Polsby-Popper), to ensure that estimates captured variation in school attendance zone gerrymandering independent of the gerrymandering of the school's containing district, and a log-transformed measure of student population. Table 5 reports the results of the regression models for school attendance zone compactness.

As the penultimate row in each model reveals, the set of explanatory geographic and demographic variables explains 9.4% to 10.0% of the variance in the Schwartzberg index of perimeter compactness and 10.2% to 11.1% of the variance in the Polsby-Popper index of areal compactness. This means that, controlling for the compactness of a school attendance zone's school district boundaries and student population, roughly one-tenth of the irregularity in a school attendance zone's boundaries (i.e., the extent to which each attendance zone deviates from a circle) may be explained by the attendance zone's core-based statistical area type, locality, history of *de jure* segregation, and student racial/ethnic and socioeconomic characteristics. The unique relationship between school attendance zone gerrymandering and each of the explanatory geographic and demographic variables is discussed in detail below. Unless otherwise noted, interpretation of contextual effects below is based on coefficients from Models 1 and 4, which contain the student percent white demographic predictor.

Core-Based Statistical Area type. School attendance zones in more populous metropolitan statistical areas are slightly more compact on average than school attendance zones in micropolitan statistical areas, even after controlling for school geographic and demographic characteristics. Thus, on average, attendance zones in smaller micropolitan areas are more gerrymandered, in terms of both perimeter and areal indentation, than school attendance zones in metropolitan areas, even after controlling for the size of the school population.

Examination of the coefficients in the regression models reveals that the disparity in school attendance zone gerrymandering between metropolitan and micropolitan areas is relatively small. Specifically, an average micropolitan school attendance zone has a Schwartzberg index of 0.590, while an average metropolitan school attendance zone has a Schwartzberg index of 0.622. Thus, school attendance zones in metropolitan areas are 3.2 percentage points more compact in terms of perimeter than attendance zones in micropolitan areas. Likewise, an average micropolitan school attendance zone has a Polsby-Popper index of 0.397, while the average metropolitan school attendance zone has a Polsby-Popper value of 0.435. Thus, school attendance zones in metropolitan areas are 3.8 percentage points more compact in terms of area than micropolitan school attendance zones.

Locality. Table 5 demonstrates that school attendance zones in rural areas (reference category) are most compact, while school attendance zones in towns are most gerrymandered, after controlling for other school geographic and demographic characteristics. In terms of perimeter (i.e., Schwartzberg), school attendance zones in rural areas are 3.3 percentage points less gerrymandered than those in cities, 3.8 percentage points less gerrymandered than those in suburbs, and 11.1 percentage points less gerrymandered than those in towns. Differences among localities are even more pronounced for measures of areal compactness. Indeed, in terms of the Polsby-Popper index, school attendance zones in rural areas are 6.2 percentage points less gerrymandered than those in cities, 7.0 percentage points less gerrymandered than those in suburbs, and 14.8 percentage points less gerrymandered than those in towns. School attendance zones in cities and suburbs did not differ significantly from each other in terms of their perimeter or areal compactness.

History of *de jure* segregation. Schools located in the formerly *de jure* segregated South have less compact attendance zone boundaries than schools in the rest of the U.S., after controlling for other school geographic and demographic characteristics. Specifically, school attendance zones in the formerly *de jure* segregated South are 6.3 percentage points less compact in terms of perimeter and 7.4 percentage points less compact in terms of area than school attendance zones in the rest of the U.S.

Free- and reduced-price lunch. After controlling for other school geographic and demographic characteristics, school attendance zone compactness is unrelated to the proportion of students in a school that qualify for free- and reduced-price lunch, after controlling for the proportion of students in a school that are white (Schwartzberg b = 0.016, *ns*; Polsby-Popper b = 0.008, *ns*). However, school attendance zone compactness is positively related to the proportion of students in a school that qualify for free- and reduced-price lunch in models controlling for the proportion of students in a school that are black (Schwartzberg b = 0.060, $p < .001$; Polsby-Popper b = 0.072, $p < .001$) and Hispanic (Schwartzberg b = 0.044, $p < .001$; Polsby-Popper b = 0.046, $p < .001$).

As such, after controlling for the proportion of students that are black and Hispanic, school attendance zones with higher proportions of economically disadvantaged students tend to be more compact than more affluent schools, while less disadvantaged schools are more gerrymandered. For example, a high-poverty school, defined as having a proportion of students eligible for free- and reduced-price lunch that is two standard deviations above the mean for the sample (50.1%), has an expected Polsby-Popper index of 0.411. A low-poverty school, defined as having a proportion of student eligible for free- and reduced-price lunch that is two standard deviations below the mean, has an expected Polsby-Popper index of 0.325. Thus, high-poverty schools are, on average, 8.6 percentage points less gerrymandered, in terms of area, than low-poverty schools.

Student race/ethnicity. Models 1 and 4 reveal that school attendance zone compactness is negatively related to the proportion of whites at a school, controlling for other school geographic and demographic characteristics (Schwartzberg $b = -0.061$, $p < .001$; Polsby-Popper $b = -0.086$, $p < .001$). As such, schools with higher proportions of whites tend to be more gerrymandered than schools with higher proportions of non-whites. For example, a high-white school, defined as a school with a proportion of whites that is two standard deviations above the mean, would have an expected Schwartzberg index that is 8.2 percentage points less compact in terms of perimeter than a low-white school. Likewise, high-white schools are, on average, 11.6 percentage points less compact in terms of area than low-white schools.

By contrast, Models 2 and 5 reveal that school attendance zone compactness has a weak positive association with the proportion of blacks at a school, controlling for other school geographic and demographic characteristics (Schwartzberg $b = 0.015$, $p < .05$; Polsby-Popper $b = 0.017$, $p < .05$). Thus, on average, schools with fewer blacks tend to be more gerrymandered than schools with more blacks. For example, a high-black school, defined as a school with a proportion of blacks that is two standard deviations above the mean, would have an expected Schwartzberg index that is 1.5 percentage points less compact in terms of perimeter than a low-black school. Likewise, high-black schools are, on average, 1.8 percentage points less compact in terms of area than low-black schools.

Likewise, Models 3 and 6 reveal that school attendance zone compactness is positively related to the proportion of Hispanics at a school, controlling for other school geographic and demographic characteristics (Schwartzberg $b = 0.037$, $p < .001$; Polsby-Popper $b = 0.054$, $p < .001$). Thus, schools with fewer Hispanics tend to be more gerrymandered than schools with more Hispanics. For example, a high-Hispanic school, defined as a school with a proportion of Hispanics that is two standard deviations above the mean, would have an expected Schwartzberg index that is 4.1 percentage points less compact in terms of perimeter than a low-Hispanic school. Likewise, high-Hispanic schools are, on average, 6.0 percentage points less compact in terms of area than low-Hispanic schools.

History of desegregation order. To examine the relationship between school attendance zone gerrymandering and school district desegregation status, a separate analysis was conducted on the subsample of school attendance zones for which federal district desegregation status information is available via the U.S. Commission on Civil Rights was selected for further analysis. The final sample for this analysis consisted of 1,286 school attendance zones in 23 districts in the states of Florida, Georgia, and North Carolina. School districts were classified as: 1) never subject to federal desegregation litigation, or 2) subject to desegregation order. The latter category includes both school districts formerly under desegregation orders but now declared unitary as well as the handful of school districts in the SABINS sample that are still under federal supervision for desegregation according to Office of Civil Rights data (n = 21). All districts in this analysis were located in states in the formerly *de jure* segregated South. Table 6 presents the results of the regression analyses examining the relationship between school attendance zone compactness and school district desegregation status, after controlling for the compactness of district boundaries and other school geographic and demographic characteristics.

As Table 6 reveals, although school attendance zones in the formerly *de jure* South are more gerrymandered than those in the rest of the U.S., school attendance zones in districts that were subject to desegregation orders are significantly more compact than school attendance zones in districts that were never subject to federal desegregation litigation. Specifically, schools subject to desegregation orders have attendance zone boundaries that are 5.2 percentage points more compact in terms of perimeter (Model 7) and 5.8 percentage points more compact in terms of area (Model 8) than school attendance zones that were never litigated.

Phase I Summary

Descriptive analyses documenting the severity and prevalence of school attendance zone gerrymandering revealed a high degree of variability in the gerrymandering of school attendance zones. While some boundaries are remarkably compact, others are exceedingly gerrymandered, exhibiting severe violations of both areal and perimeter compactness.

Analyses revealed systematic variation the gerrymandering of school attendance zones across geographic contexts, although the magnitude of these effects is fairly small.

Gerrymandering of school attendance zones is more severe in smaller, micropolitan areas than in more populous metropolitan areas. However, the gerrymandering of school attendance zones is negatively related to school population, such that more populous schools have more gerrymandered boundaries than less populous schools. In addition, while the gerrymandering of school attendance zones is most severe in towns, school attendance zones in rural areas are particularly compact.

Findings regarding the relationship between gerrymandering and history of *de jure* segregation and federal desegregation oversight are particularly illuminating. School attendance zones in the formerly *de jure* segregated South are significantly more gerrymandered than attendance zones in the rest of the U.S. Although further analysis is necessary to investigate whether this gerrymandering serves to segregate or integrate, the finding that attendance zones are more gerrymandered in the South is consistent with the interpretation that attendance zones in the South may have been gerrymandered to maintain *de facto* segregation in response to integration pressures.

Moreover, analysis revealed that school attendance zones in Southern school districts currently or formerly subject to federal desegregation orders are significantly less gerrymandered than those never subject to desegregation litigation. This stands in contrast to anecdotal and historical accounts suggesting that attendance zone gerrymandering may be an artifact of desegregation efforts in the South, with irregular, tortuous boundaries resulting from busing patterns intended to enhance integration.

Taken together, these findings suggest that desegregation orders may have suppressed, and continue to suppress, the gerrymandering of school attendance zone boundaries in the South. By contrast, districts not subject to federal oversight of desegregation order may have responded to pressures to dismantle formal *de jure* segregation by establishing gerrymandered attendance zones maintaining *de facto* segregation. However, more direct evidence of the segregative or integrative effects of gerrymandering, which will be provided in the subsequent section, is necessary to substantiate these propositions.

The relationship between school attendance zone compactness and school demographic characteristics provides interesting insight into the racial and socioeconomic dynamics of gerrymandering. Findings suggest that school attendance zones with more whites tend to be more gerrymandered than school attendance zones with more non-white students. Moreover, schools with higher proportions of black and Hispanic students tended to be less gerrymandered than schools with fewer non-whites. . In addition, school attendance zones with more affluent students are more gerrymandered than school attendance zones with more economically disadvantaged students; underscoring the socioeconomic, as well as racial, dimension of gerrymandering.

Inasmuch as irregular boundaries are a symptom of student exchange, the more gerrymandered boundaries of whiter and more affluent schools suggest that they are more likely to engage in an egregious process of student exchange than schools with more non-white students. Although this analysis does not provide direct evidence of the effects of gerrymandering on school racial/ethnic equity, the finding that gerrymandering is particularly severe in high-white, high-socioeconomic status, low-black and low-Hispanic schools is consistent with an exclusionary pattern of student exchange that serves to exclude non-white and poor students in favor or whiter and more affluent students.

Evidence that gerrymandering is higher in areas of the formerly *de jure* segregated South that were never subject to desegregation orders and that gerrymandering is more severe in attendance zones with higher proportions of white and affluent students are consistent with the narrative of boundary gerrymandering as segregative. However, such correlational evidence does not provide evidence of a causal relationship. Indeed, it is possible that, unrelated to history of segregation or the racial dynamics of student exchange, attendance zone gerrymandering is simply more severe in the South and in areas with more whites, and that schools would be equally segregated or perhaps more segregated if their boundaries were less gerrymandered. As such, the following analysis was conducted to provide a more direct test of the effects of gerrymandering on the racial/ethnic composition of schools.

Phase II: Does School Attendance Zone Gerrymandering Segregate or Integrate?

To assess the segregative or integrative effects of school attendance zone gerrymandering, and to answer research question two, geospatial analyses were conducted estimate the extent to which racial/ethnic homogeneity of school attendance zones is directly attributable to gerrymandering of educational boundaries. As discussed in Chapter 3, the effect of gerrymandering on diversity is captured by comparing the diversity of actual school attendance zones and school district boundaries to the diversity of the "natural" boundaries that would be expected in the absence of gerrymandering, as defined by the equal land area circle of Angel and Parent (2011). In addition, for the subset of school attendance zones located in districts for which all school attendance zone boundaries were available, comparable analyses were conducted comparing the diversity of each current school attendance zone to the diversity of its Voronoi polygonal zone. The results of each analysis are presented in turn below.

Actual School Attendance Zones vs. Equal Land Area Circle Zones

Table 7 reveals that, on average, school attendance zones are less diverse than their corresponding equal land area circle zones across all measures of racial/ethnic diversity. As such, on average, the gerrymandering of school attendance zone boundaries serves to segregate students by race/ethnicity. The disparity between the diversity of the actual school attendance zone and the non-gerrymandered equal land area circle zone is particularly large for black-white diversity. Thus, although the gerrymandering of school attendance zone boundaries serves to segregate students of all races and ethnicities, irregular boundaries are a particularly strong mechanism of segregating blacks and whites. As such, school racial/ethnic diversity, particularly between blacks and whites, could be significantly improved through attendance re-zoning designed to minimize gerrymandering.

Specifically, school attendance zones are, on average, 3.1% less diverse than their corresponding equal land area circle zones in terms of multiracial diversity and 5.3% less diverse than their corresponding equal land area circle zones in terms of Hispanic-white diversity. As such, school attendance zones would experience small increases in multiracial and Hispanic diversity of 3.1% and 5.3%, respectively, if school attendance zones were not gerrymandered. The effect for black-white diversity is even more pronounced than the effects for multiracial and Hispanic-white diversity. Indeed, on average, school attendance zones are 15.4% less black-white diverse than their corresponding equal land area circle zones. As such, school attendance zones would be expected to experience substantial 15.4% increases in black-white diversity in the absence of gerrymandering.

Example. Figure 22 below provides an example to illustrate how gerrymandering serves to decrease the diversity of a school attendance zone. In the figure, the focal school (Fountain Lake Elementary in Hot Springs, Arkansas) is indicated by a black star, while the actual school attendance zone is outlined in blue. The “natural”, equal land area circle attendance zone circle is outlined in red. In the left panel of the figure, the Census blocks in each area are shaded by the percentage of students that are white. In the right panel, the Census blocks are shaded by the percentage of students that are black.

The actual attendance zone (blue region) is extremely homogeneous: its students are overwhelmingly white (91%) and a trivial proportion are black (1%). Accordingly, the attendance zone has an extremely low black-white diversity value of 0.02, meaning that there is only a 2.0% chance that two randomly selected black or white students in this district are of different racial-ethnic groups. The “natural” district (red circle), however, is much more heterogeneous. While it is still majority-white, it is only 65% white and 17% black. Accordingly, the natural district has a much higher diversity index of 0.33, meaning that there is a one-third chance that two randomly selected black or white students are of different racial-ethnic groups.

The maps below illustrate how the gerrymandering of the attendance zone boundary facilitates this racial/ethnic disparity. The left panel reveals that the areas "zoned into" the actual attendance zone have a high proportion of whites, while the areas "zoned out" have a much lower proportion of whites, especially in the smaller, more densely-populated blocks. The exclusionary pattern of the gerrymandering is even more evident in the right panel, which reveals that blacks are concentrated in the southern areas "zoned out" of the attendance zone.

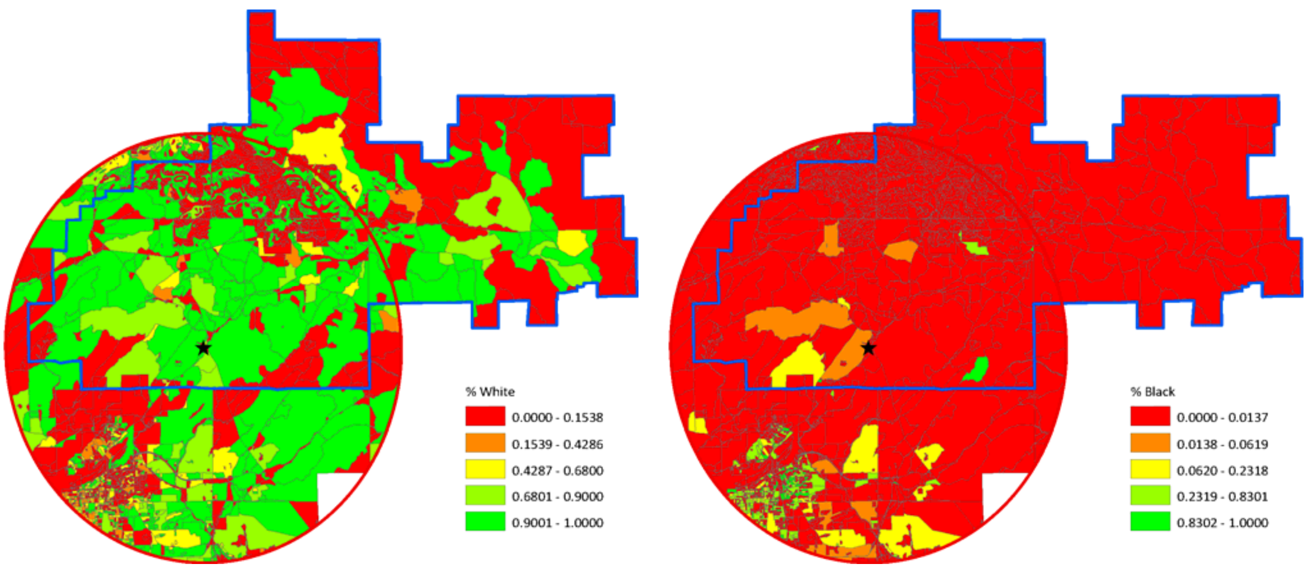


Figure 22. Example of school attendance zone gerrymandered to reduce diversity (Fountain Lake Elementary, Arkansas). School location indicated by black star. Actual school attendance zone outlined in blue, "natural" school attendance zone outlined in red circle. Census blocks shaded by percentage of students in block that are white (left) and black (left).

Variability in Effects. While the results above suggest that, on average, school attendance zone gerrymandering has a segregative effect, it should be emphasized that these are average effects, and do not apply to all school attendance zones. Indeed, gerrymandering actually increases diversity for a slight majority of schools. Although gerrymandering reduces the multiracial diversity of 49.6% of school attendance zones

(4,822 of 9,717), it is associated with increases diversity for 50.4% of school attendance zones (4,895). Likewise, while gerrymandering is associated with reductions in black-white diversity for 49.0% of school attendance zones (4,766), it facilitates increases in diversity for 51.0% of school attendance zones. Gerrymandering serves to increase the Hispanic-white diversity of a slightly larger proportion of school attendance zones (51.2%), it is still associated with decreases in Hispanic-white diversity for 48.8% of school attendance zones. While more school attendance zones are gerrymandered to integrate than are gerrymandered to segregate, the magnitude of the decreases in diversity attributable to gerrymandering are, on average, larger than the increases in diversity attributable to gerrymandering. As such, on average, gerrymandering is associated with decreases in diversity beyond schools' equal land area circle zones.

Although school attendance zone gerrymandering is associated with increases in diversity for a small majority of attendance zones in the sample, examination of geographic variation reveals that, on average, gerrymandering is associated with reductions in diversity for the vast majority of states. As Table 8 and Maps 7 through 9 demonstrate, on average, school attendance zone gerrymandering serves to reduce diversity in all states except Alabama, Delaware, the District of Columbia, Florida, Utah, and Vermont, where gerrymandering is associated with increases in diversity on average. Moreover, only in the District of Columbia and Delaware is school attendance zone gerrymandering associated with increases in all three measures in diversity. In Alabama, Florida, Utah, and Vermont, school attendance zone gerrymandering has mixed effects –

reducing diversity on one dimension (e.g., multiracial), but increasing it on another (e.g., black-white).

Table 8 reveals that school attendance zone gerrymandering has the largest effect on school multiracial diversity in Indiana. Indeed, school attendance zones in the Indiana sample would be 27% more diverse on average if they were not gerrymandered. Gerrymandering has the largest impact on black-white diversity in Arkansas, where many attendance zones look similar to that of Fountain Lake Elementary in Hot Springs. Indeed, on average, school attendance zones in the Arkansas sample would be 195% more diverse, in terms of black-white diversity, if attendance zones were not gerrymandered. The effect of gerrymandering on Hispanic-white diversity is strongest in the sample of school attendance zones in South Carolina, where Hispanic-white diversity would be 51% higher in the absence of gerrymandering.

Actual School Attendance Zones vs. Voronoi Polygonal Zones

Table 9 presents results of the analysis assessing the effects of school attendance zone gerrymandering on diversity by comparing actual attendance zones to their corresponding Voronoi polygonal attendance zones. The Voronoi analysis reveals that school attendance zone gerrymandering is, on average, associated with decreases in black-white and Hispanic-white diversity and small increases in multiracial diversity. As such, on average, school attendance zones would expect to achieve moderate increases in black-white diversity, small increases in Hispanic-white diversity, and very small decreases in diversity under a more efficient Voronoi rezoning scheme.

Specifically, Voronoi school attendance zones are on average 18.3% more black-white diverse than their corresponding attendance zones. Thus, on average, school attendance zones in the sample would experience an 18.3% increase in black-white diversity if their districts adopted an optimally-efficient Voronoi polygonal attendance rezoning scheme. In addition, Voronoi school attendance zones are on average 7.3% more Hispanic-white diverse than their corresponding attendance zones. As such, on average, school attendance zones in the sample would experience a 7.3% increase in Hispanic-white diversity if their districts adopted an optimally-efficient Voronoi polygonal attendance rezoning scheme. However, on average, Voronoi school attendance zones are slightly (0.5%) less diverse than their corresponding attendance zones, meaning that school attendance zones would experience trivial decreases in multiracial diversity if their districts adopted an optimally-efficient Voronoi polygonal attendance rezoning scheme.

Comparison of the results of the Voronoi analysis and the results of the equal land area circle analysis from the same sample of districts suggests that the equal land area circle analysis may slightly underestimate the segregative effects of gerrymandering on black-white and Hispanic-white diversity, but overestimate the integrative effects of gerrymandering on multiracial diversity. Indeed, the estimated 18.3% gain in black-white diversity under the Voronoi polygonal zoning scheme reflects is higher than the 15.4% gain in black-white diversity projected under the equal land area circle analysis. Likewise, the estimated 7.3% gain in Hispanic-white diversity under the Voronoi polygonal zoning scheme is higher than the 5.3% gain in Hispanic-white diversity projected by the equal land area circle analysis. Thus, the Voronoi analysis may systematically underestimate the potential benefits of attendance re-zoning on school racial/ethnic equity.

By contrast, the Voronoi analysis suggests that the equal land area circle analysis may overestimate the effects of gerrymandering on multiracial diversity and, by extension, the potential benefits of re-zoning in terms of multiracial diversity. Indeed, whereas the equal land area circle analysis suggests that rezoning would be associated with a modest 3.1% increase in diversity, the Voronoi analysis estimates that school attendance zones would, on average, experience a small 0.5% decrease in multiracial diversity under a Voronoi polygonal rezoning scheme.

The findings from the Voronoi analysis generally corroborate the findings from the analyses above, suggesting that the gerrymandering of school attendance zones serves to segregate students by race/ethnicity, particularly segregating whites from blacks and Hispanics. Moreover, because they use a more feasible attendance re-zoning scheme than the circles in the previous analysis, they provide an even more sound basis to infer that re-zoning schools to increase efficiency would also reap benefits in terms of improving the diversity of schools.

Because the Voronoi analysis was conducted on a subsample of schools in the SABINS sample located in districts which reported attendance zone data for all schools, the results of the Voronoi analysis are not directly comparable to the results of the equal land area circle analysis. Thus, to provide a more direct comparison of the magnitude of the segregative effect of gerrymandering, the results of the Voronoi sample were compared to the results of the equal land area circle analysis for the subset of schools in the Voronoi sample.

As Table 10 demonstrates, when comparing the results of the Voronoi analysis to the results of the equal land area circle for the same sample of schools, the estimates of the segregative effect of gerrymandering on black-white diversity from the Voronoi analysis are nearly three times as high as the estimates from the equal land area circle analysis (18.34% vs. 6.30%). Likewise, the estimates of the segregative effect of gerrymandering on Hispanic-white diversity from the Voronoi analysis are more than twice as high as the estimates from the equal land area circle analysis (7.30% vs. 2.99%). Taken together, these findings suggest that estimates obtained from the equal land area circle analysis may underestimate the true segregative effect of gerrymandered boundaries on black-white and Hispanic-white diversity. As such, the equal land area circle results may also underestimate the potential for re-zoning to improve black-white and Hispanic white diversity.

Findings were somewhat more equivocal for multiracial diversity. Although the Voronoi analysis suggests that gerrymandering may have a very small integrative effect on diversity, the equal land area circle analysis found a very small segregative effect for the same school attendance zones (-0.5% vs. 0.69%). This suggests that the equal land area circle analysis may slightly overestimate the segregative effect of gerrymandered boundaries on multiracial segregation, as well as the potential for rezoning to improve multiracial diversity.

Overall, results from the Voronoi analysis corroborate the finding from the equal land area circle that, on average, school attendance zone gerrymandering serves to segregate students by race/ethnicity. However, it should again be emphasized that these are average effects and do not apply to all school attendance zones. As with the equal land area circle analysis, gerrymandering actually increases diversity for a slight majority of schools in the Voronoi sample across all measures of diversity. Indeed, while gerrymandering reduces the multiracial diversity of 45.7% of school attendance zones (1,465 of 3,204), it is associated with increases diversity for 54.3% of school attendance zones (4,895). Likewise, while gerrymandering is associated with reductions in black-white diversity for 44.5% of school attendance zones (1,425), it facilitates increases in diversity for 55.5% of school attendance zones. However, as with the equal land area circle analysis, gerrymandering serves to increase the Hispanic-white diversity of a slightly larger proportion of school attendance zones (47.5%), it is still associated with decreases in Hispanic-white diversity for 52.5% of school attendance zones. Thus, although more school attendance zones are gerrymandered to integrate than are gerrymandered to segregate, the magnitude of the decreases in diversity attributable to gerrymandering are, on average, larger than the increases in diversity attributable to gerrymandering. As such, on average, gerrymandering is associated with decreases in diversity beyond schools' Voronoi polygonal attendance zones.

Because the Voronoi analysis generally validates the results of the equal land area circle analysis, and because the findings from the equal land area circle are generally more conservative than those achieved in the Voronoi sample, the measures of the effect of gerrymandering on diversity obtained via the equal land area technique are used for the analyses assessing geographic and demographic variation below. In addition, use of the equal land area circle measures, which were conducted on the full sample of school attendance zones, permits a larger sample size for the regression models assessing contextual effects.

How Does the Effect of School Attendance Zone Gerrymandering on Segregation Vary across Geographic and Demographic Contexts?

To address the third research question, regarding contextual variation in the effects of school attendance zone gerrymandering on school diversity, three ordinary least squares regression models were estimated. In these models, measures of the effect of gerrymandering on diversity (i.e., the percentage increase in diversity that would be expected in the absence of gerrymandering), were regressed on a variety of school geographic and demographic characteristics.

Three different measures of the effect of gerrymandering on diversity, corresponding with the three measures of diversity computed and analyzed above were used as the dependent variables for the analysis: 1) the effect of gerrymandering on multiracial diversity (Model 1), 2) the effect of gerrymandering on black-white diversity (Model 2), and 3) the effect of gerrymandering on Hispanic-white diversity (Model 3). As noted previously, because the result of the equal land area circle analysis were generally validated by the Voronoi analysis, but provide a much larger sample size and, therefore more power to detect a significant effect, the effect of gerrymandering on each measure of diversity was computed by comparing the diversity of actual attendance zones to the diversity of their corresponding equal land area circle zones. Each model included a variety of categorical geographic variables, including: core-based statistical area type, locality, and *de jure* segregation status.

To examine whether the pattern of segregative gerrymandering documented in the preceding section is being driven by the racial/ethnic characteristics of students in the "core zone" (i.e., the area of overlap between the actual attendance zone and the equal land area zone), a measure of student race/ethnicity in the core zone was also included in the model. For the model predicting the effect of gerrymandering on multiracial diversity, a measure of the multiracial diversity of students in the core zone was added to the model. For the models predicting the effect of gerrymandering on black-white and Hispanic-white diversity, measures of black-white and Hispanic-white diversity were included in the models. In addition, for each dependent variable, separate models were estimated to examine the relationship between the effect of gerrymandering and the proportion of whites, blacks, and Hispanics in the core zone. Again, because of multicollinearity between these racial/ethnic predictors, coefficients were obtained by running separate models. The results of each regression model are shown in Table 11.

As the penultimate row in each model reveals, the set of explanatory geographic and demographic variables explains a small proportion of the variance in the effect of school attendance zone gerrymandering on diversity. Indeed, the models explain less than 3% of the variance in the effect of gerrymandering on multiracial diversity, 1.8% of the variance in the effect of school attendance zone gerrymandering on black-white diversity, and 1.9% of the variance in the effect of gerrymandering on Hispanic-white diversity.

This suggests that variability in the effect of gerrymandering on segregation may be better explained by school-specific characteristics not captured in this analysis. However, regression analyses did capture some systematic variation in the effect of school attendance zone gerrymandering on segregation across geographic and demographic contexts. The unique relationship between the effect of school attendance zone gerrymandering on segregation and each of the explanatory geographic and demographic variables is discussed in detail below.

Core-Based Statistical Area type. Table 11 reveals that, in addition to having more gerrymandered school attendance zones than metropolitan areas, micropolitan statistical areas have school attendance zones that are more gerrymandered to segregate than metropolitan statistical areas, holding. Holding other school geographic and demographic characteristics constant, across all three measures of diversity, school attendance zones in micropolitan statistical areas would experience larger increases in diversity if their boundaries were not gerrymandered than would attendance zones in metropolitan areas.

Specifically, for multiracial and Hispanic-white diversity, attendance zones micropolitan areas are 5.1 and 5.6 percentage points more gerrymandered to segregate than attendance zones in metropolitan areas. The effect was considerably stronger for black-white diversity – attendance zones in micropolitan areas are 25.7 percentage points more gerrymandered to segregate blacks from whites than attendance zones in metropolitan areas. Indeed, holding other school geographic and demographic factors constant, school attendance zones in micropolitan areas are nearly twice as gerrymandered to segregate as school attendance zones in metropolitan areas (expected increase in black-white diversity of 24.0% for metropolitan areas vs. 49.2% for micropolitan areas). Thus, the role of gerrymandering in perpetuating black-white segregation is particularly concerning in smaller urbanized areas.

Locality. Despite being less segregated than school attendance zones in other localities, Table 11 reveals that across all measures of diversity, school attendance zones in rural areas are significantly more gerrymandered to segregate than school attendance zones in other localities. Moreover, across all measures of diversity, school attendance zones in cities are least gerrymandered to segregate than school attendance zone in other localities.

The most notable finding with regards to locality is the pronounced disparity between rural areas and other localities in terms of the effect of gerrymandering on black-white diversity. Indeed, compared to school attendance zones in rural areas, school attendance zones in cities, suburbs, and towns are 21.7, 17.5, and 16.9 percentage points less gerrymandered to segregate, respectively. As such, the effect of school attendance zone boundary gerrymandering on black-white segregation—while problematic in all localities—constitutes a peculiar problem of rural areas.

History of *de jure* segregation. The previous analysis found that school attendance zones in the formerly *de jure* segregated South are more gerrymandered than school attendance zones in the rest of the U.S. Table 11 demonstrates that while attendance zones in the South are more gerrymandered, they are slightly less gerrymandered to segregate in terms of multiracial diversity and equally gerrymandered to segregate in terms of black-white and Hispanic-white diversity than school attendance zones in the rest of the U.S. Specifically, holding other school characteristics constant, schools in the South are 1.4 percentage points less gerrymandered to segregate than schools in the rest of the U.S. in terms of multiracial diversity. School attendance zones in the South and the rest of the U.S. do not differ in terms of the segregative effect of gerrymandering on black-white or Hispanic-white diversity.

It should be emphasized that although results of this analysis suggest that school attendance zones in the formerly *de jure* segregated South are no *more* gerrymandered to segregate than attendance zones in the rest of the U.S., they are still gerrymandered to segregate. As such, findings fail to corroborate the notion that school attendance zones are affirmatively gerrymandered to integrate, as has been suggested by some anecdotal and historical accounts of district irregularity resulting from a legacy of busing efforts designed to combat residential segregation.

Core student demographics. Across all measures of diversity, school attendance zones with more racially/ethnically homogeneous student populations in their "core" zone (i.e., students residing in the area of overlap between the actual school attendance zone and the equal land area circle zone) were more gerrymandered to segregate than school attendance zones with more diverse cores. This suggests that the extent to which school attendance zones "zone out" more racially and ethnically dissimilar students and "zone in" more similar students depends upon the level of racial and ethnic homogeneity in the core zone. School attendance zones that have more homogeneous cores exhibit patterns of student exchange that are more racialized and more segregative, resulting in more racially identifiable schools. By contrast, the student exchange process perpetrated by school attendance zones with more heterogeneous cores tend to be less driven by race.

The first column in Table 11 reveals that school attendance zones with more multiracially diverse core zones are less gerrymandered to multiracially segregate than school attendance zones with less diverse cores ($b = -0.136$, $p < .001$). For example, a school attendance zone with a core student population that is very multiracially homogeneous, defined as having a multiracial diversity index two standard deviations below the mean, would be 15.4 percentage points more diverse if its boundaries were not gerrymandered. By contrast, a school attendance zone with a core student population that is very multiracially diverse would be 4.4 percentage points more diverse if it was not gerrymandered. As such, on average, a school attendance zone with low multiracial diversity is 11.0 percentage points more gerrymandered to segregate than a school attendance zone with high multiracial diversity.

Likewise, the third column in the table reveals that school attendance zones with more Hispanic-white diverse core zones are less gerrymandered to segregate Hispanics from whites than school attendance zones with less diverse cores ($b = -0.208$, $p < .001$). For example, a school attendance zone with a core student population that is very Hispanic-white homogeneous, defined as having a Hispanic-white diversity index two standard deviations below the mean, would be 19.0 percentage points more diverse if its boundaries were not gerrymandered. By contrast, a school attendance zone with a core student population that is very Hispanic-white diverse would be 5.8 percentage points more diverse if it was not gerrymandered. As such, on average, a school attendance zone with low Hispanic-white diversity is 13.2 percentage points more gerrymandered to segregate Hispanics from whites than a school attendance zone with high Hispanic-white diversity.

Interestingly, the second column in the table demonstrates that while school attendance zones with more black-white diverse core zones are slightly less gerrymandered to segregate blacks from whites than school attendance zones with less diverse cores (b = -0.551, $p < .001$), the effect is considerably weaker than for multiracial or Hispanic-white diversity. For example, a school attendance zone with a core student population that is very black-white homogeneous, defined as having a black-white diversity index two standard deviations below the mean, would be 32.6 percentage points more diverse if its boundaries were not gerrymandered. By contrast, a school attendance zone with a core student population that is very black-white diverse would be 33.0 percentage points more diverse if it was not gerrymandered. As such, on average, a school attendance zone with low black-white diversity is 0.4 percentage points more gerrymandered to segregate than a school attendance zone with high black-white diversity.

Additional analyses, documented in final four lines of the table, were conducted examining the specific relationships between the proportion of students of each focal racial ethnic group and the effect of gerrymandering on multiracial, black-white and Hispanic-white diversity. Analyses revealed that the proportion of whites in the core zone was positively related to the segregative effect of gerrymandering on multiracial (b = 0.027, $p < .01$) and black-white diversity (b = 0.231, $p < .001$). Specifically, high-white school attendance zones are 35.4 percentage points more gerrymandered to segregate blacks from whites than low-white attendance zones. Moreover, the proportion of blacks and Hispanics in a school attendance zone's core was negatively related to the segregative effect of gerrymandering on multiracial and black-white diversity. Taken together, these findings suggest that whiter school attendance zones are more gerrymandered to segregate while school attendance zones with more blacks and Hispanics are less gerrymandered to segregate, providing additional evidence that whites are the primary catalyst behind the process of student exchange perpetrated by gerrymandered boundaries.

History of desegregation order. To directly investigate the relationship between federal desegregation oversight and the segregative or integrative effects of gerrymandering, the subsample of 1,286 school attendance zones for which federal district desegregation status information is available via the U.S. Commission on Civil Rights was selected for further analysis. Table 12 presents the results of the regression analyses examining the relationship between desegregation status and the effect of gerrymandering on segregation, controlling for all covariates above with the exception of *de jure* segregation status (because all districts were in states formerly subject to *de jure* segregation).

The previous analysis found that school attendance zones in districts never subject to desegregation litigation are more gerrymandered than school attendance zones in district subject to desegregation orders. The table reveals that school attendance zones in districts never subject to desegregation litigation are also more gerrymandered to segregate than school attendance zones in districts subject to desegregation orders, in terms of multiracial and black-white diversity.

School attendance zones in districts never subject to desegregation litigation are 6.2% and 7.9% less diverse, in terms of multiracial and black-white diversity, than their corresponding equal land area circles. However, school attendance zones in districts currently or formerly subject to desegregation orders are only 3.4% and 2.1% less diverse than their corresponding equal land area circles. On average, schools in districts subject to desegregation orders are 2.8 percentage points less gerrymandered to segregate in terms of multiracial diversity and 5.8 percentage points less gerrymandered to segregate in terms of black-white diversity than schools in districts never subject to federal desegregation oversight. This suggests that while schools subject to desegregation orders are not affirmatively gerrymandered to integrate, they are significantly less gerrymandered to segregate than schools in districts that were never litigated.

Phase II Summary

To address the second research question, regarding the segregative or integrative effects of gerrymandering on school racial/ethnic composition, the diversity of current school attendance zones were compared to the diversity of non-gerrymandered, "natural" school attendance zones. Analyses revealed that, on average, school attendance zones are more racially/ethnically homogeneous than their natural zones, meaning that the gerrymandering of public school attendance zones is largely segregative. Thus, irregularities in school attendance zone boundaries serve to facilitate a process of student exchange whereby more racially/ethnically similar students are "zoned in" and more dissimilar students are “zoned out”. Although school attendance zone gerrymandering segregates students of all racial/ethnic groups from each other, irregularities in school attendance zone boundaries play a particularly important role in perpetuating segregation between black students and white students.

The effects of school attendance zone gerrymandering on school diversity vary significantly across school geographic and demographic contexts. In addition to having attendance zones that are more gerrymandered than those in metropolitan areas, micropolitan areas have school attendance zone boundaries that are substantially more gerrymandered to segregate, especially blacks from whites. It is not clear why micropolitan areas have attendance zones that are more gerrymandered to segregate than metropolitan areas; it may be a function of differential levels of income and educational attainment between residents of metropolitan and micropolitan areas (Miller, 2009), or of the slower growth in micropolitan areas vis-à-vis metropolitan areas (Dunne & Fee, 2011). Previous research has demonstrated that segregation is higher in micropolitan areas than metropolitan areas (Parisi, Lichter & Grice, 2007) – the gerrymandering of school attendance zone boundaries may be one important reason for this difference.

Analyses of the effects of gerrymandering on segregation by locality revealed that school attendance zones in rural areas are significantly more gerrymandered to segregate than school attendance zones in all other localities. Moreover, the gerrymandering of school attendance zone boundaries in rural areas serves as a particularly strong mechanism of segregating blacks and whites. Although the finding that segregative school attendance zone gerrymandering is a particular problem of rural areas may be somewhat counterintuitive, it should be emphasized that while these are school attendance zones in schools coded as a “rural” locality, they are still located within the confines of metropolitan and micropolitan statistical areas. As such, they generally represent schools in fringe, exurban, and bedroom-developing areas, where new schools may be opening to accommodate continued outward migration of residents, especially non-whites, from central cities and inner suburbs. Thus, their boundaries may be in flux, and irregularities may reflect responses to rapidly changing demographics. Moreover, the boundaries of schools in outlying areas with more recent population booms, which were historically racially homogeneous, may not have been subject to as much scrutiny as older areas that are historically more diverse.

Results indicate that school attendance zones in districts currently under desegregation order or formerly subject to desegregation order are substantially less gerrymandered overall and are less gerrymandered to segregate than school attendance zones that were never subject to federal desegregation litigation or oversight. In addition, although school attendance zones in the formerly *de jure* segregated South are more gerrymandered overall than attendance zones in the rest of the U.S., they are less gerrymandered to segregate than school attendance zones in the rest of the U.S. Taken together, these findings suggest that the presence of desegregation orders and federal oversight has served to inhibit the gerrymandering in the South, resulting in more regular boundaries. Moreover, to the extent that boundaries in districts subject to desegregation orders have been manipulated to deviate from compactness, they have had a much smaller effect on racial/ethnic diversity, suggesting that desegregation orders may have mitigated the segregative effects of gerrymandering on school racial/ethnic equity observed elsewhere in the U.S.

Analyses also provided insight into the racial dynamics of exclusion manifest in gerrymandered school attendance zone boundaries. Findings reveal that more homogeneous attendance zones tend to be more gerrymandered to segregate, using gerrymandered boundaries to "zone out" more racially and ethnically dissimilar students and "zone in" similar students. As such, as a result of gerrymandering, schools become even more racially identifiable as schools with more whites become even whiter, and schools with more non-whites become even less white. While more diverse attendance zones are also gerrymandered to segregate, the effects are considerably weaker, exhibiting patterns of student exchange that are less driven by race. In addition, the finding that school attendance zones with higher proportions of whites are significantly more gerrymandered to segregate than school attendance zones with fewer whites, while school attendance zones with higher proportions of blacks and Hispanics are less gerrymandered to segregate suggests that white populations may be driving the process of gerrymandering.

CHAPTER 5: SCHOOL DISTRICT GERRYMANDERING

In this chapter, I address the third and fourth research questions of the study, reporting the results of two phases of analysis on school district gerrymandering. In the first phase of analysis, I address the third research question, employing complementary measures of areal and perimeter compactness to document the severity and prevalence of the gerrymandering of public school districts. I compare measures of school district gerrymandering to measures of school attendance zone gerrymandering to evaluate the relative severity of and the association between school attendance zone and school district gerrymandering. In addition, I analyze how attendance zone boundary gerrymandering varies across school district geographic and demographic contexts.

In the second phase of analysis, I address the fourth research question, comparing the diversity of current school district boundaries to the diversity of "natural", non-gerrymandered school districts to estimate the segregative or integrative effect of district gerrymandering on the racial/ethnic diversity of school districts. Based on this analysis, I estimate how much school district diversity would be enhanced or reduced via redistricting to minimize gerrymandering. In addition, I examine how the effect of gerrymandering on district diversity varies across school geographic and demographic contexts. In particular, I attend to how the racial and ethnic characteristics of students in a school district's "core" (i.e., students residing in the portion of the actual school district that were not "zoned in" via gerrymandering) drive the process of student exchange. The results of both phases of analysis are presented below.

Phase I: How Gerrymandered are School Districts?

To address the third research question, regarding the severity and prevalence of school district gerrymandering, measures of compactness were calculated for all 9,796 school attendance zones in the analytic sample identified in Chapter 3. To ensure that examination of gerrymandering attended to irregularities in both perimeter and area, the analysis employed the complementary Schwartzberg and Polsby-Popper indices, which quantify compactness in terms of irregularity of perimeter and area, respectively, which are discussed in detail in Chapter 3.

The mean Schwartzberg index for school districts is 0.594, meaning that the perimeter of a school districts is, on average, 59.4% of the perimeter of a circular district with equal area. The mean Polsby-Popper index for school districts is 0.374, meaning that the area of a school district is, on average, 37.4% of the area of a circular district with equal perimeter. As with school attendance zones, Polsby-Popper and Schwartzberg indices for school district compactness were highly correlated ($R = 0.983$, $p < .001$).

Because interpretation of these spatial summary indices is not intuitive, Figure 23 below provides a frame of reference for interpretation, with examples of school districts with very low, low, average, high, and very high levels of compactness. Low and high compactness school districts were selected at approximately one standard deviation below and above the mean in terms of both areal and perimeter compactness, while very low and very high compactness school districts were selected at approximately two standard deviations below and above the mean. Because areal and perimeter compactness were so highly correlated, only one school district was selected to illustrate each level of compactness.

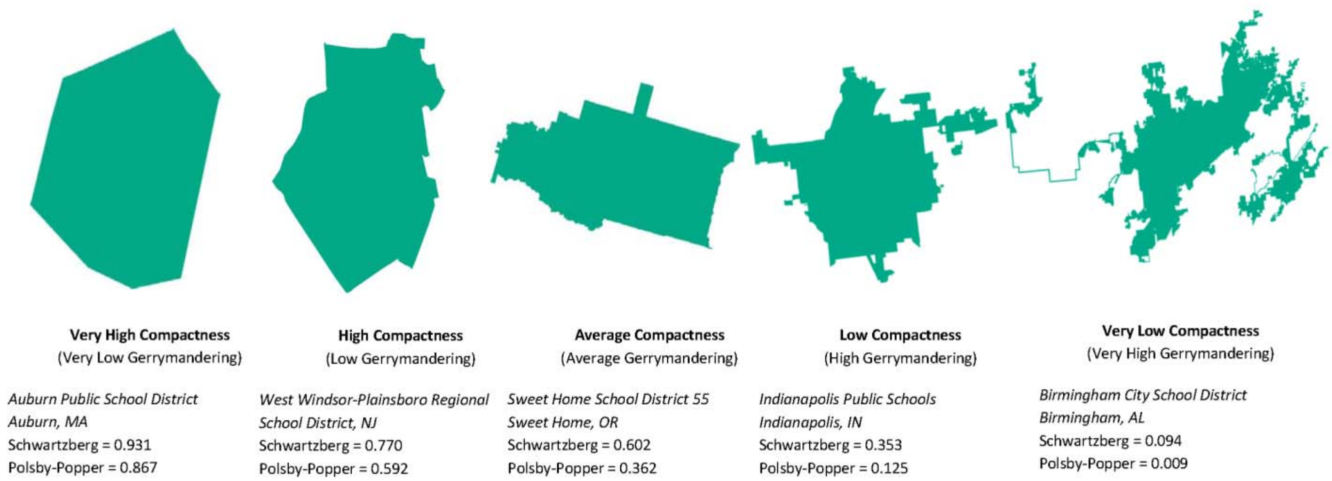


Figure 23. Examples of school districts of very high, high, average, low, and very low compactness and their corresponding compactness values.

The Sweet Home School District 55 in Sweet Home, Oregon (center) represents an "average" school district, in terms of both its areal and perimeter compactness. As the figure reveals, Sweet Home's district boundary fairly regular, with one major protuberance and some border irregularities, particularly on its western boundary. The Schwartzberg index for Sweet Home School district is 0.602, slightly higher than the national average of 0.594, meaning that the perimeter of the district 60.2% of the perimeter of a circular district with equal area. Likewise, the Polsby-Popper index for Sweet Home is 0.362, slightly lower than the national average of 0.374, meaning that the area of the district is 36.2% of the area of a circular district with equal perimeter.

The West Windsor-Plainsboro Regional School District in New Jersey (second from left) represents a "high compactness" school district. While West Windsor-

Plainsboro's boundaries have a number of protuberances and concavities, they are relatively small, and the district's perimeter is much smoother than Sweet Home's. The Schwartzberg index for West Windsor-Plainsboro is 0.770, while its Polsby-Popper index is 0.592. Thus, West Windsor-Plainsboro Regional School District is 16.8 percentage points more compact in terms of perimeter and 23.0 percentage points more compact in terms of area than an average district, as represented by Sweet Home School District.

The Auburn Public School District in Auburn, Massachusetts (left) represents a "very high compactness" school district. Auburn's district shape is almost perfectly polygonal, with little elongation, no concavities, and no protuberance. The Schwartzberg index for Auburn is 0.931, while its Polsby-Popper index is 0.867. Thus, Auburn is 32.9 percentage points more compact in terms of perimeter and 50.5 percentage points more compact in terms of area than an average district, as represented by Sweet Home School District.

The Indianapolis Public Schools district (second from right) represents a "low compactness" district. Indianapolis's district boundary is highly irregular, with numerous concavities, protuberances, and discontiguities. The Schwartzberg index for Indianapolis is 0.353, while its Polsby-Popper index is 0.125. Thus, the Indianapolis Public Schools district is 24.9 percentage points less compact in terms of perimeter and 23.7 percentage points less compact in terms of area than an average district, as represented by Sweet Home School District.

The Birmingham City School District in Birmingham, Alabama (right) represents a "very low compactness" district. Birmingham's district boundary is exceedingly irregular, with a crenellated perimeter and narrow isthmuses connecting far-flung areas. Accordingly, the Schwartzberg index for Birmingham is an exceedingly low 0.094, while its Polsby-Popper index is 0.009. Thus, Birmingham is 50.8 percentage points less compact in terms of perimeter and 35.3 percentage points less compact in terms of area than an average district, as represented by Sweet Home School District.

Readers may find it helpful to refer to this figure and the percentage-point differences in compactness between each of the example districts to assist in visualization and interpretation of the magnitude of each of the contextual effects discussed below.

How Is School District Gerrymandering Related to School Attendance Zone Gerrymandering?

Direct comparison of areal and perimeter measures of compactness for school attendance zone and school district gerrymandering reveals that, on average, school attendance zones are slightly more gerrymandered than school attendance zones. The mean Schwartzberg index for school districts is 0.594, while the mean for school attendance zones is 0.587. Thus, on average, school attendance zones are 0.7 percentage points less compact in terms of perimeter than school districts. Likewise, the Polsby-Popper for school districts is 0.374, while the mean for school attendance zones is 0.363, meaning that, on average, school attendance zones are 1.1 percentage points less compact in terms of area than school districts.

To provide a more direct comparison between the compactness of school attendance zones and the compactness of their containing districts, measures of compactness for each school attendance zone "normalized" by the compactness of their containing district. Using the procedure outlined in Azavea (2010), school attendance zone compactness values were divided by their corresponding school district compactness values to yield the normalized compactness index. The normalized index takes a value of greater than one when school attendance zones are more compact than their containing school districts and a value of less than one when school attendance zones are less compact than their containing school districts. The index has a value of one for districts comprised of a single attendance zone; however, these districts were previously excluded from the analytic sample.

Table 13 reveals that the mean of the normalized Schwartzberg index is 1.274, meaning that on average school attendance zones are 1.274 times more compact, in terms of area, than their containing school districts. Likewise, the mean of the normalized Polsby-Popper index is 2.070, meaning that on average school attendance zones are 2.070 times more compact, in terms of perimeter, than their containing school districts. Moreover, the majority of school attendance zones are less gerrymandered than their containing district: Excluding the districts with only one school attendance zone, 37.8% school attendance zones (*n* = 3,075) are less compact (i.e., more gerrymandered) than their containing district, while 62.2% of school attendance zones (*n* = 5,068) are more compact (i.e., less gerrymandered) than their containing districts.

To determine how the gerrymandering of boundaries at the district level is related the gerrymandering of boundaries at the school level, measures of school district compactness were correlated with measures of school attendance zone compactness (normalized to control for the effect of district boundaries). Analysis revealed that the gerrymandering of school district boundaries is positively related to the gerrymandering of school attendance zone boundaries (Schwartzberg $R = 0.341$, $p < .001$; Polsby-Popper $R = 0.191$, $p < .001$). As such, more gerrymandered school districts have more gerrymandered school attendance zones, while more compact school districts have more compact school attendance zones.

How Does School District Gerrymandering Vary Across Geographic and Demographic Contexts?

To assess how school district gerrymandering varies across district geographic and demographic contexts, compactness indices were regressed on a variety of district characteristics. As with the school attendance zone analysis, six ordinary least squares regression models were estimated regressing the Schwartzberg (Models 1 through 3) and Polsby-Popper (Models 4 through 6) indices on a variety of explanatory variables capturing district geographic and demographic characteristics.

Each model contained categorical geographic variables capturing core-based statistical area type and school district locality. In addition, each model contained continuous district-level demographic variables, including: student eligibility for free- and reduced-price lunch, student race/ethnicity, and a log-transformed measure of student population, used as a control variable. Because the proportion of whites in a district is a strong predictor of the proportion of students that are Hispanic ($R = -0.733$) and, to a lesser extent, black ($R = -0.546$), demographic predictors were multicollinear when added to regression models simultaneously. Indeed, regression analysis yielded VIF values greater than 5.0 for percent white and percent Hispanic predictors, exceeding the recommended VIF value suggested by Rogerson (2001) (i.e., White VIF = 9.24, Hispanic VIF = 5.21). The VIF value of black segregation was also relatively high (Black VIF = 3.58). As such, the effects of each racial/ethnic predictor were estimated via separate models to avoid statistical problems associated with multicollinearity. Models 1 and 4 included the proportion of students that are white, while Models 2 and 5 included the proportion of students that are black, and Models 3 and 6 included the proportion of students that are Hispanic. Each model also contained a measure of log-transformed student population as a control variable. Table 14 reports the results of the regression models for school district compactness.

As the penultimate row in each model reveals, the set of explanatory geographic and demographic variables explains a fairly small 4.3% to 5.1% of the variance in both the Schwartzberg and Polsby-Popper indices of compactness. This means that less than 5% of the irregularity in a school district's boundaries (i.e., the extent to which each school district deviates from a circle) may be explained by the district's core-based statistical area type, locality, history of *de jure* segregation, and student racial/ethnic and socioeconomic characteristics. The models containing the percent black demographic predictor explained significantly less variance than the models containing the percent white and Hispanic demographic predictors. Overall, the relatively small effect sizes for the models suggest that there is extreme variability in the gerrymandering of school districts that is not a function of the model predictors. As such, it may be better explained by other characteristics of the district, state, or region not captured in this analysis. However, regression analyses did capture some systematic variation in the gerrymandering of school attendance zones across geographic and demographic contexts. The unique relationship between school district gerrymandering and each of the explanatory geographic and demographic variables is discussed in detail below. Unless otherwise noted, interpretation of contextual effects below is based on coefficients from Models 1 and 4, which contain the student percent white demographic predictor.

Core-Based Statistical Area type. As with school attendance zones, school districts in more populous metropolitan statistical areas are slightly more compact on average than school districts in micropolitan statistical areas, holding other district geographic and demographic characteristics constant. On average, school districts in smaller micropolitan areas are more gerrymandered, in terms of both perimeter and areal indentation, than school districts in metropolitan areas, even after controlling for the size of the district population.

Examination of the coefficients in the regression models reveals that the disparity in school district gerrymandering between metropolitan and micropolitan areas is relatively small. Specifically, an average micropolitan school district has a Schwartzberg index of 0.576, while average metropolitan school district has a Schwartzberg value of 0.590. Thus, school districts in metropolitan areas are 1.4 percentage points more compact in terms of perimeter than districts in micropolitan areas. Likewise, an average micropolitan school district has a Polsby-Popper index of 0.355, while the average metropolitan school district has a Polsby-Popper value of 0.368. Thus, school districts in metropolitan areas are 1.3 percentage points more compact in terms of area than micropolitan school districts.

Locality. Table 14 demonstrates that school districts in suburbs are substantially more compact than school districts in all other localities, after controlling for other district geographic and demographic characteristics. Specifically, in terms of perimeter (i.e., Schwartzberg), school districts in suburbs are 3.8 percentage points more compact than those in rural areas, 5.3 percentage points more compact than those in towns, and 6.1 percentage points more compact than those in cities. The disparity between suburbs and other localities is even more pronounced in terms of area (i.e., Polsby-Popper), school districts in suburbs are 4.7 percentage points more compact than those in rural areas and 6.3 percentage points more compact than those in towns and cities. School districts in rural areas are less compact than suburbs, but slightly more compact than school districts in cities and towns. School districts in cities are slightly more gerrymandered than those towns in terms of perimeter, but do not differ significantly from school districts in towns in terms of area. Taken together, findings suggest a clear geographic division between suburbs and all other areas in terms of school district gerrymandering, whereby school districts in suburbs are uniquely more compact than districts in all other areas.

Free- and reduced-price lunch. Although school attendance zone compactness was found to be positively related to the proportion of students in a school that qualify for free- and reduced-price lunch, school district compactness is negatively related to the proportion of economically disadvantaged students in models controlling for the proportion of students in a district that are white (Schwartzberg $b = -0.046$, $p < .001$; Polsby-Popper $b = -0.065$, $p < .001$) and Hispanic (Schwartzberg $b = -0.026$, $p < .001$; Polsby-Popper $b = -0.038$, $p < .001$). School district compactness is unrelated to the proportion of students in a district that qualify for free- and reduced-price lunch in the models controlling for the proportion of students that are black (Schwartzberg $b = 0.002$, *ns*; Polsby-Popper $b = -0.012$, *ns*).

As such, after controlling for the proportion of students that are white and Hispanic, districts with higher proportions of economically disadvantaged students tend to be slightly less compact than more affluent districts. For example, affluent districts, defined as those with a proportion of students qualifying for free- or reduced-price lunch that is two standard deviations below the mean for the sample, would have an expected Polsby-Popper index that is 4 percentage points more compact, in terms of area, than a disadvantaged district. Likewise, affluent districts are 2.4 percentage points more compact, in terms of perimeter, than disadvantaged districts. Thus, although poorer school attendance zones are less gerrymandered than more affluent attendance zones, poorer school districts are more gerrymandered than more affluent districts.

Student race/ethnicity. As with school attendance zones, school district compactness is negatively related to the proportion of whites in a district and positively related to the proportion of Hispanics, controlling for other district geographic and demographic characteristics. However, school district compactness is unrelated to the proportion of blacks in a district. Models 1 and 3 reveal that districts with higher proportions of whites tend to be less compact than districts with higher proportions of non-whites (Schwartzberg $b = -0.066$, $p < .001$; Polsby-Popper $b = -0.079$, $p < .001$). For example, a high-white district, defined as a district with a proportion of whites that is two standard deviations above the mean, would have an expected Schwartzberg index that is

7.4 percentage points less compact, in terms of perimeter, than a low-white district. Likewise, high-white districts are 8.8 percentage points less compact, in terms of area, than low-white districts.

By contrast, Models 3 and 6 reveal that school district compactness is positively related to the proportion of Hispanics in a district, controlling for other district geographic and demographic characteristics (Schwartzberg $b = 0.072$, $p < .001$; Polsby-Popper $b = 0.079$, $p < .001$). Thus, districts with fewer Hispanic students tend to be more gerrymandered than districts with more Hispanics. For example, a high-Hispanic school district, defined as a district with a proportion of Hispanics that is two standard deviations above the mean, would have an expected Schwartzberg index that is 5.1 percentage points less compact in terms of perimeter than a low-Hispanic district. Likewise, high-Hispanic districts are, on average, 5.6 percentage points less compact in terms of area than low-Hispanic districts.

Phase I Summary

Descriptive analyses documenting the severity and prevalence of school district gerrymandering revealed a high degree of variability in the gerrymandering of school districts. While some district boundaries are remarkably compact, others are exceedingly gerrymandered, exhibiting severe violations of both areal and perimeter compactness. On average, school districts have a perimeter that is 58.7% of the perimeter of a circular zone with equal area and an area that is 36.3% of the area of a circular zone with equal perimeter. The example of Sweet Home School District, which is somewhat regular, with one major protuberance and some border irregularities, represents an “average” attendance zone for U.S. school districts. Analyses comparing the compactness of school district and school attendance zone boundaries reveal that school districts are slightly less gerrymandered overall than school attendance zones. In addition, school attendance zones are on average substantially more gerrymandered than the districts they comprise.

School district gerrymandering is positively related to school attendance zone gerrymandering, such that more gerrymandered districts have more gerrymandered school attendance zones, and more compact school districts have more compact school attendance zones. This suggests that although processes for establishing and modifying school attendance zone and school district boundaries differ substantially—with the former subject to frequent periodic review and change under the authority of the district, and the latter more stable and subject to review at the state level—in practice, these different processes yield similar results (i.e., school districts and attendance zones with correlated levels of gerrymandering). Although it is unclear why this might be the case, it is possible that the establishment of school attendance zone and school district boundaries are both governed by state or other municipal statutes, policies, or practices that enforce similar standards of permissiveness with regards to boundary irregularity. However, it is also possible that the effect is a spurious artifact of the coterminity between school attendance zone boundaries and the boundaries of their containing districts. To the extent that the normalized measure of school attendance zone compactness does not adequately control for the compactness of school attendance zone boundaries, estimates of the association between school district and attendance zone gerrymandering may be inflated.

Analyses revealed systematic variation the gerrymandering of school districts across geographic contexts, although the magnitude of these effects is fairly small. As with attendance zones, gerrymandering of district boundaries is more severe in smaller, micropolitan areas than in more populous metropolitan areas. This may reflect long-standing differences in the demographic characteristics and attitudes of residents of micropolitan areas which, as noted previously, tend to have lower levels of income and educational attainment than residents of metropolitan areas (Miller, 2009).

Results also indicate a clear geographic division between suburbs and all other areas in terms of school district gerrymandering, whereby school districts in suburbs are uniquely more compact than districts in all other areas. Given the stability of district boundaries over time, it is possible that the relative compactness of suburban school districts may be attributable to the fact that many suburban districts were established in racially homogeneous white enclaves created by whites fleeing from urban cores in the post-World War II era. Because they were established in areas with little racial/ethnic diversity, meaning that there were few racially and ethnically dissimilar students to "exchange", manipulation of district boundaries in suburban areas may have been minimal.

In addition, analysis of the relationship between school district compactness and district demographic characteristics provides some insight into the racial dynamics of gerrymandering. Findings suggest that school districts with more whites tend to be more gerrymandered than school districts with more non-white students. Moreover, schools with higher proportions of Hispanic students tend to be less gerrymandered than schools with fewer Hispanics. Although previous research has focused on how individuals sort themselves across district boundaries, the finding that district boundaries irregularity is related to district racial composition suggests that the irregularity of boundaries themselves plays a role in facilitating racial and ethnic homogeneity beyond Tiebout sorting, a proposition that will be more directly evaluated in the following analysis.

Interestingly, while more affluent school attendance zones are more gerrymandered than school attendance zones with more economically disadvantaged students, more affluent school districts are *less* gerrymandered than school districts with more economically disadvantaged students. Moreover, it is especially surprising in light of the finding that school districts with higher proportions of whites are more gerrymandered than school districts with more non-whites. It is possible that the discrepant findings for socioeconomic status and race/ethnicity suggest that race/ethnicity is a stronger impetus for gerrymandering of school district boundaries than socioeconomic status. Alternately, it is possible that the discrepancy is a result of geographic differences in the distribution of affluence and disadvantage across localities. Indeed, it is conceivable that more affluent school districts tend to be located in areas with more compact districts, such as suburban areas, even as those areas have become more diverse over time. Conversely, less affluent school districts may be located in localities with more gerrymandered districts, such as rural areas, towns and cities, which have remained relatively racially/ethnically homogeneous.

Evidence that district gerrymandering is related to school district demographics is consistent with the narrative of educational boundary gerrymandering as segregative.

However, such correlational evidence does not provide evidence of a causal relationship. Indeed, it is possible that, school districts with more whites simply happen to have more gerrymandered boundaries, but that districts would be equally or more segregated if their boundaries were less gerrymandered. As such, the following analysis was conducted to more directly assess the extent to which gerrymandered school district boundaries serve to segregate or integrate students by race/ethnicity.

Phase II: Does School District Gerrymandering Segregate or Integrate?

To address the third research question, the diversity of each current school district was compared to the diversity of its non-gerrymandered equal land area circle district to estimate the effect of gerrymandering on district diversity. Table 15 below presents the results of the analysis assessing the effects of school district gerrymandering on district diversity. The top panel reveals that, as with school attendance zones, school districts are significantly less diverse than their corresponding equal land area circle, suggesting that school district gerrymandering serves to segregate students by race/ethnicity. As such, school districts would experience increases across all three measures of multiracial segregation if gerrymandering were eliminated. As with school attendance zones, the disparity between the diversity of actual school districts and the non-gerrymandered equal land area circle districts is particularly large for black-white diversity. Thus, although the gerrymandering of school district boundaries serves to segregate students of all races and ethnicities, irregular boundaries are a particularly strong mechanism of segregating blacks and whites. As such, district racial/ethnic diversity, particularly between blacks and whites, could be significantly improved through attendance re-zoning designed to minimize gerrymandering.

Specifically, school districts are, on average, 3.1% less diverse than their corresponding equal land area districts in terms of multiracial diversity and 4.8% less diverse than their corresponding equal land area districts in terms of Hispanic-white diversity. As such, school districts would be 3.1% more multiracially diverse and 4.8% more Hispanic-white diverse if their boundaries were not gerrymandered. As with school attendance zones, school district gerrymandering has a particularly strong effect on black-white diversity. Indeed, on average, school districts are 13.6% less black-white diverse than their corresponding equal land area districts. As such, school districts would be 13.6% more black-white diverse if their boundaries were not gerrymandered.

Example. Figure 24 below provides an example to illustrate how gerrymandering serves to decrease the diversity of a school district. In the figure, the focal school district (Whitesboro Central School District, New York) is outlined in blue, with the geographic centroid of the district indicated by a black star. The "natural" school district is outlined in red. In the left panel of the figure, the Census blocks in each area are shaded by the percentage of students that are white. In the right panel, the Census blocks are shaded by the percentage of students that are black.

The actual school district (blue region) is fairly homogeneous: its student population is overwhelmingly white (90%), and only 3% black. Accordingly, the attendance zone has an extremely low black-white diversity value of 0.05, meaning that there is only a 1 in 20 chance that two randomly selected black or white students in this district are of different racial/ethnic groups. The “natural” district (red circle), however, is much more heterogeneous. While it is still majority-white, it is only 52% white and 17% black. Accordingly, the natural district has a much higher diversity index of 0.37, meaning that there is a 37% chance that two randomly selected black or white students are of different racial-ethnic groups.

The maps below illustrate how the gerrymandering of the school district boundary facilitates this racial/ethnic disparity. The left panel reveals that the areas “zoned into” the actual district have a high proportion of whites, while the areas “zoned out” have a much lower proportion of whites, especially in the smaller, more densely-populated blocks. Again, the exclusionary pattern of the gerrymandering is even more evident in the right panel, which reveals that blacks are concentrated in the southern areas “zoned out” of the school district.

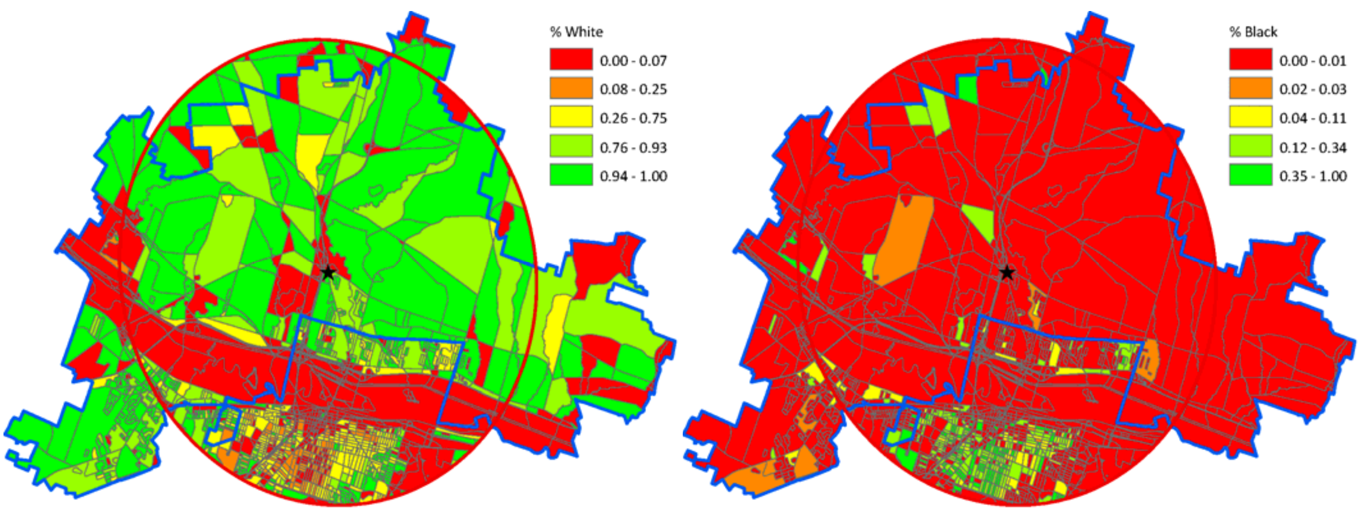


Figure 24. Example of school district gerrymandered to reduce diversity (Whitesboro Central School District, New York). School district centroid indicated by black star. Actual school district boundary outlined in blue, “natural” school district outlined in red circle. Census blocks shaded by percentage of students in block that are white (left) and black (left).

Variability in effects. While the results above suggest that, on average, school district serves to segregate students by race/ethnicity, it should again be emphasized that these are average effects. Indeed, for a substantial number of school districts, existing gerrymandered boundaries are less diverse than their corresponding equal land area circle districts. While gerrymandering is associated with decreases in the multiracial diversity of 52.6% of school districts (4,426 of 8,421), it is associated with increases diversity for 47.4% of school districts (3,995). Likewise, while gerrymandering is associated with reductions in black-white diversity for 53.0% of school districts (4,210), it facilitates integration for 47.0% of districts. Gerrymandering serves to decrease the Hispanic-white diversity of 54.4% of school districts, but is associated with higher levels of diversity in 45.6% of districts.

However, while school district gerrymandering is associated with higher levels of diversity for a large minority of school districts in the sample, examination of geographic variation reveals that, on average, gerrymandering is associated with reductions in diversity for the majority of states. As Table 16 and Maps 10 through 12 demonstrate, school district gerrymandering serves to reduce diversity in all states except Alaska (not shown), California, Colorado, Delaware, Florida, Idaho, Illinois, Nevada, Oregon, Virginia, Washington and West Virginia. Moreover, only in Illinois, Nevada, Virginia, and Delaware (which only has two school districts) is gerrymandering associated with increases in all three measures of diversity. In Alaska, California, Colorado, Florida, Idaho, Oregon, Washington and West Virginia, school district gerrymandering is associated with lower levels of diversity on one dimension (i.e., multiracial), but higher levels on another (e.g., Hispanic-white).

Table 16 reveals that school district gerrymandering serves to reduce multiracial diversity most in Wyoming and Utah. Indeed, school districts in these states would be 16.7% and 17.1% more diverse, respectively, on average if district boundaries were not gerrymandered. Gerrymandering has the largest impact on black-white diversity in Wisconsin. Indeed, on average, school districts in Wisconsin would be 73.3% more diverse, in terms of black-white diversity, if district boundaries were not gerrymandered. Gerrymandering serves to decrease Hispanic-white diversity most in Utah, where Hispanic-white diversity would be 27.6% higher in the absence of gerrymandering.

How Does the Effect of School District Gerrymandering on Segregation Vary across Geographic and Demographic Contexts?

To examine contextual variation in the effects of school district gerrymandering on school district diversity, three ordinary least squares regression models were estimated. In these models, the percentage increase in diversity that would be expected in the absence of gerrymandering was regressed on a variety of school district geographic and demographic characteristics. As with school attendance zones, three different measures of diversity were used to calculate the dependent variables for the analysis: 1) the effect of gerrymandering on multiracial diversity (Model 1), 2) the effect of gerrymandering on black-white diversity (Model 2), and 3) the effect of gerrymandering on Hispanic-white diversity (Model 3). Model predictors included categorical geographic variables capturing core-based statistical area type and locality code. In addition, each model included a measure of the size of the district student population.

To examine how the racial/ethnic characteristics of students in the "core district" (i.e., the area of overlap between the actual school district and the equal land area district) are related to the segregative effect of gerrymandering, measures of student race/ethnicity in the core district were also included in the models. For the model predicting the effect of gerrymandering on multiracial diversity, a measure of the multiracial diversity of students in the core district was added to the model. For the models predicting the effect of gerrymandering on black-white and Hispanic-white diversity, measures of black-white and Hispanic-white diversity were included in the models. In addition, for each dependent variable, separate models were estimated to examine the relationship between the effect of gerrymandering and the proportion of whites, blacks, and Hispanics in the core district. Again, because of multicollinearity between these racial/ethnic predictors, coefficients were obtained by running separate models. The results of each regression model are shown in Table 17.

As the penultimate row in each model reveals, the set of explanatory geographic and demographic variables explains a very small proportion of the variance in the effect of school district gerrymandering on diversity. Indeed, the models explain less than 2% of the variance in the effect of gerrymandering on multiracial and Hispanic-white diversity and less than 1% of the variance in the effect of gerrymandering on black-white diversity. This suggests that variability in the effect of school district gerrymandering on segregation may be better explained at by district-specific characteristics not captured in this analysis. However, regression analyses did capture some systematic variation in the effect of school district gerrymandering on segregation across geographic and demographic contexts. The unique relationship between the effect of school district gerrymandering on segregation and each of the explanatory geographic and demographic variables is discussed in detail below.

Core-Based Statistical Area type. In addition to having school district boundaries that are more gerrymandered than metropolitan areas, micropolitan statistical areas have school districts that are more gerrymandered to segregate, in terms of multiracial and Hispanic-white diversity, than those in metropolitan statistical areas. Holding other school geographic and demographic characteristics constant, school districts in micropolitan areas are 6.6 percentage points less multiracially diverse than their corresponding equal land area circle districts. By contrast, school districts in metropolitan areas are 5.0 percentage points less multiracially diverse than their corresponding equal land area circle districts. Thus, on average, school districts in micropolitan areas are 1.6 percentage points more gerrymandered to multiracially segregate than districts in metropolitan areas. Likewise, in terms of Hispanic-white diversity, school districts in micropolitan areas are 9.4 percentage points less racially diverse than their corresponding equal land area circle districts; school districts in metropolitan areas are 7.1 percentage points less racially diverse than their corresponding equal land area circle districts. Thus, on average, school districts in micropolitan areas are 2.3 percentage points more gerrymandered to multiracially segregate than districts in metropolitan areas.

Interestingly, attendance zones in micropolitan areas were significantly more gerrymandered to segregate blacks from whites than attendance zones in metropolitan areas, core-based statistical area status was unrelated to the effect of school district gerrymandering on black-white diversity. The finding that school district boundaries serve to perpetuate black-white segregation in both larger and smaller urban areas underscores the geographic universality of gerrymandering as a mechanism of segregating blacks from whites.

Locality. As with school attendance zones, across all measures of diversity, school districts in rural areas are more gerrymandered to segregate than districts in other localities, despite having relatively compact boundaries. School districts in suburbs are slightly less gerrymandered to segregate than those in rural areas, while school districts in towns are in turn slightly less gerrymandered to segregate than those in suburbs. School districts in cities are least gerrymandered to segregate across all measures of diversity.

For example, in terms of black-white diversity, school districts in rural areas are 7.5 percentage points more gerrymandered to segregate than school districts in suburbs, 14.5 percentage points more gerrymandered to segregate than school districts in towns, and 21.9 percentage points more gerrymandered to segregate than school districts in cities. Thus, although school districts in suburbs were significantly less gerrymandered than school districts in other localities, to the extent that they are gerrymandered, they are remarkably effective in serving to segregate.

Core student demographics. Across all measures of diversity, school districts with more racially/ethnically diverse student populations in their “core” district (i.e., students residing in the area of overlap between the actual school district and the equal land area circle district) are more gerrymandered to segregate than school districts with more homogeneous cores. This suggests that the extent to which school district boundaries serve to “zone out” more racially and ethnically dissimilar students and “zone in” more similar students depends upon the level of racial and ethnic homogeneity in the core district. Contrary to patterns observed for school attendance zones, school districts that have more diverse cores exhibit patterns of student exchange that are more racialized and more segregative, resulting in more racially identifiable districts and facilitating between-district segregation. By contrast, the student exchange process perpetrated by school districts with more homogeneous cores tends to be less driven by race.

The first column in Table 17 reveals that school districts with more multiracially diverse cores are more gerrymandered to multiracially segregate than school districts with less diverse cores ($b = 0.183$, $p < .05$). For example, a school district with a core student population that is very multiracially diverse, defined as having a multiracial diversity index two standard deviations below the mean, would be 13.6 percentage points more diverse if its boundaries were not gerrymandered. By contrast, a school district with a core student population that is very multiracially homogeneous would be 0.4 percentage points *less* diverse if it was not gerrymandered. As such, on average, a school district with high multiracial diversity is 14.0 percentage points more gerrymandered to segregate than a school district with low multiracial diversity.

Likewise, the second column in the table reveals that school districts with more black-white diverse cores are more gerrymandered to segregate blacks from whites than school districts with less diverse cores (*b* = 0.236, *p* < .001). For example, a school district with a core student population that is very black-white diverse, defined as having a black-white diversity index two standard deviations below the mean, would be 40.8 percentage points more diverse if its boundaries were not gerrymandered. By contrast, a school district with a core student population that is very black-white homogeneous would be 6.4 percentage points more diverse if it was not gerrymandered. As such, on average, a school district with high black-white diversity is 34.4 percentage points more gerrymandered to segregate than a school district with low black-white diversity.

In addition, the third column in the table reveals that school districts with more Hispanic-white diverse cores are more gerrymandered to segregate Hispanics from whites than school districts with less diverse cores (*b* = 0.206, *p* < .001). For example, a school district with a core student population that is very Hispanic-white diverse, defined as having a Hispanic-white diversity index two standard deviations below the mean, would be 17.3 percentage points more diverse if its boundaries were not gerrymandered. By contrast, a school district with a core student population that is very Hispanic-white diverse homogeneous would be 1.5 percentage points more diverse if it was not gerrymandered. As such, on average, a school district with high Hispanic-white diversity is 15.9 percentage points more gerrymandered to segregate than a school district with low Hispanic-white diversity.

Additional analyses, documented in final four lines of the table, were conducted examining the specific relationships between the proportion of students of each focal racial ethnic group and the effect of gerrymandering on multiracial, black-white and

Hispanic-white diversity. Again, analyses revealed the opposite effect of racial composition than was observed for school attendance zones. For school districts, the proportion of whites in the core district was negatively related to the segregative effect of gerrymandering on multiracial (b = -0.051, p < .001), black-white (b = -0.172, p < .001), and Hispanic-white diversity (b = -0.087), p < .001). For example, a high-white school district is on average 17.1 percentage points less gerrymandered to segregate blacks from whites than a low-white school district. Conversely, the proportion of blacks in a school district was positively related to the segregative effect of gerrymandering on multiracial, black-white, and Hispanic-white diversity. For example, a high black school district is on average 18.9 percentage points less gerrymandered to segregate blacks from whites than a low-black district.

The finding that core homogeneity is associated with boundaries that are more gerrymandered to segregate for school attendance zones but with boundaries that are less gerrymandered to segregate for school districts reflects an interesting difference in the racial dynamics of gerrymandering by boundary type. One possible explanation for this difference that the segregative effects of school attendance zone boundary gerrymandering are inversely related to the segregative effects of their containing districts. Thus, for example, more homogeneous districts may have district boundaries that are less gerrymandered to segregate; however, within the district, segregation may be maintained through school attendance zone boundaries that serve to segregate. Likewise, more heterogeneous districts may have boundaries that are severely gerrymandered to segregate; however, within the district, school attendance zones may be fairly regular or, to the extent that they are irregular, may be fairly race-neutral.

To test the hypothesis that segregative gerrymandering at the school district level may suppress gerrymandering at the school level or neutral boundaries at the district level may prompt more gerrymandered school attendance zone boundaries, a supplemental diagnostic analysis was conducted examining the relationship between the segregative effects of school district and attendance zone gerrymandering. Contrary to the hypothesis, analysis revealed the effect of school attendance zone gerrymandering on diversity was positively related to the effect of school district gerrymandering on diversity (Multiracial $R = 0.288$, $p < .001$; Black-white $R = 0.391$, $p < .001$; Hispanic-white $R = 0.272$, $p < .001$). This suggests that, on average, districts that are more gerrymandered to segregate also have school attendance zone boundaries that are more gerrymandered to segregate.

Phase II Summary

To address the fourth research question, the diversity of current school district boundaries was compared to the diversity of non-gerrymandered, equal land area circle school districts. Analyses revealed that, on average, school districts are more racially/ethnically homogeneous than their "natural" districts, suggesting that the gerrymandering of school districts serves to segregate students by race and ethnicity. Although school district gerrymandering, like school attendance zone gerrymandering, segregates students of all racial/ethnic groups from each other, irregularities in district boundaries are particularly "effective" in segregating white students from black and, to a lesser extent, Hispanic students.

While the current analysis cannot be used to substantiate inferences about the discriminatory intent of district boundary gerrymandering, it can offer insight into the segregative effect of district boundaries. Indeed, this analysis establishes that, regardless of their original intent, irregularities in district boundaries currently serve to exacerbate segregation between districts. This is particularly important given the current emphasis on district boundaries as a mechanism of racial/ethnic segregation, in light of evidence that segregation between districts is now substantially higher than segregation within districts and accounts for a majority of all public school segregation (Reardon et al., 2000; Richards & Stroub, 2011).

The effects of school district boundary gerrymandering on district diversity also vary significantly by district geographic and demographic characteristics. In addition to having boundaries that are more gerrymandered than those in metropolitan areas, the gerrymandering of school district boundaries in micropolitan areas serves to segregate more than the gerrymandering of metropolitan school district boundaries, in terms of multiracial and Hispanic-white diversity. However, metropolitan and micropolitan areas did not differ in terms of the effect of gerrymandering on black-white diversity. The finding that school district boundaries serve to perpetuate black-white segregation in both larger and smaller urban areas underscores the geographic universality of gerrymandering as a mechanism of segregating blacks and whites. It is not clear why the gerrymandering of school district boundaries in micropolitan areas serves to segregate more than the gerrymandering of metropolitan school district. It is possible that the effect may also be a function of the lower levels of income and educational attainment in micropolitan areas

(Miller, 2009). Conversely, it is possible that the difference relates to different scales of segregation for urban areas of different sizes. For example, while residential segregation in larger metropolitan areas may be stronger at the macro-level, segregation in smaller micropolitan areas may be stronger at a micro-level. Coupled with the finding that segregation is higher in micropolitan areas than metropolitan areas (Parisi, Lichter & Grice, 2007), findings suggest that the gerrymandering of both school attendance zone and school district boundaries may be one factor contributing to high rates of segregation in micropolitan areas.

Despite having relatively compact district boundaries, school districts in rural areas are more gerrymandered to segregate than districts in other localities, while school districts in cities are least gerrymandered to segregate across all measures of diversity. Again, this finding may be a function of the fact that the "rural" districts in the study represent districts in fringe, exurban, and bedroom-developing areas outside more populous metropolitan and micropolitan areas. Over the past decades, these areas have experienced rapid population growth and demographic change associated with the continued outward expansion and sprawl of metropolitan areas; as a result, new school districts may be created and existing district boundaries modified to accommodate these new populations. As such, the irregularities in these boundaries may reflect the tension created by the juxtaposition of older, more homogeneous resident populations and the newer, more racially/ethnically diverse populations.

The racial dynamics of exclusion manifest in gerrymandered school district boundaries are particularly interesting when considered in light of findings for school attendance zones. For school attendance zones, more diverse schools tend to be less gerrymandered to segregate than more homogeneous schools, while whiter schools tend to be more gerrymandered to segregate schools with fewer whites. This suggests that the gerrymandering of attendance zone boundaries is being perpetrated by whites to exclude non-whites and include whites. However, findings for school districts reveal the opposite phenomenon. More homogeneous districts are *less* gerrymandered to segregate than more diverse districts, while districts with more whites tend to be *less* gerrymandered to segregate than districts with more non-whites.

Analyses reveal that the different patterns of exclusion for school attendance zones and school districts are not attributable to a compensatory effect of school attendance zone gerrymandering in non-gerrymandered school districts. Another possible explanation for the finding that school district diversity is positively related to segregative gerrymandering is that diverse district contexts may be "threatening" to certain parents who may be motivated to establish segregated boundaries than parents residing in more homogeneous areas, who feel less immediately threatened by these racial/ethnic minorities. Alternately, given that district boundaries are often subject to more careful scrutiny, it is possible that the segregative gerrymandering of boundaries has been inhibited in more homogeneous districts, which may be more closely monitored than more diverse districts.

CHAPTER 6: POLICY IMPLICATIONS AND FUTURE RESEARCH

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 adopt a "student exchange" framework which refocuses attention on how educational institutions exacerbate segregation by deliberately choosing students through irregular, "gerrymandered" boundaries. According to this perspective, irregularities in the shapes of educational boundaries reflect an inclusionary and exclusionary process whereby schools and districts "zone in" more racially and ethnically similar students in outlying areas while "zoning out" dissimilar students nearby. The distortion of attendance zone and district boundaries therefore provides a mechanism by which schools and districts facilitate segregation beyond existing patterns of residential segregation.

In this study, I provide initial empirical evidence on the gerrymandering of educational boundaries, employing geospatial methodological techniques operationalizing the study's student exchange framework to directly examine the effects of gerrymandering on the racial/ethnic diversity of U.S. public schools and school districts. Consistent with the student exchange framework, findings reveal that the gerrymandering of school attendance zones and school districts is segregative, with whiter districts "zoning out" more non-white students and "zoning in" more white student, while districts with students of color "zoning out" whites and "zoning in" more students of color. As a result of this process of student exchange, schools and districts are significantly more racially and ethnically homogeneous than they would be in the absence of gerrymandering (i.e., than their corresponding equal land area circle zones/districts or Voronoi polygonal zones). In particular, the gerrymandering of educational boundaries serves to exclude blacks and, to a lesser extent, Hispanics from predominantly white schools and districts, reinforcing the deep historical divisions between these groups. As a result of these dynamics, the gerrymandering of boundaries adds another pernicious layer of segregation to public education institutions, which are already highly segregated owing to residential patterns.

The finding that educational institutions actively facilitate segregation and, thereby, unequal access to educational opportunity through irregular and inequitable boundaries is concerning. However, by refocusing attention to the role of educational institutions in perpetuating segregation, the findings of this study also offer grounds for cautious optimism. Although, on average, educational boundaries have generally been manipulated in ways that increase their racial/ethnic homogeneity and segregate students, a substantial proportion of educational boundaries are integrative, exchanging students in ways that increase the racial/ethnic diversity of schools. Moreover, whereas individual residential decisions fall outside the control of educational institutions, school and district boundaries are subject to manipulation, and thus may be modified to make them less inequitable. Indeed, establishing affirmative race-conscious boundaries designed to mitigate the effects of residential segregation was specifically endorsed by Justice Kennedy in the *Parents Involved* decision. Below I discuss specific implications of the study findings for educational policies at the school and district levels.

Policy Implications

School Attendance Zones

Although the finding that school attendance zones are gerrymandered to segregate is somewhat discouraging, it also means that school diversity could be significantly improved through re-zoning efforts designed to minimize gerrymandering, or through standards limiting attendance zone gerrymandering. Findings from Voronoi analyses, which represent a more feasible re-zoning alternative to circular attendance zones, reveal that, on average, the black-white diversity of school attendance zones could be improved by 19% under a Voronoi attendance zoning scheme. Likewise, Hispanic-white segregation could be improved by 7% under a Voronoi attendance zoning scheme. Moreover, in addition to being more equitable, Voronoi attendance zones would also be more efficient, since by their very definition, Voronoi zones minimize student travel distance to school. Thus, rezoning is appealing in that it could satisfy the convergent interests of equity and efficiency.

In particular, the rezoning of attendance zones presents a particularly fruitful path for achieving equity in schools located in smaller, micropolitan urban areas, and in rural localities on the outskirts of major cities, areas which are undergoing rapid demographic changes and experiencing substantial increases in segregation (Parisi et al., 2007; Stroub & Richards, 2011). Moreover, attendance rezoning would be particularly effective in whiter, more homogeneous schools, which tend to use boundaries to further consolidate their homogeneity. Unfortunately, however, districts in which rezoning is likely to be successful (i.e., that are most gerrymandered to segregate) are perhaps the least likely to pursue this option, owing to the same racial dynamics that caused them to be gerrymandered in the first place.

The finding that school attendance zone boundaries are significantly less gerrymandered to segregate students in school districts subject to federal desegregation oversight suggests that desegregation orders have been, and continue to be, effective in suppressing the practice of segregative gerrymandering in the South. Although this analysis suggests that a history of federal oversight over desegregation orders may remain effective in suppressing gerrymandering even after unitary status is granted, it is unclear whether this effect will continue in the longer-term. Indeed, data from the U.S. Commission on Civil Rights indicates that the vast majority of school districts receiving declarations of unitary status have done so since the year 2000. As such, it is too soon to tell whether federal oversight will continue to inhibit segregative gerrymandering or whether boundaries will be gradually modified to segregate after the termination of desegregation orders. However, this finding suggests that more stringent oversight and monitoring of local zoning practices may be an important policy lever for suppressing discriminatory practices related to educational boundaries.

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 be strongly dependent on the commitment of district leadership to equitable boundaries. New school attendance zones are frequently established (i.e., whenever a new school is created), eliminated (i.e., whenever a school is closed down), and modified (i.e., to accommodate demographic changes, changes in facilities or school capacity, or school openings and closures). 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 (e.g., Orange County Public Schools, 2007; Richards & Stroub, 2011). 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 (Holme, Diem & Welton, forthcoming).

Although, on average, school attendance zones are gerrymandered to segregate, it should be emphasized that a large proportion of school attendance zones are actually gerrymandered to integrate, in that they are more diverse than their "natural" attendance zones. For these attendance zones, re-zoning with the objective of increasing efficiency or to returning to "neighborhood schools" could pose a threat to racial and ethnic equity. As such, it is critical to ensure that rezoning processes carefully consider the potentially adverse consequences of any new attendance zone plans. In addition, because changes to one boundary necessarily mean changes to another, it is especially important to consider the impact of boundary changes to the complement of schools in a district.

School Districts

Although school district boundaries are generally subject to greater state oversight and more stringent regulations regarding the racial/ethnic impact of boundary changes, this study finds that school district boundaries are gerrymandered as severely as attendance zones. Moreover, the irregularities in district boundaries serve to exacerbate segregation between districts. This suggests that gerrymandering is one factor contributing to the high rates of between-district segregation, which now accounts for the majority of all public school segregation (e.g., Reardon et al., 2000). However, it also indicates that between-district segregation, which has been rendered sacrosanct by *Milliken*, could be significantly improved by minimizing gerrymandering. Moreover, school redistricting initiatives designed to reduce school finance inequities and equalize educational opportunity may also have the ancillary benefit of increasing racial/ethnic equity.

It should be emphasized that although the methodology employed in this study provides direct evidence of the current effect of school district gerrymandering on the racial/ethnic composition of school districts, it does not substantiate inferences about the intent of school district gerrymandering. While deviations from regularity suggest that boundaries were intentionally manipulated, it cannot be inferred from the demographic characteristics of current residents whether the boundaries were intentionally manipulated to segregate students by race/ethnicity. While school district boundaries do change over time, they are more stable than school attendance zone boundaries, reflecting their coterminity with other political boundaries and political and legal barriers to their modification. As such, current district boundaries were often established decades or even a century ago. Thus, the demographic characteristics of students residing in and around school districts may have changed substantially since the boundaries were originally adopted. The current effect of gerrymandering on segregation, therefore, may not be the result of the intentional manipulation of exclusionary boundaries, but of individual residential decisions reflected in Tiebout sorting across district boundaries.

Moreover, because of the relative stability of district boundaries, the potential for redistricting as an instrument of integration is somewhat less promising than school rezoning. Indeed, relative to school attendance zones, school district boundaries are relatively fixed and are often tied to other jurisdictional boundaries. They are subject to more bureaucratic, formal state-imposed processes and require state and, in some cases, federal approval. Thus, changes in district boundaries require significantly more political will than school attendance zone changes. This should not be interpreted to suggest that redistricting is impossible, however; large-scale reorganization has been contemplated in some states, such as in Texas, where new districts have been proposed as a means of resolving school finance inequities. Moreover, continuing a trend that may be traced to the 1800s, school district boundaries are consolidating in rural areas (Bard & Gardener, 2011), and may be fragmenting in others (Author), presenting opportunities to review boundaries. Thus, while change is often more incremental, district boundaries do change, providing some windows of opportunity to create more equitable boundaries.

Because of these limitations, a more practical approach to obviating the effects of segregative gerrymandering of school district gerrymandering may be through policies governing changes to district boundaries. While many states contain measures preventing "discriminatory" district boundaries, the results of this study suggest that these measures have been too weak or insufficiently prescriptive to prevent gerrymandering that exacerbates segregation. For example, states may wish to consider imposing compactness standards for school districts, particularly for any new districts or modifications to existing district boundaries. In practice, this standard may be similar to the 50% equal land area circle ratio standard proposed by Angel and Parent (2011) or an areal compactness standard as has been endorsed by Polsby and Popper (1991). Failure to meet a prescribed standard for compactness would trigger a more comprehensive review to ensure that irregularities do not have an adverse impact on equity, with the effect of gerrymandering on equity. This may be established empirically using a method similar to that used in this study, comparing the equity of the existing district to the equity of alternative redistricting schemes.

It should be noted that even if gerrymandered school districts and school attendance zones were adjusted to be maximally compact, the long-term benefits of more equitable boundaries on the racial/ethnic diversity of schools and districts cannot be assured. Indeed, it is conceivable that individuals will respond to new school and district boundaries by Tiebout "voting with their feet" and re-sorting across school and district boundaries. Thus, in the long-term, levels of segregation may return to their current level. However, such processes take time, and should not overshadow the gains that may be achieved in the short term. Moreover, in the case of school attendance zones, boundaries may be re-adjusted more frequently to adapt to changing demographics.

Study Limitations

Although this study makes a number of contributions to the existing literature on segregation in schools, a number of important limitations must be acknowledged. First, it should again be emphasized that this study cannot establish discriminatory or affirmative *intent* on the part of educational agencies, although the basis for inferring intent is stronger for school attendance zone boundaries than for school district boundaries, for reasons discussed at length above. Rather, it establishes the segregative or integrative *effect* of gerrymandered boundaries, by determining the extent to which gerrymandered boundaries currently serve increase or decrease the diversity of schools or districts beyond what would be expected on the basis of existing patterns of residential segregation.

In addition, it should be emphasized that the impetus for and effects of gerrymandering may not be exclusively racial. Indeed schools and districts may gerrymander their boundaries to include and exclude certain areas for a variety of reasons. In addition to race, socioeconomic status may play a particularly strong role in driving educational boundaries. Given the local nature of education finance, this may be particularly true for districts, which may gerrymander to "tax grab" resource-rich areas to increase district revenues. Likewise, the effects of gerrymandering may not be limited to racial/ethnic segregation, but may separate students according to other dimensions. Because this study is narrowly focused on the effects of gerrymandering on racial and ethnic equity in schools, it fails to capture the full spectrum of equity effects of educational boundaries that may be important to schools, such as socioeconomic diversity. For example, the gerrymandering of boundaries may serve to segregate students by socioeconomic status even when it facilitates integration by race. Alternately, gerrymandering may integrate students by socioeconomic status even as it segregates by race.

Unfortunately, because the Census does not report block-level data on the socioeconomic status (which were used to determine the characteristics of the actual and non-gerrymandered districts in the analysis), it is impossible to determine on the basis of this analysis the relative contributions of race/ethnicity and socioeconomic status in driving student exchange via gerrymandered boundaries. However, it should again be emphasized that the effect of gerrymandering in perpetuating or ameliorating racial/ethnic segregation, which is the focus of this study, is independent of the original intent of the boundary manipulation. Thus, while it is possible that the intent of a boundary change is racially neutral, the impact of that change may be segregative or integrative.

For the analysis of school district boundaries, the study analyzes the full population of U.S. school districts, obviating any problems with sample size or bias. The school attendance zone sample, however, reflects only a quarter of the population of U.S. school attendance zones. While the SABINS sample is fairly large (n = 9,717), because schools are not required to supply their attendance zone boundaries, it is a voluntary, non-random sample and may not be representative of the population of school attendance zones as a whole. Comparison of the SABINS sample to the comparable population of U.S. public school districts revealed that they were remarkably similar in terms of demographic and geographic characteristics. However, the voluntary nature of the sample introduces the possibility of response bias. For example, schools with less gerrymandered and more equitable boundaries may have been more likely to report their boundaries than schools with less equitable boundaries. As such, the study's estimates of the effect of attendance zone gerrymandering on diversity and the amount by which diversity would be increased through rezoning to increase compactness may not be generalizable to all U.S. public schools.

In documenting the severity and prevalence of gerrymandering and in estimating the effect of gerrymandering on diversity, this study relied exclusively on measures of compactness. Compactness was selected because it represents the single most important dimension of gerrymandering, and it facilitated alignment between both phases of the study. However, as the discussion in Chapter 2 reveals, the literature on gerrymandering has identified four dimensions of compactness. Although compactness is a flexible spatial measure that captures some violations of contiguity and embeddedness, it is less sensitive to violations of these principles. Moreover, this study focuses exclusively on spatial measures of gerrymandering, and fails to capture the effects of aspatial gerrymandering through population inequivalence.

In addition, it is often difficult to disentangle deliberate gerrymandering from boundary irregularity resulting from adherence with other geographic boundaries (e.g., rivers, coastlines, mountains) or from coterminity with other jurisdictional boundaries (e.g., county). As discussed in Chapters 2 and 3, where possible, indices of gerrymandering were adjusted to reflect the unique effects of educational gerrymandering from the effects of other geographic or jurisdictional boundaries. However, it is possible that some of the instances of gerrymandering captured by the study do not reflect intentional manipulation, but merely adherence with other boundaries or manipulation for unique reasons not captured in the study (e.g., around tribal lands). To the extent that educational boundaries are gerrymandered to segregate because they adhere to other jurisdictional boundaries that are also gerrymandered to segregate suggests that while educational agencies may not be culpable for the gerrymandering of other political institutions, they are failing to mitigate it.

Future Research

As the foregoing discussion has emphasized, perhaps the single most important limitation of this study is that it is limited to examining the effects of gerrymandering; it cannot assess the extent to which these boundaries were intentionally manipulated to segregate. This is primarily because the study relies on boundaries and residential characteristics measured at a single point in time (2010), and lacks data on the racial/ethnic composition of each area at the time the boundary was established. Future research using contemporaneous data on new school boundaries and residential racial/ethnic characteristics would permit stronger inferences about the intent of boundaries to segregate.

The Census has disseminated boundary data on all U.S. school districts annually since 2006, and twice prior to 2006 (2000 and 1992). Paired with data on residential race/ethnicity from the decennial Census and American Community Survey, the sample of district boundaries that were established or modified in those years could be used to examine the extent to which boundaries were intentionally segregative. The SABINS database currently contains school attendance zone boundaries for a single year (2009-10); however, Minnesota has released annual school attendance zone shapefiles since the year 2000. This sample would permit analysis of the intent to segregate in the full sample of Minnesota attendance zones that have been created or changed over the past 12 years.

In addition to establishing the intent of gerrymandering, future research should examine the causal mechanisms contributing to gerrymandering. For example, the results of this study have been interpreted to suggest that the gerrymandering of boundaries may be initiated in response to rapid demographic changes, particularly in rural areas. However, annual boundary and demographic data such as those described above could also provide insight into how boundaries are being manipulated in response to broader population dynamics.

Another limitation of the current study is its singular focus on the racial dynamics of inclusion and exclusion manifest in gerrymandered boundaries, which neglects other potentially important factors, such as socioeconomic status and, relatedly, tax capacity. Although the current study was focused on race for theoretical reasons as well as practical reasons – the decennial Census does not report socioeconomic data at the block level – future research could determine the relationship between gerrymandering and socioeconomic indicators using block group-level data. On average, however, block groups are 39 times more populous than blocks (U.S. Census, 2010), meaning that such an analysis would be more accurate in the context of larger districts and school attendance zones. Such research would contribute to the emerging literature on the shifting dynamics of exclusion based on class and race in American schools.

Although this study constitutes a first effort to empirically study the gerrymandering of educational boundaries, it is limited to examining the severity and consequences of violations of compactness. As such, further research is necessary to extend the literature on gerrymandering beyond compactness. This is particularly important because highly compact and regular boundaries may obfuscate some of the ways in which boundaries perpetuate exclusion. In particular, additional geospatial analyses should address how educational boundaries are gerrymandered through violations of contiguity and embeddedness. In particular, further research should examine how educational institutions, particularly school districts, gerrymander through inequinumerosity, and the relationship between population inequivalence and other spatial measures of segregation.

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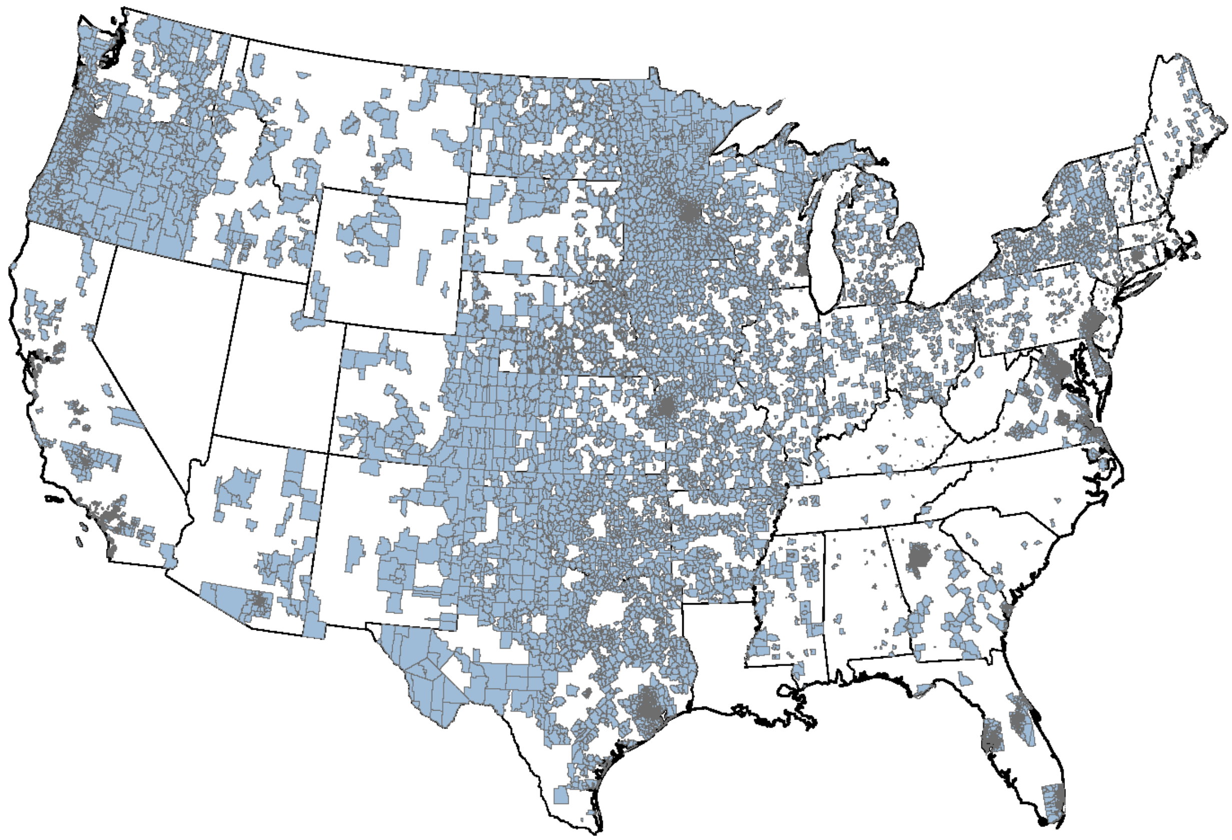
Maps

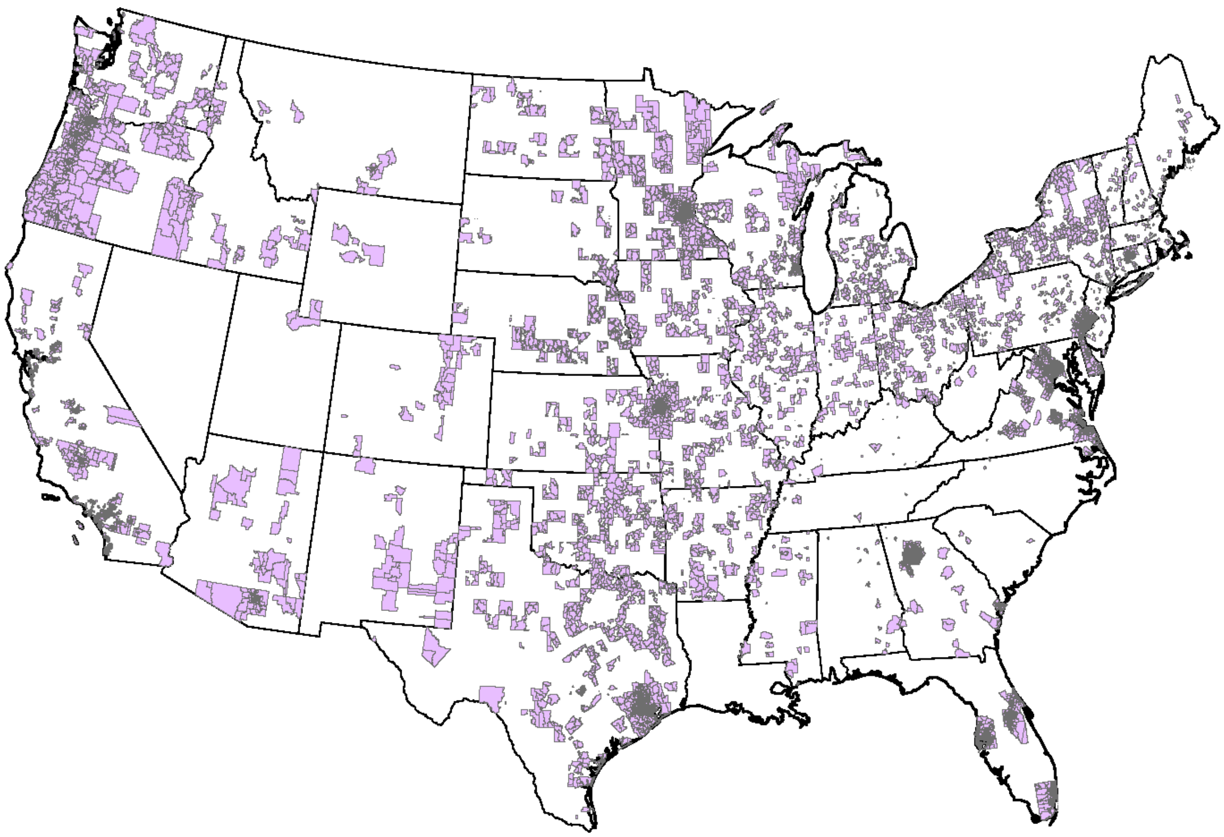
Map 1

Elementary School Attendance Zones in the SABINS Sample (N = 13,412)



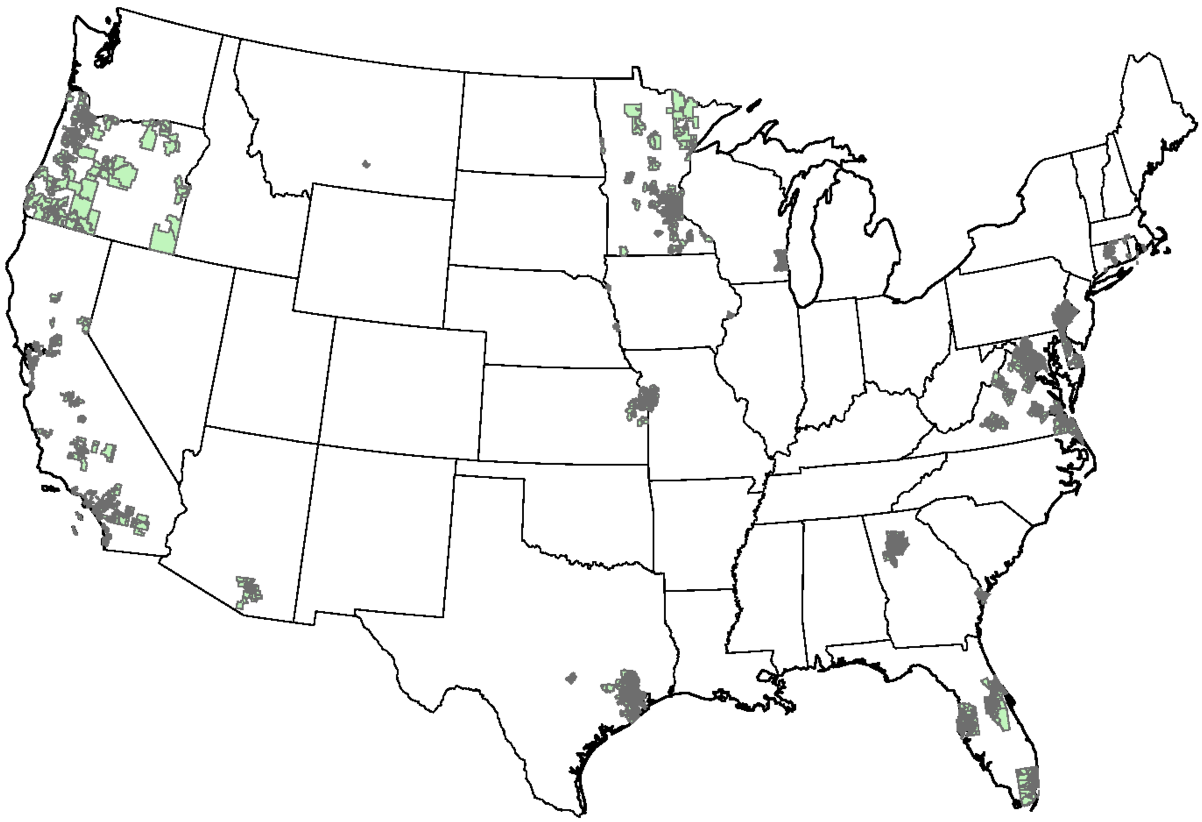
Map 2

School Attendance Zones in SABINS Sample in Core-Based Statistical Areas (n = 11,013)



Map 3

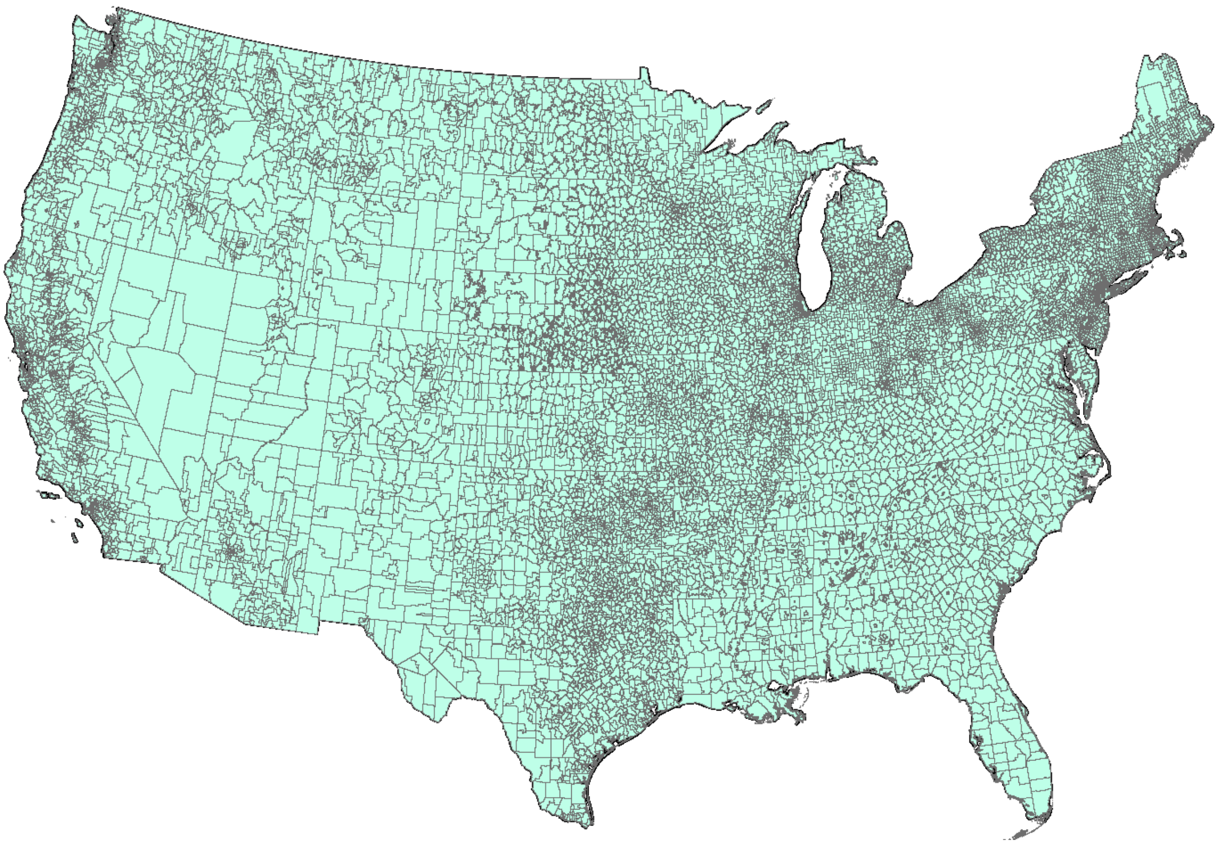
School Attendance Zones in SABINS Sample in Districts with Two or More School Attendance Zones (n = 9,717)



Map 4
School Attendance Zones in Voronoi Sample (n = 3,204)

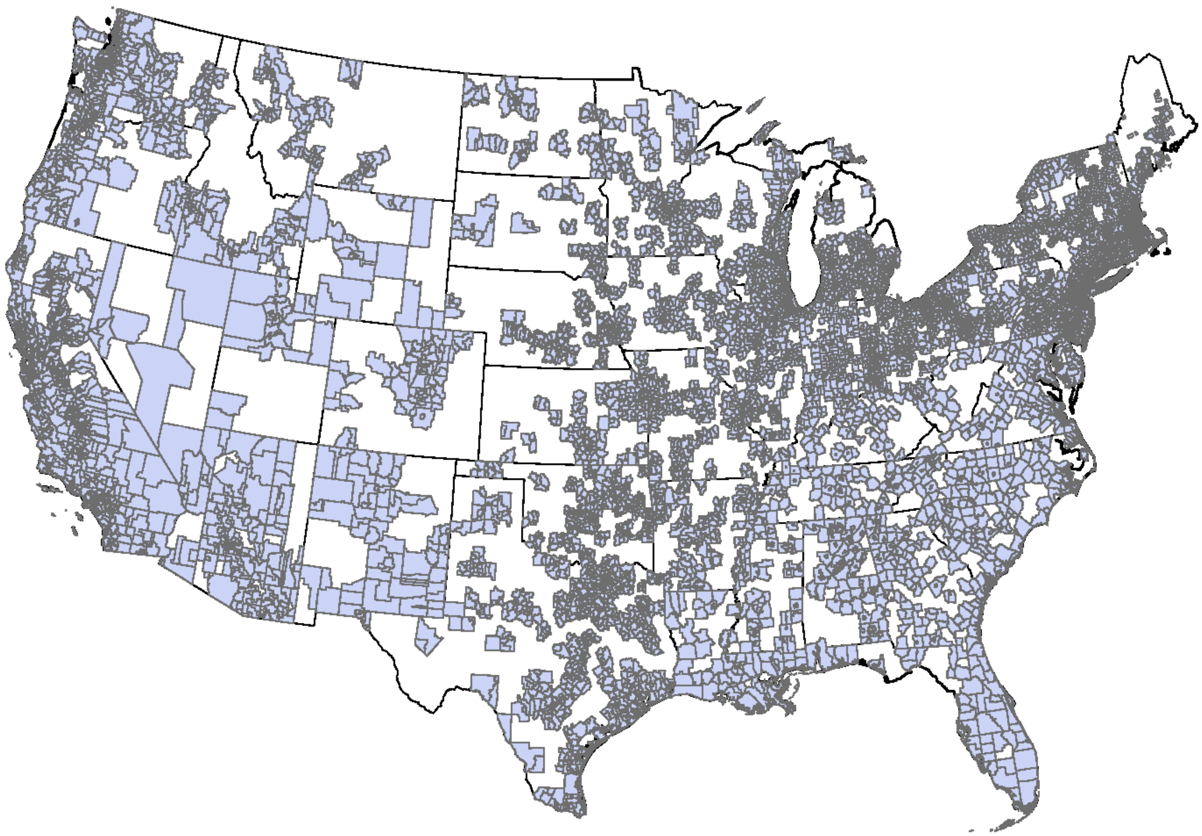
Map 5

Spatial School Districts in U.S. (n = 13,543)



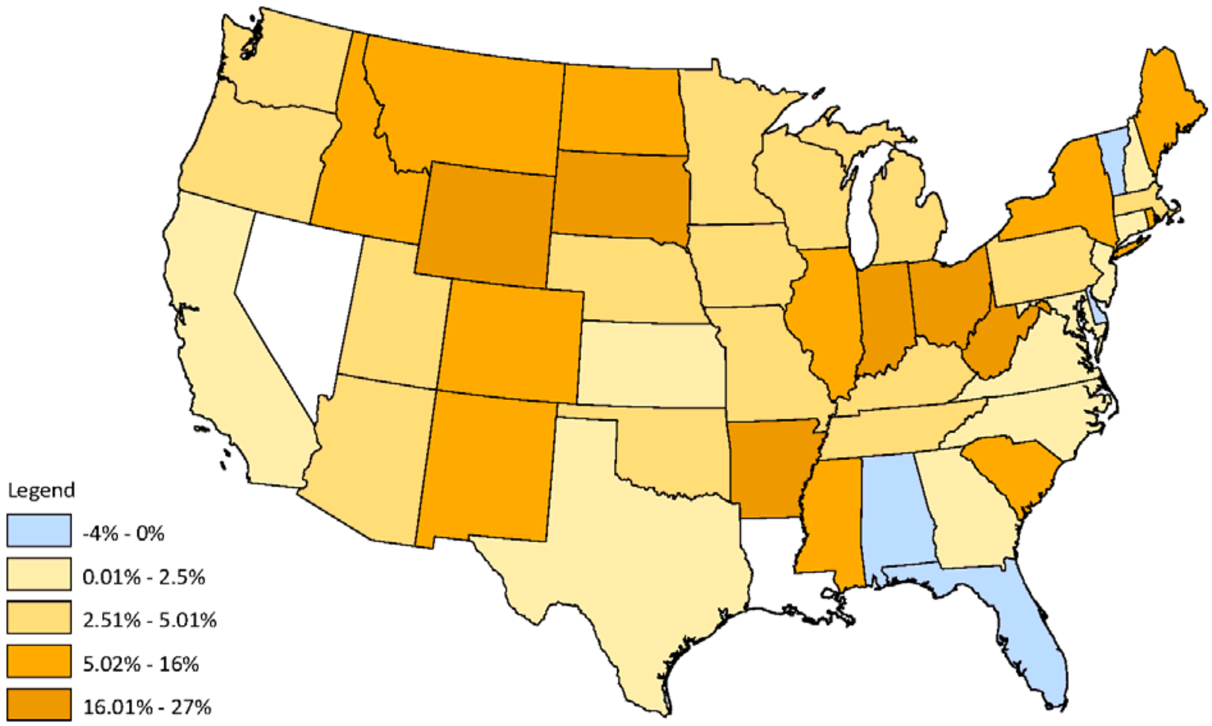
Map 6

Sample of Districts in U.S. in Core-Based Statistical Areas (n = 9,796)



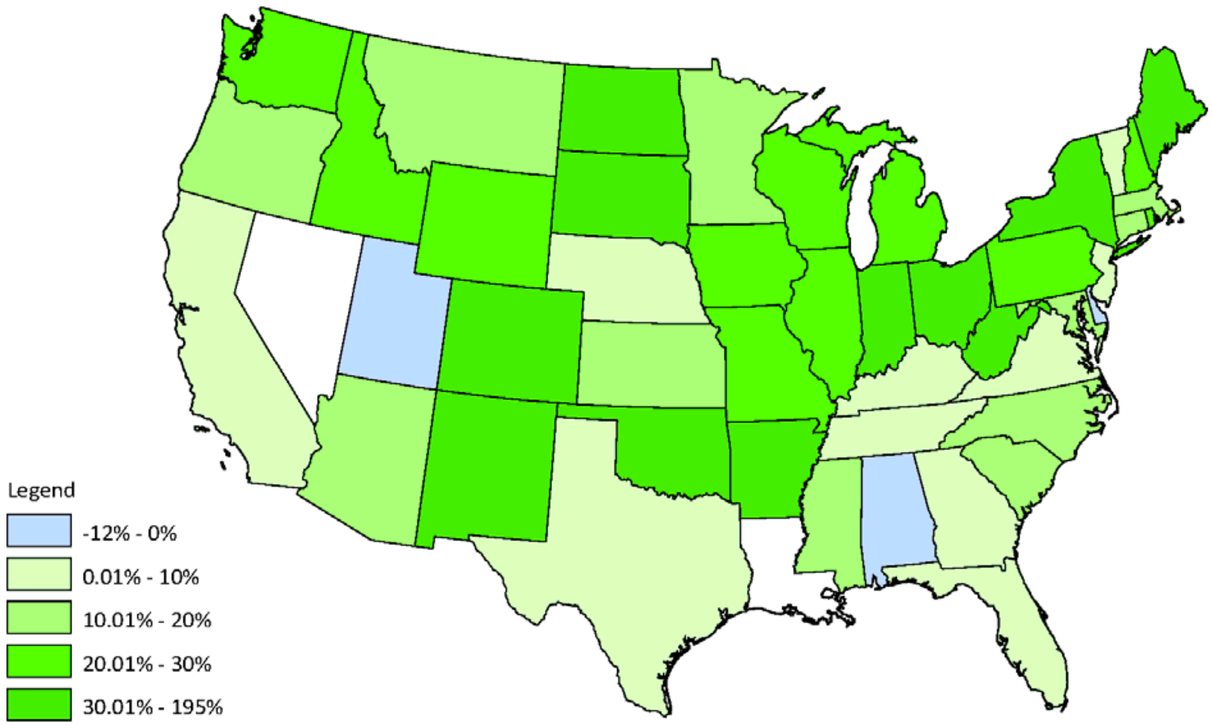
Map 7

Average Effect of School Attendance Zone Gerrymandering on Diversity - Multiracial



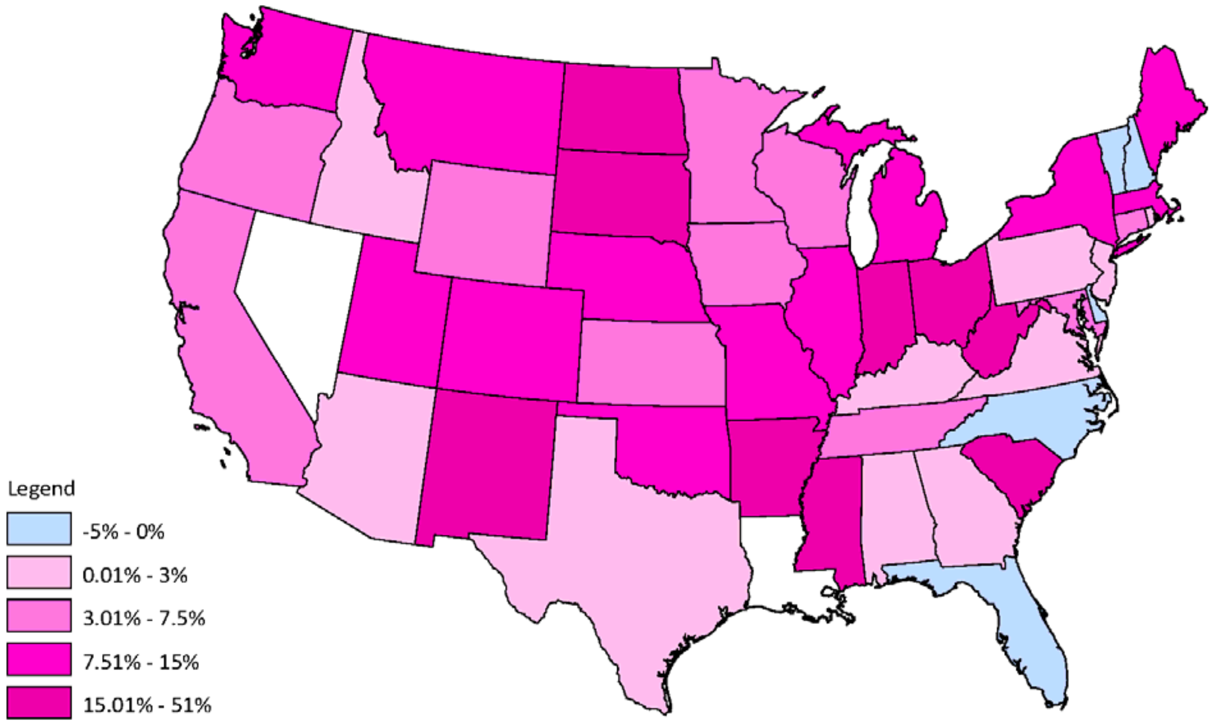
Map 8

Average Effect of School Attendance Zone Gerrymandering on Diversity - Black-White



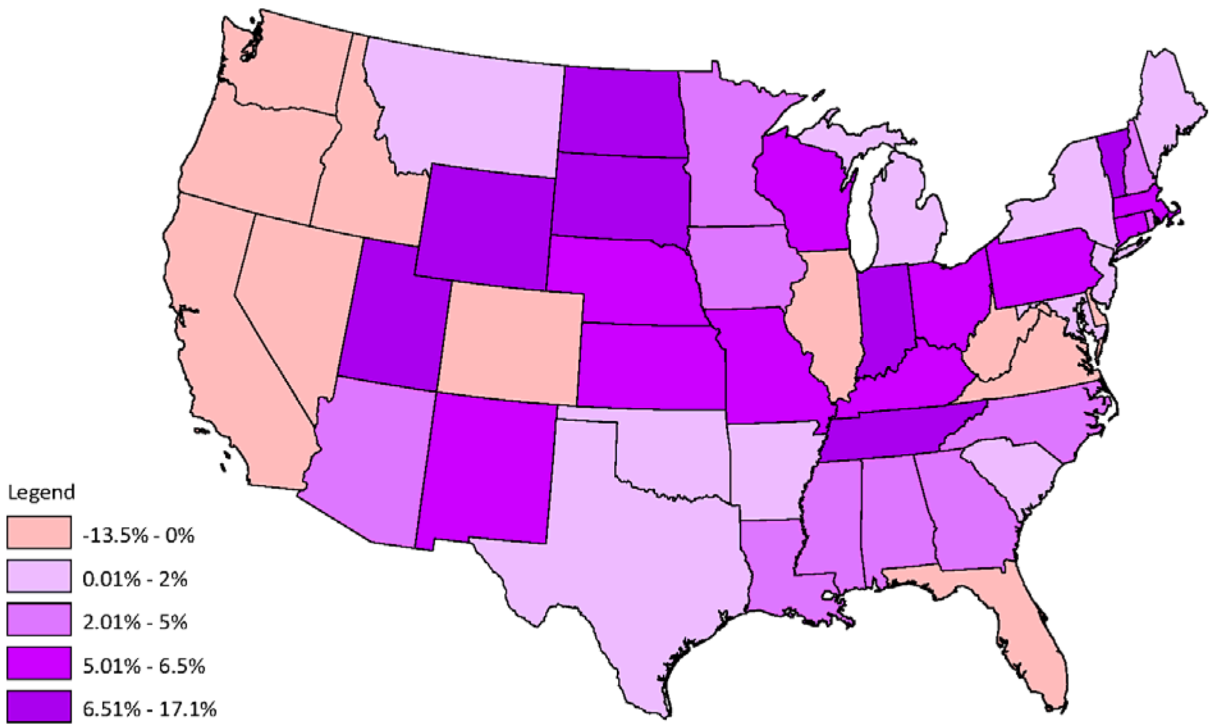
Map 9

Average Effect of School Attendance Zone Gerrymandering on Diversity - Hispanic-White



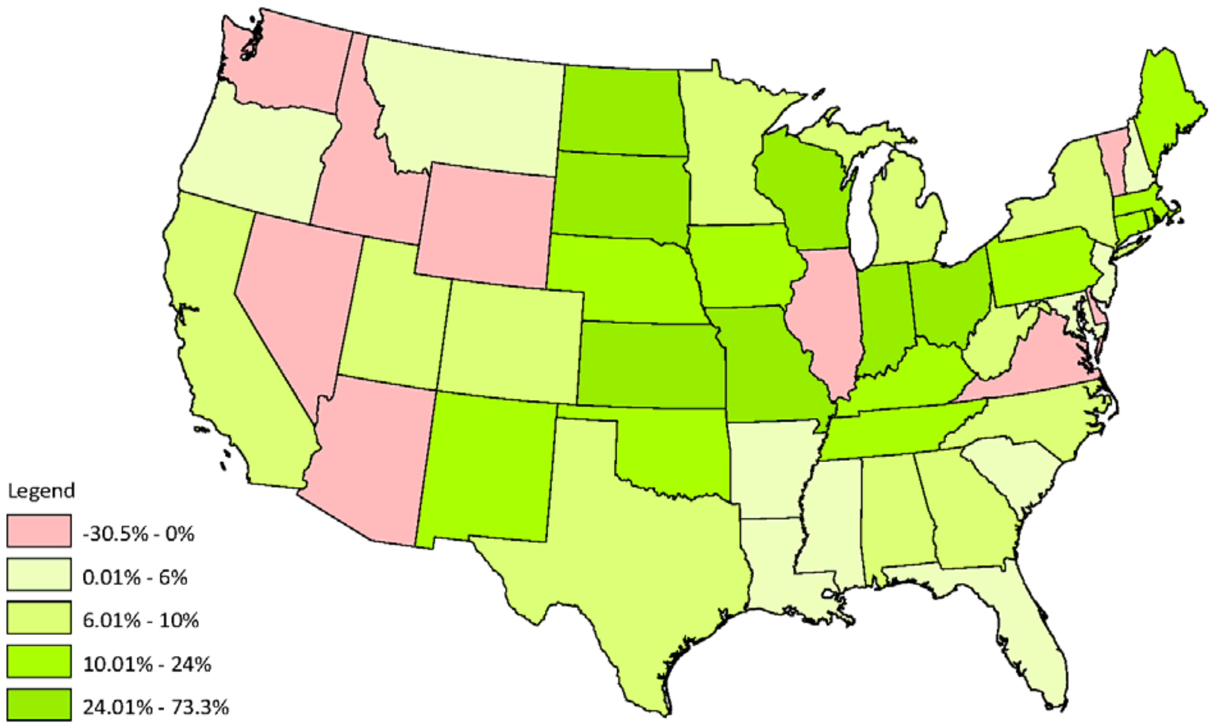
Map 10

Average Effect of School District Gerrymandering on Diversity - Multiracial



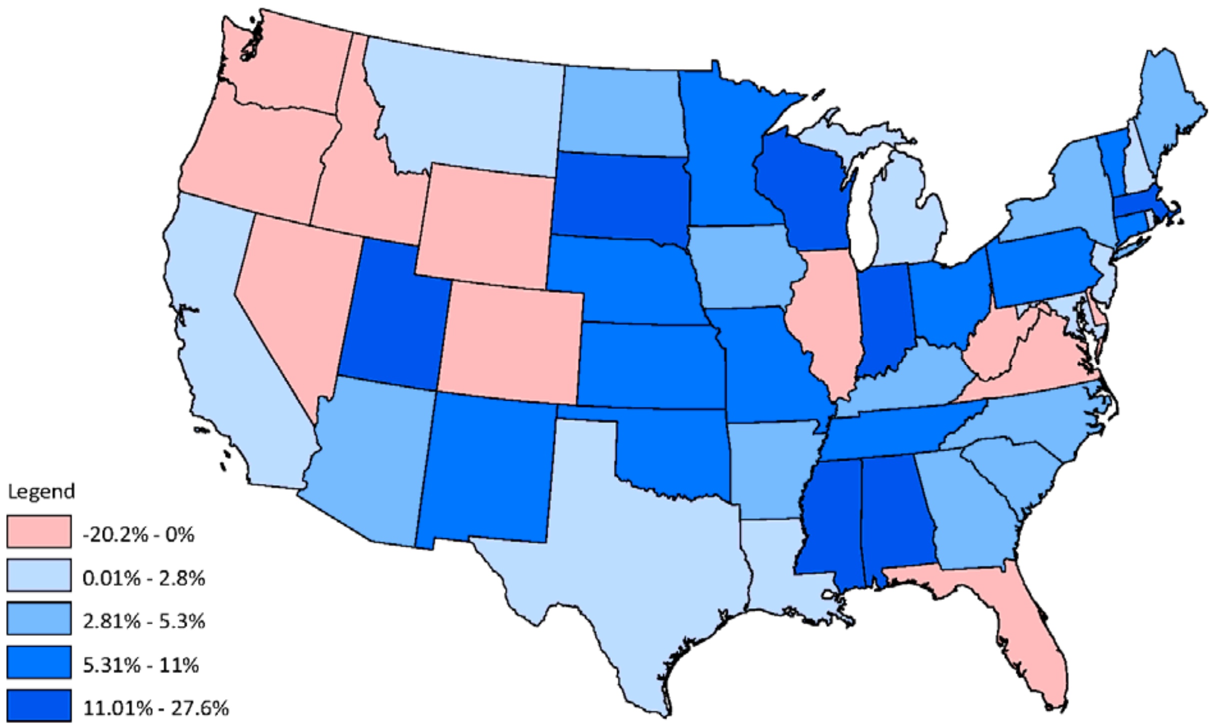
Map 11

Average Effect of School District Gerrymandering on Diversity - Black-White



Map 12

Average Effect of School District Gerrymandering on Diversity - Hispanic-White



Tables

Table 1
Measures of Compactness

Measure/Author	Equation	Description
Indentation		
Area to Perimeter Ratios		
Schwartzberg (1966), Attneave & Arnoult (1956)	$C = \frac{p}{2\sqrt{\pi a}}$	Ratio of perimeter of district to perimeter of circle with equal area
Polsby-Popper (1991), Cox (1927)	$C = \frac{4\pi a}{p^2}$	Ratio of area of district to area of circle with equal perimeter
Convexity		
Simple Convexity (Taylor, 1973)	$C = \frac{(N - R)}{(N + R)}$	Proportion of angles in district polygon that are non-reflexive (outward) vs. reflexive (inward)
Chambers & Miller (2010)	$s_Z^q(K, f) = \iint \left[\frac{d(x, y; Z)}{d(x, y; K)}\right]^q \frac{f(y)f(x)}{(F(K))^2}\, dy\, dx$	Probability that a district contains the shortest path between a randomly-selected pair of points
Dispersion		
Length-Width Displacement		
Harris (1964)	$D = \frac{W}{L}$	L is the longest axis of the district polygon and W is the maximum length perpendicular to L
	$D = L - W$	
Reported in Niemi et al. (1990)	$D = \frac{W}{L}$	W and L are the width and length of the circumscribing rectangle with minimum perimeter

Measure/Author	Equation	Description
Young (1988)	$D = \frac{W}{L}$	W and L are the width and length of the rectangle enclosing the district and touching it on all four sides for which the ratio of length to width is maximized
Reported in Niemi et al. (1990)	$D = \frac{W}{L}$	L is the longest axis and W and L are the width and length of a rectangle enclosing the district and touching it on all four sides
Eig & Seitzinger (1981)	$D = L - W$	L and W are measured on the North-South and East-West axes, respectively
Frolov (1974)	$C = \frac{d_{min}}{d_{max}}$	Ratio of diameter of maximum inscribed circle to diameter of minimum circumscribing circle
Morrill (1987)	$C = \frac{d_{min}}{d_{max}}$	Ratio of district's minimum diameter to maximum diameter
Ratio of District Area to Area of Compact Figure		
Reock (1961)		Ratio of area of district to area of minimum circumscribing **circle**
Geisler (1985)		Ratio of area of district to area of minimum circumscribing **regular hexagon**
Reported in Niemi et al. (1991)		Ratio of area of district to area of minimum convex **polygon/hull** that completely contains the district
Horton (1932); Gibbs (1961)		Ratio of area of district to area of circle with diameter equal to the district's longest axis
Ehrenberg (1892), cited in Frolov (1974)		Ratio of area of maximum inscribed circle to area of district polygon
Maximum-Minimum Circle Ratio Flaherty & Crumplin (1992)		Ratio of area of maximum inscribed circle to area of minimum circumscribing circle
Equal Land Area Circle Ratio Angel & Parent, 2011		Ratio of area of district to area included in circle about the center of gravity of the district that has the same land area as district

Measure/Author	Equation	Description
Moment of Inertia		
Schwartzberg (1966); Kaiser (1966)	$M = \frac{A}{\sqrt{2 \iint r^2 dD}}$	Sum of squared distances of every point in shape to the moment of inertia or areal “center of gravity” of the district
Boyce & Clark (1964)	$M = \sum_{1}^{n} \left| \left(\frac{r_i}{\sum_1^n} \right) * 100 - \frac{100}{n} \right|$	Average distance from district’s areal center of gravity to point on the district perimeter reached by a set of equally spaced radial lines

Note: Highlighted measures were used to assess gerrymandering in the current study.

Table 2
Study Variables and Data Sources

	Measure	Description	Data Source	Data Fields
PHASE I				
Dependent Variables	SAZ Compactness	• Schwartzberg • Polsby-Popper	SABINS 2009-10	Elementary School Attendance Zones (Grade 1)
	School District Compactness	• Schwartzberg • Polsby-Popper	Census TIGER/Line 2010	• Elementary School Districts – All states • Secondary School Districts – All states • Unified School Districts – All states
Independent Variables (SAZ and District)	Core-Based Statistical Area Type	• Metropolitan statistical area • Micropolitan statistical area (Reference category)	NCES CCD LEA Universe Survey Data File	METMIC: Indicates whether the CBSA is a metropolitan or micropolitan area
	Locality	• Rural: Fringe, Distant, Remote (Reference category) • Town: Fringe, Distant, Remote • Suburb: Large, Medium, Small • City: Large, Medium, Small	NCES CCD LEA Universe Survey	ULOCAL: NCES urban-centric locale code
	Free- and Reduced-Price Lunch	% Students qualifying for free- or reduced-price lunch	NCES CCD Public School Universe Survey	TOTFRL: Total students qualifying for free- and reduced-price lunch
	Student Race/Ethnicity	• % Black • % Hispanic • % White	NCES CCD Public School Universe Survey	BLACK: Total black students HISP: Total Hispanic/Latino students WHITE: Total white students
	Student Population	Number of students in SAZ	NCES CCD Public School Universe Survey	MEMBER: Total reported student membership

	Measure	Description	Data Source	Data Fields
Independent Variables (SAZ Only)	History of *De Jure* Segregation	• Located in 17 states formerly subject to *de jure* segregation	Watras (1997)	Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia
	History of Desegregation Order	• Granted Unitary Status/ Currently Under Court Order • Never Litigated	U.S. Commission on Civil Rights	N/A
	District compactness	Compactness of containing district: • Schwartzberg • Polsby-Popper	Census TIGER/Line 2010	• Elementary School Districts – All states • Secondary School Districts – All states • Unified School Districts – All states
PHASE II				
Dependent Variables	Effect of SAZ Gerrymandering on SAZ Diversity	% difference in diversity between actual SAZ and natural SAZ	• Census 2010 Summary File 1 demographic data, spatially linked to actual SAZ and natural SAZ boundaries	• P9: Hispanic or Latino, and Not Hispanic or Latino by Race • P11: Hispanic or Latino, and Not Hispanic or Latino by Race for the Population 18 Years and Over
	Effect of District Gerrymandering on District Diversity	% difference in diversity between actual district and natural district	• Census 2010 Summary File 1, spatially linked to actual district and natural district boundaries	• P9: Hispanic or Latino, and Not Hispanic or Latino by Race • P11: Hispanic or Latino, and Not Hispanic or Latino by Race for the Population 18 Years and Over

	Measure	Description	Data Source	Data Fields
Independent Variables (SAZ and District)	Core-Based Statistical Area Type	• Metropolitan statistical area • Micropolitan statistical area (Reference category)	NCES CCD LEA Universe Survey Data File	METMIC: Indicates whether the CBSA is a metropolitan or micropolitan area
	Locality	• Rural: Fringe, Distant, Remote (Reference category) • Town: Fringe, Distant, Remote • Suburb: Large, Medium, Small • City: Large, Medium, Small	NCES CCD LEA Universe Survey	ULOCAL: NCES urban-centric locale code
	Core Student Race/Ethnicity	• % Black • % Hispanic • % White	Census 2010 Summary File 1, spatially linked to area of overlap between actual and natural boundaries	• P9: Hispanic or Latino, and Not Hispanic or Latino by Race • P11: Hispanic or Latino, and Not Hispanic or Latino by Race for the Population 18 Years and Over
	Core Student Diversity	• Multiracial diversity • Black-white diversity • Hispanic-white diversity	Census 2010 Summary File 1, spatially linked to area of overlap between actual and natural boundaries	• P9: Hispanic or Latino, and Not Hispanic or Latino by Race • P11: Hispanic or Latino, and Not Hispanic or Latino by Race for the Population 18 Years and Over
	Student Population	Number of students in SAZ	Census 2010 Summary File 1, spatially linked actual school attendance zone and school district boundaries	P11: Hispanic or Latino, and Not Hispanic or Latino by Race for the Population 18 Years and Over (TOTAL)

	Measure	Description	Data Source	Data Fields
Independent Variables (SAZ Only)	History of *De Jure* Segregation (SAZ only)	• Located in 17 states formerly subject to *de jure* segregation	Watras (1997)	Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia
	History of Desegregation Order (SAZ only)	• Granted Unitary Status/ Currently Under Court Order • Never Litigated	U.S. Commission on Civil Rights	N/A

Table 3

Characteristics of School Attendance Zones in Sample vs. Population

	Full Sample		Voronoi Sample		Population[1]	
	N	%	N	%	N	%
Demographic Characteristics						
Student Race/Ethnicity						
American Indian/Alaska Native	50,425	1.0%	9,962	0.5%	223,211	1.0%
Asian	312,962	6.2%	156,851	8.5%	1,179,564	5.3%
Black (non-Hispanic)	804,570	15.9%	278,071	15.1%	3,823,251	17.2%
Hispanic	1,361,300	27.0%	525,864	28.5%	5,522,701	24.8%
Pacific Islander/Hawaii Native	7,301	0.1%	2,634	0.1%	22,767	0.1%
White	2,392,158	47.4%	828,678	44.9%	10,993,645	49.4%
Two or More Races	58,137	1.2%	25,419	1.4%	180,684	0.8%
Free- and Reduced-Price Lunch						
FRL Eligible	2,543,019	50.4%	820,825	44.4%	11,088,271	49.8%
Not FRL Eligible	2,504,510	49.6%	1,025,966	55.6%	11,161,172	50.2%
Total Population	5,047,529		1,846,791		22,249,443	
Population per SAZ	519		576		464	
Geographic Characteristics						
Core-Based Statistical Area Type						
Metropolitan	8,360	86.0%	3,097	96.7%	41,385	86.3%
Micropolitan	1,357	14.0%	107	3.3%	6,568	13.7%
Locality						
City	2,654	27.3%	804	25.1%	15,118	31.5%
Suburb	3,509	36.1%	1,687	52.7%	15,926	33.2%
Town	853	8.8%	184	5.7%	5,409	11.3%
Rural	2,701	27.8%	529	16.5%	11,479	23.9%
De Jure Segregation Status						
In *De Jure* Segregated South	4,105	42.2%	1,382	43.1%	17,021	35.5%
Not in *De Jure* South	5,571	57.3%	1,822	56.9%	30,932	64.5%
Total	9,717		3,204		47,953	

[1] Elementary schools located in metropolitan and micropolitan districts with two or more schools

Table 4

Characteristics of School District Sample

	N	%
Demographic Characteristics		
Student Race/Ethnicity		
American Indian/Alaska Native	443,031	1.0%
Asian	2,207,629	5.0%
Black (non-Hispanic)	7,146,010	16.3%
Hispanic	9,887,035	22.5%
Pacific Islander/Hawaii Native	47,022	0.1%
White	23,342,929	53.2%
Two or More Races	319,662	0.7%
Free- and Reduced-Price Lunch		
FRL Eligible	20,096,432	45.8%
Not FRL Eligible	23,767,339	54.2%
Total Population	43,863,771	
Population per District	4,491	
Geographic Characteristics		
Core-Based Statistical Area Type		
Metropolitan	6,936	71.0%
Micropolitan	2,860	29.3%
Locality		
City	727	7.4%
Suburb	2,694	27.6%
Town	1747	17.9%
Rural	4,628	47.4%
De Jure Segregation Status		
In *De Jure* Segregated South	2,358	24.1%
Not in *De Jure* South	7,438	76.2%
Total	9,767	

Table 5

Effects of School Geographic and Demographic Characteristics on School Attendance Zone Compactness

	Schwartzberg (Perimeter Ratio)			Polsby-Popper (Area Ratio)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metropolitan CBSA Type[1]	0.032 **	0.040 ***	0.038 ***	0.038 **	0.050 ***	0.047 ***
Locality[2]						
City	-0.033 ***	-0.021 ***	-0.019 **	-0.062 ***	-0.045 ***	-0.042 ***
Suburb	-0.038 ***	-0.031 ***	-0.029 ***	-0.070 ***	-0.061 ***	-0.058 ***
Town	-0.111 ***	-0.111 ***	-0.110 ***	-0.148 ***	-0.149 ***	-0.147 ***
De Jure Segregation[3]	-0.063 ***	-0.060 ***	-0.055 ***	-0.074 ***	-0.070 ***	-0.063 ***
Free- and Reduced-Price Lunch (%)	0.016	0.060 ***	0.044 ***	0.008	0.072 ***	0.046 ***
White (%)	-0.061 ***	--	--	-0.086 ***	--	--
Black (%)	--	0.015 *	--	--	0.017 *	--
Hispanic (%)	--	--	0.037 ***	--	--	0.054 ***
District Compactness	0.057 ***	0.068 ***	0.064 ***	0.090 ***	0.103 ***	0.098 ***
Student Population (Log)	-0.026 ***	-0.018 ***	-0.026 ***	-0.037 ***	-0.026 ***	-0.038 ***
Intercept	0.590	0.567	0.567	0.397	0.368	0.368
Model R^2	0.100	0.094	0.097	0.111	0.102	0.107
N	9,717	9,717	9,717	9,717	9,717	9,717

*$p < .05$, ** $p < .01$, *** $p < .001$. Effects estimated using ordinary least squares regression.

[1] Reference group is micropolitan statistical area

[2] Reference group is rural locality

[3] Reference group is not in formerly *de jure* segregated South

Table 6

Effects of District Desegregation Status on SAZ Compactness

	Schwartzberg (Perimeter Ratio) Model 7		Polsby-Popper (Area Ratio) Model 8	
Desegregation Order[1]	**0.052**	***	**0.058**	***
Metropolitan CBSA Type[2]	-0.054	*	-0.064	*
Locality[3]				
City	0.002		0.008	
Suburb	-0.010		-0.007	
Town	-0.047		-0.031	
Free- and Reduced-Price Lunch (%)	-0.033		-0.028	
White (%)	-0.123	***	-0.129	***
District Compactness	0.144	***	0.158	***
Student Population (Log)	0.008		0.008	
Intercept	0.558		0.329	
Model R^2	0.113		0.109	
N	1,286		1,286	

*$p < .05$, ** $p < .01$, *** $p < .001$. Effects estimated using ordinary least squares regression.

Note: De jure Segregation excluded from model because all school attendance zones in the sample were located in formerly *de jure* segregated South.

[1] Reference group is never subject to federal desegregation litigation

[2] Reference group is micropolitan statistical area

[3] Reference group is rural locality

Table 7

Mean Diversity for Actual and Equal Land Area Circle SAZs and Effect of Gerrymandering on Diversity

School Attendance Zones		N	Actual SAZ	Equal Land Area Circle SAZ	Effect of Gerrymandering[1]
Multiracial Diversity		9,717	0.427	0.428	+3.08%
	SD		(0.203)	(0.200)	(0.267)
Black-White Diversity		9,717	0.176	0.179	+15.44%
	SD		(0.169)	(0.167)	(1.381)
Hispanic-White Diversity		9,717	0.248	0.249	+5.32%
	SD		(0.160)	(0.158)	(0.389)

[1] Figure represents average increase in diversity that would be achieved by eliminating gerrymandered boundaries.

Table 8

Effect of School Attendance Zone Gerrymandering on Segregation by State

		Effect of Gerrymandering[1]		
		Multiracial Diversity	Black-White Diversity	Hispanic-White Diversity
Alabama	Mean	-0.028	-0.122	0.017
	N	13	13	13
	SD	0.212	0.371	0.251
Arizona	Mean	0.045	0.146	0.027
	N	143	143	143
	SD	0.314	1.213	0.204
Arkansas	Mean	0.191	1.950	0.270
	N	74	74	74
	SD	0.533	10.009	0.587
California	Mean	0.014	0.026	0.041
	N	1687	1687	1687
	SD	0.277	0.544	0.439
Colorado	Mean	0.101	0.798	0.110
	N	17	17	17
	SD	0.190	1.384	0.209
Connecticut	Mean	0.018	0.155	0.055
	N	146	146	146
	SD	0.187	0.991	0.294
Delaware	Mean	-0.037	-0.026	-0.007
	N	66	66	66
	SD	0.147	0.271	0.238
DC	Mean	-0.015	0.024	-0.012
	N	41	41	41
	SD	0.150	0.505	0.268
Florida	Mean	-0.016	0.008	-0.011
	N	773	773	773
	SD	0.130	0.521	0.144
Georgia	Mean	0.006	0.066	0.033
	N	450	450	450
	SD	0.159	0.409	0.325
Idaho	Mean	0.086	0.210	0.026
	N	15	15	15
	SD	0.183	0.612	0.212
Illinois	Mean	0.074	0.266	0.096
	N	106	106	106
	SD	0.350	1.968	0.462
Indiana	Mean	0.231	0.634	0.306
	N	75	75	75
	SD	0.782	1.992	1.131

		Effect of Gerrymandering[1]		
		Multiracial Diversity	Black-White Diversity	Hispanic-White Diversity
Iowa	Mean	0.054	0.264	0.073
	N	122	122	122
	SD	0.288	1.440	0.386
Kansas	Mean	0.018	0.146	0.040
	N	209	209	209
	SD	0.181	1.179	0.259
Kentucky	Mean	0.029	0.040	0.034
	N	19	19	19
	SD	0.183	0.305	0.159
Maine	Mean	0.124	0.608	0.111
	N	18	18	18
	SD	0.313	2.046	0.271
Maryland	Mean	0.013	0.101	0.042
	N	308	308	308
	SD	0.155	0.732	0.420
Massachusetts	Mean	0.053	0.136	0.090
	N	44	44	44
	SD	0.248	0.444	0.417
Michigan	Mean	0.048	0.217	0.075
	N	123	123	123
	SD	0.232	0.857	0.299
Minnesota	Mean	0.044	0.187	0.065
	N	509	509	509
	SD	0.256	1.025	0.393
Mississippi	Mean	0.144	0.126	0.163
	N	31	31	31
	SD	0.477	0.359	0.352
Missouri	Mean	0.049	0.292	0.100
	N	373	373	373
	SD	0.306	1.725	0.501
Montana	Mean	0.078	0.125	0.104
	N	31	31	31
	SD	0.201	0.483	0.235
Nebraska	Mean	0.029	0.053	0.079
	N	138	138	138
	SD	0.303	0.580	0.639
New Hampshire	Mean	0.013	0.198	-0.013
	N	22	22	22
	SD	0.141	0.967	0.154

		Effect of Gerrymandering[1]		
		Multiracial Diversity	Black-White Diversity	Hispanic-White Diversity
New Jersey	Mean	0.011	0.030	0.015
	N	40	40	40
	SD	0.131	0.337	0.167
New Mexico	Mean	0.117	0.462	0.167
	N	20	20	20
	SD	0.266	1.156	0.339
New York	Mean	0.084	0.426	0.100
	N	221	221	221
	SD	0.405	1.822	0.418
North Carolina	Mean	0.013	0.134	-0.047
	N	5	5	5
	SD	0.094	0.323	0.140
North Dakota	Mean	0.139	1.056	0.209
	N	39	39	39
	SD	0.328	3.633	0.771
Ohio	Mean	0.173	0.566	0.182
	N	221	221	221
	SD	0.493	2.248	0.552
Oklahoma	Mean	0.037	0.314	0.114
	N	178	178	178
	SD	0.127	1.221	0.373
Oregon	Mean	0.025	0.139	0.062
	N	585	585	585
	SD	0.159	0.688	0.299
Pennsylvania	Mean	0.035	0.199	0.033
	N	592	592	592
	SD	0.382	1.619	0.391
Rhode Island	Mean	0.077	0.265	0.030
	N	7	7	7
	SD	0.177	0.396	0.217
South Carolina	Mean	0.087	0.115	0.513
	N	6	6	6
	SD	0.167	0.290	0.895
South Dakota	Mean	0.172	0.364	0.320
	N	38	38	38
	SD	0.472	1.968	1.427
Tennessee	Mean	0.038	0.034	0.056
	N	12	12	12
	SD	0.131	0.183	0.141

		Effect of Gerrymandering[1]		
		Multiracial Diversity	Black-White Diversity	Hispanic-White Diversity
Texas	Mean	0.007	0.085	0.032
	N	1035	1035	1035
	SD	0.167	0.597	0.264
Utah	Mean	0.028	-0.033	0.113
	N	1	1	1
	SD	.	.	.
Vermont	Mean	-0.025	0.058	-0.048
	N	25	25	25
	SD	0.152	0.331	0.210
Virginia	Mean	0.014	0.037	0.007
	N	733	733	733
	SD	0.193	0.430	0.248
Washington	Mean	0.049	0.222	0.087
	N	81	81	81
	SD	0.199	0.708	0.397
West Virginia	Mean	0.265	0.862	0.304
	N	29	29	29
	SD	0.525	2.057	0.702
Wisconsin	Mean	0.046	0.264	0.069
	N	280	280	280
	SD	0.218	1.889	0.274
Wyoming	Mean	0.178	0.223	0.037
	N	16	16	16
	SD	0.401	0.724	0.343
Total	Mean	0.031	0.154	0.053
	N	9717	9717	9717
	SD	0.267	1.381	0.389

[1] Figure represents average increase in diversity that would be achieved by eliminating gerrymandered boundaries.

Table 9

Mean Diversity for Actual and Voronoi SAZs and Effect of Gerrymandering on Diversity

School Attendance Zones		N	Actual SAZ	Voronoi SAZ	Effect of Gerrymandering[1]
Multiracial Diversity		3,204	0.474	0.481	-0.50%
	SD		(0.173)	(0.172)	(0.156)
Black-White Diversity		3,204	0.199	0.207	+18.34%
	SD		(0.161)	(0.163)	(4.249)
Hispanic-White Diversity		3,204	0.265	0.269	+7.30%
	SD		(0.148)	(0.148)	(2.441)

[1] Figure represents average increase in diversity that would be achieved by eliminating gerrymandered boundaries.

Table 10

Mean Diversity for Actual and Equal Land Area Circle SAZs and Effect of Gerrymandering on Diversity - Voronoi Sample

		N	Actual SAZ	Equal Land Area Circle SAZ	Effect of Gerrymandering[1]
Multiracial Diversity		3,204	0.474	0.478	+0.69%
	SD		(0.173)	(0.171)	(0.170)
Black-White Diversity		3,204	0.199	0.203	+6.30%
	SD		(0.161)	(0.162)	(0.593)
Hispanic-White Diversity		3,204	0.265	0.268	+2.99%
	SD		(0.148)	(0.148)	(0.287)

[1] Figure represents average increase in diversity that would be achieved by eliminating gerrymandered boundaries.

Table 11

Effects of SAZ Gerrymandering on Diversity by School Geographic and Demographic Characteristics

	Multiracial Diversity Models 1-4	Black-White Diversity Models 5-8	Hispanic-White Diversity Models 9-12
Metropolitan CBSA Type[1]	-0.051 ***	-0.257 ***	-0.056 ***
Locality[2]			
City	-0.032 ***	-0.217 ***	-0.038 **
Suburb	-0.024 **	-0.175 ***	-0.017
Town	-0.015	-0.169 **	-0.017
De Jure Segregation[3]	-0.014 *	0.008	-0.010
Core Diversity (Multi/Black-white/Hispanic-white)	-0.136 ***	-0.551 ***	-0.208 ***
Student Population (Log)	0.012 *	0.071 *	-0.017 *
Intercept	0.099	0.510	0.124
Model R^2	0.028	0.018	0.019
N	9,621	9,621	9,621
Models Containing Additional Demographic Predictors[4]			
Core White (%)	0.027 **	0.230 ***	0.012
Core Black (%)	-0.009 *	-0.041 *	0.006
Core Hispanic (%)	-0.025 **	-0.180 **	0.005

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$. Effects estimated using ordinary least squares regression. Dependent variable represents the increase in diversity that would be achieved by eliminating gerrymandered boundaries.

[1] Reference group is micropolitan statistical area

[2] Reference group is rural locality

[3] Reference group is not in formerly *de jure* segregated South

[4] Coefficients obtained by adding core demographic predictors incrementally to each model in lieu of the core diversity value (because of collinearity in demographic predictors).

Table 12

Effects of School Attendance Zone Gerrymandering on Diversity by School District Desegregation Status

	Multiracial Diversity Model 13	Black-White Diversity Model 14	Hispanic-White Diversity Model 15
Desegregation Order[1]	**-0.028** *	**-0.058** *	**-0.018**
Metropolitan CBSA Type[2]	-0.024	0.135 *	-0.090 *
Locality[3]			
City	-0.011	-0.102 *	-0.012
Suburb	-0.021	-0.131 ***	-0.006
Town	0.077 *	0.067	0.050
Core Diversity (Multi/Black-white/Hispanic-white)	0.038	-0.133	-0.051
Student Population (Log)	-0.032 *	-0.064 *	-0.016
Intercept	0.062	0.079	0.124
Model R^2	0.032	0.017	0.018
N	1,286	1,286	1,286

*$p < .05$, ** $p < .01$, *** $p < .001$. Effects estimated using ordinary least squares regression. Dependent variable represents the increase in diversity that would be achieved by eliminating gerrymandered boundaries.

[1] Reference group is never subject to federal desegregation litigation

[2] Reference group is micropolitan statistical area

[3] Reference group is rural locality

Table 13

Mean Compactness for SAZs and School Districts

	N	Schwartzberg (Perimeter Ratio)		Polsby-Popper (Area Ratio)		Correlation
		Mean	SD	Mean	SD	
School Attendance Zones						
Raw	9,717	0.587	(0.136)	0.363	(0.165)	0.989*
Normalized	9,717	1.274	(0.669)	2.070	(3.492)	0.915*
School Districts	9,796	0.594	(0.147)	0.374	(0.169)	0.983*

*Correlation is significant at $p < .01$ (two-tailed).

Table 14

Effects of District Geographic and Demographic Characteristics on School District Compactness

	Schwartzberg (Perimeter Ratio)			Polsby-Popper (Area Ratio)		
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metropolitan CBSA Type	0.014 ***	0.019 ***	0.014 ***	0.013 **	0.017 ***	0.013 **
Locality						
City	-0.023 ***	-0.010	-0.016 *	-0.016 *	-0.001	-0.007
Suburb	0.038 ***	0.048 ***	0.044 ***	0.047 ***	0.058 ***	0.055 ***
Town	-0.015 ***	-0.013 ***	-0.015 ***	-0.016 ***	-0.014 **	-0.016 ***
Free- and Reduced-Price Lunch (%)	-0.046 ***	0.002	-0.026 ***	-0.064 ***	-0.012	-0.038 ***
White (%)	-0.066 ***	--	--	-0.079 ***	--	--
Black (%)	--	-0.004	--	--	0.015	--
Hispanic (%)	--	--	0.072 ***	--	--	0.079 ***
Student Population (Log)	-0.016 ***	-0.014 ***	-0.015 ***	-0.019 ***	-0.017 ***	-0.018 ***
Intercept	0.576	0.569	0.574	0.355	0.347	0.352
Model R^2	0.051	0.043	0.051	0.053	0.044	0.051
N	9,611	9,611	9,611	9,611	9,611	9,611

*$p < .05$, ** $p < .01$, *** $p < .001$. Effects estimated using ordinary least squares regression.

Table 15

Mean Diversity for Actual and Non-Gerrymandered Districts and Effect of Gerrymandering on Diversity

School Districts		N	Actual District	Equal Land Area Circle District	Effect of Gerrymandering[1]
Multiracial Diversity		8,421	0.338	0.342	+3.06%
	SD		(0.191)	(0.193)	(0.276)
Black-White Diversity		7,938	0.110	0.113	+13.61%
	SD		(0.143)	(0.146)	(1.285)
Hispanic-White Diversity		8,374	0.189	0.191	+4.77%
	SD		(0.151)	(0.151)	(0.378)

[1] Figure represents average increase in diversity that would be achieved by eliminating gerrymandered boundaries.

Table 16

Effect of School District Gerrymandering on School District Segregation by State

		Effect of Gerrymandering[1]		
		Multiracial Diversity	Black-White Diversity	Hispanic-White Diversity
Alabama	Mean	0.037	0.065	0.120
	N	78	78	78
	SD	0.165	0.350	0.231
Alaska	Mean	-0.135	-0.171	0.017
	N	9	8	9
	SD	0.228	0.963	0.553
Arizona	Mean	0.044	-0.005	0.045
	N	177	150	176
	SD	0.366	0.563	0.455
Arkansas	Mean	0.004	0.052	0.036
	N	117	116	117
	SD	0.197	0.548	0.254
California	Mean	-0.001	0.081	0.012
	N	891	819	889
	SD	0.197	0.966	0.294
Colorado	Mean	-0.011	0.061	-0.003
	N	73	66	73
	SD	0.099	0.405	0.131
Connecticut	Mean	0.052	0.218	0.089
	N	135	134	135
	SD	0.162	0.623	0.281
Delaware	Mean	-0.058	-0.126	-0.095
	N	2	2	2
	SD	0.085	0.167	0.167
Florida	Mean	-0.018	0.039	-0.053
	N	46	46	46
	SD	0.185	0.312	0.193
Georgia	Mean	0.030	0.078	0.042
	N	124	124	124
	SD	0.117	0.271	0.222
Idaho	Mean	-0.004	-0.154	0.000
	N	49	40	49
	SD	0.175	0.434	0.205
Illinois	Mean	-0.010	-0.007	-0.019
	N	93	92	93
	SD	0.229	0.574	0.275
Indiana	Mean	0.133	0.427	0.122
	N	236	228	234
	SD	0.469	1.940	0.553

		Effect of Gerrymandering[1]		
		Multiracial Diversity	Black-White Diversity	Hispanic-White Diversity
Iowa	Mean	0.025	0.164	0.042
	N	152	147	151
	SD	0.228	1.193	0.343
Kansas	Mean	0.061	0.431	0.106
	N	118	112	118
	SD	0.340	2.776	0.506
Kentucky	Mean	0.063	0.235	0.053
	N	88	88	88
	SD	0.183	0.840	0.318
Louisiana	Mean	0.026	0.038	0.015
	N	40	40	40
	SD	0.100	0.154	0.190
Maine	Mean	0.018	0.124	0.040
	N	85	76	77
	SD	0.259	0.614	0.320
Maryland	Mean	0.018	0.056	0.027
	N	20	20	20
	SD	0.061	0.133	0.089
Massachusetts	Mean	0.051	0.104	0.121
	N	268	267	268
	SD	0.218	0.505	0.494
Michigan	Mean	0.009	0.064	0.018
	N	415	396	411
	SD	0.156	0.572	0.183
Minnesota	Mean	0.022	0.084	0.055
	N	185	177	185
	SD	0.225	0.652	0.458
Mississippi	Mean	0.046	0.056	0.121
	N	102	102	102
	SD	0.245	0.226	0.288
Missouri	Mean	0.052	0.385	0.073
	N	335	306	334
	SD	0.363	4.318	0.366
Montana	Mean	0.007	0.038	0.005
	N	124	80	116
	SD	0.341	0.603	0.540
Nebraska	Mean	0.053	0.206	0.091
	N	113	98	113
	SD	0.320	1.083	0.537

		Effect of Gerrymandering[1]		
		Multiracial Diversity	Black-White Diversity	Hispanic-White Diversity
Nevada	Mean	-0.018	-0.100	-0.037
	N	27	23	27
	SD	0.119	0.574	0.227
New Hampshire	Mean	0.023	0.055	0.023
	N	157	141	155
	SD	0.208	0.517	0.349
New Jersey	Mean	0.003	0.054	0.027
	N	476	466	475
	SD	0.171	0.466	0.260
New Mexico	Mean	0.057	0.224	0.076
	N	59	49	59
	SD	0.331	0.835	0.366
New York	Mean	0.018	0.094	0.029
	N	606	601	605
	SD	0.243	0.629	0.289
North Carolina	Mean	0.033	0.077	0.041
	N	60	60	60
	SD	0.076	0.194	0.105
North Dakota	Mean	0.067	0.323	0.029
	N	69	45	64
	SD	0.358	1.053	0.438
Ohio	Mean	0.065	0.243	0.077
	N	553	550	553
	SD	0.321	1.306	0.383
Oklahoma	Mean	0.018	0.137	0.056
	N	321	301	321
	SD	0.099	0.927	0.257
Oregon	Mean	-0.018	0.025	-0.024
	N	142	114	142
	SD	0.213	0.545	0.244
Pennsylvania	Mean	0.056	0.233	0.074
	N	527	522	527
	SD	0.297	1.267	0.330
Rhode Island	Mean	0.030	0.114	0.026
	N	56	56	56
	SD	0.186	0.676	0.249
South Carolina	Mean	0.007	0.013	0.034
	N	85	85	85
	SD	0.064	0.089	0.213

		Effect of Gerrymandering[1]		
		Multiracial Diversity	Black-White Diversity	Hispanic-White Diversity
South Dakota	Mean	0.069	0.250	0.223
	N	69	54	68
	SD	0.372	1.343	1.097
Tennessee	Mean	0.106	0.231	0.104
	N	117	117	117
	SD	0.262	0.554	0.275
Texas	Mean	0.015	0.082	0.014
	N	703	663	703
	SD	0.169	0.586	0.177
Utah	Mean	0.167	0.067	0.276
	N	37	34	37
	SD	0.670	0.312	1.080
Vermont	Mean	0.086	-0.098	0.100
	N	76	61	71
	SD	0.813	1.235	0.880
Virginia	Mean	-0.020	-0.015	-0.007
	N	26	26	26
	SD	0.269	0.466	0.377
Washington	Mean	-0.114	-0.305	-0.202
	N	39	35	39
	SD	0.434	0.615	0.483
West Virginia	Mean	-0.068	0.067	-0.058
	N	47	47	47
	SD	0.381	0.975	0.461
Wisconsin	Mean	0.057	0.733	0.203
	N	67	57	66
	SD	0.770	3.800	1.335
Wyoming	Mean	0.171	-0.015	-0.072
	N	22	17	21
	SD	0.789	0.925	0.466
Total	Mean	0.031	0.138	0.048
	N	8323	7844	8279
	SD	0.276	1.291	0.379

[1] Figure represents average increase in diversity that would be achieved by eliminating gerrymandered boundaries.

Table 17

Effects of School District Gerrymandering on Diversity by District Geographic and Demographic Characteristics

	Multiracial Diversity Models 1-4	Black-White Diversity Models 5-8	Hispanic-White Diversity Models 9-12
Metropolitan CBSA Type[1]	-0.016 *	-0.045	-0.023 *
Locality[2]			
City	-0.079 ***	-0.219 ***	-0.098 ***
Suburb	-0.040 ***	-0.075	-0.040 ***
Town	-0.040 ***	-0.145 ***	-0.067 ***
Core Diversity (Multi/Black-white/Hispanic-white)	0.183 *	0.447 ***	0.206 ***
Student Population (Log)	0.001	-0.028 *	0.003
Intercept	0.066	0.236	0.094
Model R^2	0.017	0.007	0.013
N	8,417	7,937	8,373
Models Containing Additional Demographic Predictors[3]			
Core White (%)	-0.051 ***	-0.172 **	-0.087 ***
Core Black (%)	0.096 ***	0.361 ***	0.139 ***
Core Hispanic (%)	0.007	0.066	0.058 **

*$p < .05$, ** $p < .01$, *** $p < .001$. Effects estimated using ordinary least squares regression. Dependent variable represents the increase in diversity that would be achieved by eliminating gerrymandered boundaries.

[1] Reference group is micropolitan statistical area

[2] Reference group is rural locality

[3] Coefficients obtained by adding core demographic predictors incrementally to each model in lieu of the core diversity value (because of