Examining School-level Fragmentation as a Contributor to Within-district Racial and Ethnic Segregation

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Abstract

Racial/ethnic segregation, a prominent feature in most major city school systems, has more recently spread to suburban districts. Now that more of our nation's children attend school in suburbs than in central cities, racial and ethnic proportions in suburban districts have shifted from a majority white student population to a more diverse student body. In districts adhering to a local-schools policy, district leaders typically respond to increases in enrollment by building new buildings, which results in redrawing attendance zones. By doing so, these leaders increase the overall fragmentation of their districts—constructing more and smaller catchment areas. Fragmentation occurring in a racially/ethnically diverse community marked by localized residential segregation increases the potential for greater ethnic/racial homogeneity *within* neighborhood schools, while raising the likelihood of greater racial/ethnic imbalance *between* schools. This study focuses on the question: within growing and racially/ethnically diverse school districts, does the geometric process of increasing attendance zone fragmentation have an independent effect on between-school segregation, unrelated to other factors, such as residential migration?

Using GIS methodologies on a national database of elementary school attendance boundaries, projected school populations were produced by extracting the racial/ethnic characteristics of the school-aged population residing within each attendance zone from small-scale US Census data. In order to measure the effect that changing school boundaries could have on segregation, all projected school populations were extracted from the same census data into existing school zones, first for SY2009-10 and then for SY2015-16. In each district, between-school segregation was measured for each school year and the difference calculated. Residential clustering of the non-white population was also computed.

Within-district racial imbalance was found to be highly correlated to rising fragmentation between whites and African Americans, while segregation between whites and Hispanics appeared unaffected by changing fragmentation levels. These differing results were attributed to variations in residential patterns for Hispanics and for African Americans in their respective relationship to whites.

Previous studies on school segregation have failed to take into account the possible effect that increasing fragmentation may have on between-school segregation. As a result, some studies may have over-estimated the causal contributions of other segregative factors.

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Chapter 1: Introduction

In the six-plus decades since the *Brown v. Board of education* (1954) decision declared school racial segregation to be in violation of the U.S. Constitution, America's school children still sit next to classmates of similar color and social background. The goal of racial integration envisioned by *Brown* still remains an elusive ideal, in spite of some early progress, as the manner, mechanisms, and forms of school segregation have morphed and adapted to accommodate multiple legal, social, and demographic changes. No longer focused solely on the larger school systems of major cities, and no longer simply a dichotomous tale of whites excluding African Americans, the issues surrounding school segregation have broadened geographically to include surrounding suburbs and exurbs that are increasingly undergoing transformations into more multi-racial and multi-ethnic communities.

Implicit in the concept of segregation are lines of separation—lines both physical and social, drawn between groups to include some and exclude others. This dissertation will examine the role that one type of physical line—the school attendance boundary—has in the manner and degree of racial segregation in public school settings. Since *Brown,* school boundaries, drawn between neighborhoods, communities, and municipalities, have inexorably remained at the center of much of our nation's racial contentions.

In the years since the Supreme Court pronounced that "separate but equal" would no longer be the law of the land, school desegregation processes and trends have occupied social science researchers and policy makers alike. The early decades after *Brown* (1954) held promise when integration efforts led to significant declines in white/black segregation, although, immediately after this major decision, little progress was made because, although "all deliberate speed" was espoused by the Court, the Court mandated no consequences for inaction. The *Green* (1968) and

Swann (1971) cases signaled the Court's intention to hold school districts accountable for continued segregation, which resulted in the South becoming the most integrated region of the nation by the close of the 1970s (G. Orfield, Frankenberg, & Lee, 2003). However, as the Supreme Court's composition changed with the Nixon appointments, tilting the Court in a conservative direction, desegregation efforts faced a number of setbacks. While the *Keyes* (1973) decision advanced the cause of desegregation by holding schools outside the South accountable, it determined that segregative acts must be intentional and it placed the burden of proof on plaintiffs (Chemerinsky, 2005). Because discriminatory intent rather than discriminatory impact was the accepted judicial test, inequalities in school funding and educational opportunities, which were adjudicated in the *Rodriguez* (1973) case, were acceptable as long as discriminatory intent was indeterminable.

The real turning point in the retrenchment of school segregation occurred when the high court decided, in the *Milliken v. Bradley* (1974) decision, to absolve suburban districts of any responsibility to integrate students from central cities into their schools. Leaders of the Detroit Public Schools (DPS) realized that, with dwindling numbers of white students, desegregation was not possible within the DPS alone (M. Orfield, 2015). Their proposed remedy was to enjoin the whiter suburban districts into a metro-wide integration effort. The Supreme Court by a 5-4 vote rejected their plan. Justice Potter Stewart attributed the cause of

> a growing core of Negro schools [to] unknown and perhaps unknowable factors such as in-migration, birth rates, economic changes, or cumulative acts of private racial fears…The Constitution simply does not allow federal courts to attempt to change that situation unless and until it is shown that the State, or its political subdivisions, have contributed to cause the situation to exist. No record has been made in this case showing that the racial composition

> of the Detroit school population or that residential patterns within Detroit and in the surrounding areas were in any significant measure caused by governmental activity (*Milliken v. Bradley*, 1974).

Stewart wrote this conclusion despite the Court having been presented with ample evidence of the government's discriminatory activities, which included exclusionary zoning, redlining, housing discrimination, loan denials encouraged both by government regulatory agencies and the IRS, and violence sanctioned by local police. As a consequence of the *Milliken* decision, an outcome aggravated by the *Rodriguez* case, desegregation was legally limited to within-district/between-school interventions allowing whiter, richer suburban districts to effectively wall off their schools and their resources behind district lines from those of the central cities, giving a *literal* meaning to W.E.B. Du Bois's still relevant directive that "the challenge of the Twentieth Century is the problem of the color line" (Du Bois, 2001, p. 31). This study will examine color lines—lines drawn within school districts that separate children of different race, ethnicity and class.

A Missing Mechanism of Segregation: Increased Fragmentation

The overarching goal of this study is to call attention to a mechanism of segregation that could account for a consequential portion of the racial/ethnic imbalance between schools in growing and diverse districts—a mechanism that is the outcome of a rather simple geometric process.

To understand the impact of this process, it is important to recognize a fundamental attribute of a school—it is a *place*. This not only connotes the point location of a particular building but also includes the geographic space from which children are drawn and from which those children are separated from other children. "Schools are highly specialized environments, which (temporarily) isolate and segregate children from wider social and spatial contexts" (Collins & Coleman, 2008, p. 283). Of all the lines that group and isolate children—state, county, municipal, and district—school attendance boundaries literally make the final cut. With 83% of all public school students attending the school to which they are assigned (Richards & Stroub, 2015), many children have little exposure to children outside of the few blocks surrounding their homes. For this reason, boundaries matter (Weiher, 1991). Many spatially oriented studies of segregation use distances or non-socially-salient geographic units, such as census tracts or zip codes, as units of analyses (see Chodrow, 2017; England, 2014; Lee et al., 2008; Reardon et al., 2009). Others have considered school attendance zones non-spatially when measuring between- and within-district segregation (see Bischoff, 2008; Frankenberg, 2017; Holme, 2002; Owens, Reardon, & Jencks, 2016; Wells et al., 2009). "Although some spatial indices have been already developed, most of empirical studies still rely on nonspatial indices. This happens because spatial measures always require the extraction of geographical information and are more difficult to compute than nonspatial measures" (Feitosa et al., 2004, p. 62). A handful have examined school attendance zones as a spatial variable, focusing on the irregularity of their shapes as segregative mechanism (Richards, 2014; Richards & Stroub, 2015; Saporito, 2017a). Prior to this study, only Monarrez (2018) has attempted to measure how changes in school attendance boundary configurations may influence between-school segregation. His focus was on the migration tendencies of residents after attendance boundaries shifted, but not on the segregative effects that the changing boundaries themselves may have enacted.

The political processes of school attendance rezoning has received a fair amount of attention (Bartels & Donato, 2009; Frankenberg & Kotok, 2013; Frankenberg & Taylor, 2017; Siegel-Hawley, 2013; Siegel-Hawley, Bridges, & Shields, 2017). However, all studies to date have failed to account for the social consequences precipitated by the geometric process of partitioning a constant area (a school district) into more and, on average, smaller units. To my knowledge, no study of racial/ethnic segregation by school attendance zone has yet considered how increasing the number of schools, along with the accompanying shifting of catchment area boundary lines, might contribute to changes in between-school segregation. Perhaps it was unrecognized as a potential factor or perhaps it was considered as being a trivial component compared with other variables and thus discarded without comment. Whatever the reason, any effects that changing school-attendance-zone fragmentation may have on between-school segregation has heretofore been unmeasured.

Another potential reason increasing fragmentation has not been included in causal discussions of school segregation is the difficulty in measuring spatial changes of this kind over time on a large scale. Furthermore, many other variables are more fluid, such as demographic changes due to resident relocation, while school attendance zones are relatively more stable. But as lines of fragmentation go, school attendance boundaries are perhaps the most unstable of all the socially meaningful borders and, partly due to their transient nature, they also are some of the most politically contentious. It is for this reason that a more thorough accounting of the consequences of repartitioning school districts should be elucidated and that a thorough account should also be broad enough to generalize across multiple contexts.

This study, to my knowledge, is the only one to investigate the effect that changing school attendance boundaries have on within-district segregation using a nationwide sample. Therefore, this study can claim a degree of universality in its conclusions that cannot easily be discounted as unrepresentative of a larger phenomenon. That being said, distinctions are obscured between varying types of districts in different regions of the country and between districts having distinct attributes, such as size or locale designation. This study is the first to identify a previously unmeasured—and unmentioned—mechanism of segregation between schools. The current literature on segregation by school attendance boundaries is mute on the possibility that that the simple act of cutting can segregate. Although it has been widely recognized that smaller spatial units are internally more homogeneous than larger ones, only this study, so far, has described how the geometric process of creating smaller units alone, even without the contribution of other factors, can yield greater racial/ethnic imbalance.

The present study does not address the political, practical, and technical issues of the process of siting new schools and drawing new catchment areas. However, given the findings of this study, those questions could be approached with new awareness of the segregative effects of adding and adjusting attendance zones.

Research Question

There are a number of issues that must be addressed and terms that must be made explicit in any discussion of school segregation, foremost being what segregation is. Moreover, it is imperative to consider which racial/ethnic categories form the relevant groups for analysis. Since segregation can be measured from the classroom level all the way to regional and state levels, what are the relevant dimensions of segregation to be examined and at what scale should they be viewed?

This study investigates the manner in which attendance boundaries within a district allocate children to schools in a way that can either reflect, exacerbate or ameliorate underlying patterns of racial imbalance found within the residential communities served by those local schools. More specifically, this study examines the following question: when a growing district adds a new school, how does the process of drawing and redrawing attendance boundaries affect the overall level of racial/ethnic segregation within that district? The importance of this last question lies in the capacity of attendance boundaries to either include or separate children of different races, ethnicities, and classes. Furthermore, those boundaries may allow differential access of whites and nonwhites to experiences, opportunities, and resources that contribute to children's future success.

Simply stated, the focus of this dissertation examines how the process of *fragmentation* within school districts influences racial segregation. Spatial fragmentation occurs when a given fixed area is subdivided into more and smaller areal units. This study demonstrates how the very act of spatial fragmentation, *apart* from any other process or mechanism, can have its own independent effect on segregation. This effect will be most often observed in growing districts as they respond to increasing school-aged enrollments by siting and building new schools, which most often results in an increase in the number of attendance zones within the district. This study shows that increasing fragmentation can be a sufficient contributor to higher segregation if certain other conditions are present.

In order for the fragmentation process to increase segregation levels between schools, a district must possess some necessary characteristics in addition to population growth, foremost being the adherence to a neighborhood schools policy, whereby children are assigned to nearby schools according to their place of residence. Second, fragmentation processes will increase school segregation only if the foundational residential segregation exhibits a pattern of local concentrations of the minority group(s).[1] Furthermore, during the process of delineating attendance zones, there must be little to no effort on the part of district planners and leaders to

[1] This last criterion is discussed at length in a subsequent chapter.

adjust the zones for the purpose of achieving greater racial balance. A main point of this study is to show that *intent*, either to integrate or to separate children by attendance zone, is unnecessary in order for school segregation to rise. Increased fragmentation is sufficient in and of itself.

> The explicit research question addressed in this study is: Within growing and racially/ethnically diverse school districts, does increasing school attendance zone fragmentation have an independent effect on between-school segregation?

My hypothesis is that districts that serve communities containing sufficient levels of neighborhood-level racial/ethnic clustering will exhibit higher segregation due to the fragmentation process, independent of any assumption that there is some intent on the part of district leaders to segregate.

Importance of the Study

This study adds to the segregation literature by examining the effects of within-district fragmentation as a *temporal* process—a previously unexamined potential contributor to school segregation. As such, the central issue here is not the level of fragmentation and segregation at any particular time, but rather, as districts become increasingly fragmented, how does this new spatial configuration change the previous level of between-school segregation?

Previous studies have emphasized the political aspects of boundary drawing by focusing on elites' actions and intentions. Others have documented how lower fragmentation levels are related to less segregation than that observed in more fragmented landscapes at other locations. This study differs from others by investigating changes in fragmentation and segregation occurring over time in the same locations. Furthermore, even though the decision to build new schools and redraw attendance zones is a political and social process, those factors, while recognized as influencing the size, shape and number of zones, will remain as unobserved variables for the purpose of this study. Instead, only the spatial differences between zone configurations at different times are considered, apart from all other variables. No matter how those boundary changes were enacted, the inevitable result, whether intentionally or not, is greater segregation. This study contends that the very act of drawing new attendance boundaries in growing, diverse districts will group children into schools in such a way that the between-school proportions of any heterogeneously distributed attribute, i.e. race, ethnicity, or income, is likely to increase by a non-trivial amount. Intent to segregate is neither assumed nor is it excluded. Greater fragmentation is the only mechanism necessary for gains in segregation to be observed.

The impact of increasing fragmentation at this scale has yet to be examined as a possible contributor to school racial segregation. The effect of increasing fragmentation in diverse school districts on segregation needs to be estimated and, if found to be significant, the fragmentation process should to be considered alongside other identified causes of school segregation. Unless an analysis of the independent effects of increased fragmentation on school-level segregation in growing public school districts is conducted, factors perhaps more central to the causal explanation of persistent school segregation may be significantly overestimated.

An Analogy

In order to better understand how changing fragmentation *alone* can exacerbate segregation within a school district, consider the analogy of a jigsaw puzzle. Suppose a picture of a few brightly colored balloons is cut into only a dozen interlocking pieces. One can envision that many or most of the pieces would contain more than one of the balloon colors. Now suppose that the same picture is made into a 500-piece puzzle. Many of the pieces of this puzzle would consist of only a single color—some would be entirely blue and others all yellow or all red. In more general terms, envision any fixed region containing a certain feature of interest that is unevenly distributed across its domain. When this region is spatially subdivided, the segments produced by the process of subdivision will possess unequal portions of that target feature unless care is taken to subdivide the region in such a way as to apportion that feature equally among all segments. As the number of segments increases, the relative disparity of that feature distributed among the segments will also increase. Returning to the puzzle analogy, in order to avoid uneven composition among the pieces, one would need to cut out each piece with the deliberate intention of equalizing the proportions of all colors among all pieces—even if that was possible, it would be a daunting task.

Therefore, in those growing and diverse school districts that adhere to a neighborhood schools policy, adding new schools requires drawing new attendance boundaries. Like the puzzle pieces, the act of carving new attendance zones will only intensify the uneven grouping of children by race and ethnicity. The impact of increased fragmentation as a possible contributor to school racial segregation is currently unmentioned in the segregation literature. This study argues that the effect of increasing fragmentation in certain school districts needs to be estimated, and if found to be significant, the influence of school-level fragmentation needs to be taken into account when discussing the dynamics of school segregation.

Growing and Diverse School Districts

There are two primary reasons this study will chiefly examine suburban school districts. First, the *Milliken* and *Rodriguez* cases have effectively restricted segregation remedies to within school districts rather than between districts. Second, the demographics of suburban school districts have changed significantly since those cases were decided.

In the last six decades, as the number of suburbs has increased and as the proportion of all Americans living in suburbs has grown from roughly one third to now a majority, the composition of suburbs has diversified racially, ethnically and economically (Frey, 2011). While post-war suburban growth was mostly spurred by relatively affluent whites helped by government incentives (Glaeser & Kahn, 2003; Rothstein, 2017), the latest expansion is due primarily to poorer nonwhite migrations. In fact, the proportion of nonwhite, mostly Hispanic, suburban residents doubled between 1990 and 2010 (Stroub & Richards, 2017). The effect on suburban schools has been dramatic and is a source of great interest to social scientists studying this new locus of potential racial segregation. Much of this research has documented how racial/ethnic segregation has moved from the outdated stereotype of "chocolate city and vanilla suburb" to a more multi-hued consideration of the entire metropolitan landscape, where segregation now occurs along new lines of demarcation (Frankenberg, 2011b). A portion of this segregation literature has established how the fragmentation of metropolitan areas by outer-ring municipalities and the proliferation of their school districts inhibits the melting-pot potential of the nation's expanding and diversifying suburbs (Dowding & Mergoupis, 2003; Frankenberg, 2009; Frankenberg, Siegel-Hawley, & Diem, 2017; Holme & Finnigan, 2013).

Recent studies of spatial inequality attribute the amount and degree of the segregation of disadvantaged children of color from their affluent white counterparts mostly to each group residing in separate school districts (Bischoff, 2008; Fiel, 2013; Frankenberg & Orfield, 2012; Fry, 2009; Owens, 2016, 2018; Reardon & Yun, 2001; Richards & Stroub, 2014; Stroub & Richards, 2017). These studies primarily focus on segregation at the district level and largely discount any segregative mechanisms operating *within* school districts for two primary reasons. First, most large urban districts, unlike in decades past, are now more homogeneously composed of poorer children of color. Second, the fragmented nature of suburban districts have allowed parents with sufficient financial means to sort themselves into communities that are economically similar to themselves (Ayscue & Orfield, 2015; Clotfelter, 2001; Crowder, Pais, & South, 2012; Dougherty, 2012; Dougherty et al., 2009; Fiel, 2013; Rury & Saatcioglu, 2011; Zhang, 2011). However, many previously homogeneously white suburban school districts have more recently experienced an increase in their racial/ethnic and economic diversity, prompting school district leaders, expressing a need to compete in the suburban marketplace, to respond with policies that tend to favor politically savvy parents seeking to maintain their privilege (André-Bechely, 2005; Collins & Coleman, 2008; Roda & Wells, 2013). Local district leaders often respond by establishing local attendance boundaries that effectively exclude less desirable students from neighborhood schools attended by children from mostly white affluent families (Diem & Frankenberg, 2013; Frankenberg & Kotok, 2013). The effort to establish and maintain attendance boundaries favorable to the more advantaged residents is a persistent struggle in districts needing to accommodate a growing population of school-aged children. When districts grow they usually build new schools, and new schools necessitate that new catchment areas be outlined. These, in turn, have consequences for both homeowners (desiring higher property values) and the parents of children (Black, 1999) who consider, not only the distance their children must travel to school, but also the racial-ethnic and socioeconomic composition of their children's classmates (Bischoff & Tach, 2018; Owens, 2016).

Direct observation of social closure is beyond the scope of this study. There will be no attempt to document the social and political milieu in which new boundaries are decided and enacted. Rather, a possible inference may suggest whether elites are gaming the rezoning process: will the fastest growing districts with large nonwhite populations exhibit higher proportional segregation gains than similar districts with mostly white populations?[2]

The primary question posed by this study is spatial in nature—could adding more school zones and redrawing attendance boundaries alone affect the level of segregation between schools—and, therefore, will be investigated using geographic information systems (GIS) methodologies.

GIS software is able to locate all the smaller residential units (i.e. Census blocks) contained within the boundaries of any school attendance zone. The number of school-aged children within these census blocks can is then summed for each school zone creating a projected school population possessing race and ethnicity attributes. After this process is carried out for all attendance zones within a school district, the level of between-school segregation is computed. When a newer school zone configuration is similarly applied to the same residential data, a new set of projected school populations for the district is extracted. Between-school segregation is again calculated for these more recent boundaries. Any difference between the two segregation levels is due to the differences between the two boundary configurations, since all the projected school populations at both times were derived from the same residential data source.

For racial/ethnic imbalance between schools to occur requires a heterogeneous distribution of races and ethnicities among the residential population. Under the assumption that children attend their neighborhood school, a district with high localized concentrations of one or more races/ethnicities will be more likely to exhibit higher racial/ethnic unevenness between schools.

[2] This question is addressed in the discussion of Table 4.8.

In order to assess this likelihood, GIS software is used again to measure the amount of residential clustering by race/ethnicity that is present within each district.

Since even before *Brown v. Board of education* (1954), social science researchers have sought to identify and describe the sources of school segregation. Is it possible that a potential mechanism of segregation has heretofore gone unnoticed? This study argues the affirmative. Through the mechanism of increasing fragmentation, i.e. carving up a school district into more and smaller school attendance zones, racial and ethnic disparities between schools will rise if certain commonly observed conditions are met. These necessary conditions include a neighborhood-schools policy, sufficient residential clustering by race and/or ethnicity, and a growing student population precipitating the need for new schools and their accompanying school zones. This study finds that the effect of increasing fragmentation on school segregation does exist on a national scale and then estimates the magnitude of fragmentation's effects on levels of between-school segregation.

Chapter 2: Boundaries, Fragmentation and Segregation

This chapter discusses the connections—geographic, demographic, social, and political—between school attendance boundaries and the uneven sorting of white and nonwhite students into local schools. The first part argues that segregation still matters today. The chapter proceeds by outlining how the various growing and suburban school districts can be categorized and conceptualized. For fragmentation to affect segregation, children must be assigned to local schools based upon their residential location. Therefore, neighborhood schools policies are discussed as a criterion for segregation by fragmentation to occur and why various school choice schemes disrupt fragmentation's effect. It will be shown how school choice reduces the sorting power of boundaries. Fragmentation by political boundaries is then addressed in the context of various sorting theories and the causal direction between fragmentation and sorting is argued. The chapter concludes with an examination of the politics and contested processes and procedures that are implemented when school attendance boundaries are redrawn.

If the distribution of children of different races and ethnicities into separate schools did not have adverse consequences, then this study would lack its foundational purpose. Unfortunately, that purpose remains. As true now as it was when *Brown v. Board* was decided, separate and unequal persist to the present time. The reader will find that the locus of the inequities, however, have expanded from central cities into the surrounding suburban school districts and that in the last three or four decades, suburban districts have undergone significant numerical and demographic shifts. It will be documented that more school-aged children now live in suburbs than in central cities or in rural locales and that these demographic transformations accompanying this numerical growth create challenges that strain the institutional resources of suburban districts. The greatest challenges are borne unevenly by certain types of districts that receive the largest influx of new student populations that are more nonwhite and less affluent than their predecessors. The varying types of suburban communities will be discussed in some detail along with the implications for this study.

Central to the creation of differential burdens confronting many school districts is the fragmented nature of the suburban landscape. Fragmentation by political boundaries plays a central role as a mechanism promoting segregation between and within school districts. This chapter will elaborate on the functional importance of boundaries as a signaling device for prospective and current residents and how formal boundaries, allowing for differentiation between political units, are requisite for Tiebout sorting and opportunity hoarding to occur. This chapter considers the argument that differentiation can only take hold if the boundaries are perceived as relatively permanent and that when socially relevant boundaries undergo frequent change, as school attendance zones often do in growing suburbs, and also when these boundary changes affect one's children, then community elites will exercise their political voice. For this reason, it will be seen, changing school attendance boundaries are the most politically sensitive decisions district planners/leaders must make. Whites rely on relatively stable boundaries when considering home purchases and use race, ethnicity, and sometimes class as proxies for school quality and desirability.

This presnet study maintains that, within a district, school attendance boundaries cannot contribute to racial/ethnic segregation unless a district adheres to a neighborhood schools policy—a school assignment regime implemented by a majority of urban and suburban districts. When overall growth that is typically accompanied by increasing racial/ethnic and economic diversity threatens to disrupt the status quo, white elites usually exert pressure on school leaders during the boundary redrawing process (Holme et al., 2013). Some research suggests that this political pressure causes district planners/leaders to partition attendance catchment areas in such a way that the new zones are "gerrymandered" against racial/ethnic integration (M. Orfield, 2015; M. Orfield et al., 2010; Siegel-Hawley, 2013). Other studies dispute this argument, maintaining that compact zones, rather than irregularly drawn zones, are more segregative (Saporito & Van Riper, 2016). The issue of whether the shape of school attendance boundaries are designed to segregate or not misses an important independent factor that this current study takes up, namely, when growing and diverse school districts add new schools, the resulting increased fragmentation by school attendance boundaries leads inevitably to rising segregation.

Why Segregation Matters

Our Nation's schools are still highly segregated. Less than seven percent of schools in America's metropolitan areas can be considered racially integrated (Rothwell, 2012). As far back as the Coleman report in 1966 (Coleman, 2007), research has repeatedly shown that academic achievement suffers when high concentrations of students of color attend schools with few whites (Angrist & Lang, 2004; Roscigno, Tomaskovic-Devey, & Crowley, 2006; Rosenbaum, 1995; Rumberger & Palardy, 2005; Saatcioglu, 2010; Stewart, Stewart, & Simons, 2007). A literature review by Mickelson and Bottia (2010) concluded that "the preponderance of findings from the fifty-nine studies indicates that mathematics outcomes are negatively affected by minority racial isolation and concentrated poverty and that mathematics outcomes are likely to be higher for students from all grade levels, racial, and SES backgrounds if they attend integrated schools" (p. 1026).

Racially diverse school environments are associated with many positive academic and social outcomes. Because of the strong association between race and income (Reardon, 2016), students of color who attend majority white schools have greater access to resources along with higher academic expectations (Hochschild & Scovronick, 2003). Using the common measure of academic achievement, African Americans in these schools have improved chances to pass state exams (Borman et al., 2004; Card, Mas, & Rothstein, 2008; Condron, 2003). Nonwhite students who attend higher performing, more affluent schools have more experienced teachers and benefit from having higher-achieving classmates (Clotfelter, Ladd, & Vigdor, 2005; Hanushek, Kain, Markman, & Rivkin, 2003; Hanushek & Rivkin, 2009; Hoxby, 2000b) while all students perform more poorly academically when attending highly segregated, majority African American schools, even when controlling for other important dimensions of school and non-school environments (Hopson, Lee, & Tang, 2014). Moreover, all groups from integrated schools have more positive dispositions regarding race relations (Kurlaender & Yun, 2005; Wells, Holme, Revilla, & Atanda, 2004) as well as reduced levels of negative racial stereotypes (Killen & Stangor, 2001) while also reporting more cross-racial friends (Wells, Holme, et al., 2004).

Having attended a more racially diverse school is associated with a higher likelihood in adulthood of having inter-racial contacts and living in racially mixed neighborhoods (G. Orfield & Eaton, 1996; Schofield & Hausman, 2004) along with a better chance of working in an integrated environment (Trent, 1997) and having a more positive mindset about other races in general (Schofield, 1991). Wells and Crain (1994) found that African Americans who attended majority white schools had greater access to informal networks, increased social capital, such as college and career counseling, and had more aspirational and realistic plans for future careers and education. Other studies report greater success in careers, such as higher adult earnings, and gains in college attainment for this same group (Fletcher & Tienda, 2010; Trent, 1997) in addition to better health and lower probabilities of incarceration (Johnson, 2011). Many researchers report that dropout rates decreased when African Americans attended desegregated schools (Guryan, 2004; Rumberger & Palardy, 2005; Rumberger & Thomas, 2000; Saatcioglu, 2010). Mickelson and Bottia (2010) conclude:

> The current corpus of social science literature provides consistent and unambiguous evidence that attending a racially diverse school with low concentrations of poor children is positively related to mathematics outcomes for most students irrespective of their age, race, or family's SES. The inverse of this statement is also true—attending a school with high concentrations of minority or poor students is negatively related to mathematics outcomes for most students. (p. 1043)

Suburban Typology

This study argues that school districts that are most influenced by increases in fragmentation will be those that have simultaneously experienced numerical growth coupled with rises in racial/ethnic and economic diversity. The typical suburban school has changed greatly over the last 50 years such that there is no longer a typical suburban school, if there ever was one. Today, suburbs vary dramatically in their size, distance from the central city, tax base, housing options, and commercial development. Most important for school segregation, suburbs can no longer be accurately portrayed monolithically as racially homogeneous, high-income municipalities populated predominately by college-educated affluent whites. While some may fit this description, the mosaic of suburban communities requires an organizational schema that captures community characteristics pertinent to understanding segregation's various manifestations occurring beyond the borders of the central cities. While the present study's predictions are not reliant on any particular classification of communities, a useful typology of suburbs and their school districts aids in this analysis, by applying consistent categories for discussion, by grouping the various factors that are associated with levels of segregation, thereby assisting in the explanations of segregation and enabling a better understanding of the challenges faced by school districts as well as the array of options available to them.

The scholars who have attempted a typology of suburbs or suburban school districts differ in their definition of what a suburb is, except to concur that it is not the central city. These various definitions and accompanying typologies are contingent on the availability of data, the scope of the study and sample, and the variables considered important, i.e., economic, demographic, and historical (Frankenberg, 2011a; Hanlon, Vicino, & Short, 2006; Lake & Cutter, 1980; B. A. Mikelbank, 2011; M. Orfield, 2002; M. Orfield & Luce, 2013; T. Vicino, Hanlon, & Short, 2011). If a typology is to be useful for the purpose of examining school segregation, the proportion of the population and composition of school-aged children in a community is a necessary variable to be included. As the number of school-aged children has increased and continues to increase across the nation, the demographic attributes of these children varies greatly among and within suburbs and between regions of the country. The Census Bureau now identifies more children in suburbs (about 20 million or roughly 40%) than in cities (about 15 million or roughly 30%) (Snyder, de Brey, & Dillow, 2016). As of 2014, about half of the suburban children are non-Hispanic white, down from 72% in 1993-4 (Fry, 2009), a fourth are Hispanic and 16% African American (Snyder et al., 2016). In just eight years, the number of white suburban children is expected to drop to 45%, Hispanics increase to 29% and African Americans hold steady, with Asians increasing rapidly from 3.5% to around 6%. Not only are there now more children in suburbs than in cities, most of the recent growth in suburban school-aged populations has come from Hispanics, foremost, but additionally from African Americans and Asians (Frey, 2011). These increases are not occurring in every district nor are all suburbs experiencing these dramatic demographic trends in equal proportions. Some suburban school districts' enrollments are booming while a significant number (around 21%) are actually decreasing (Frey, 2011). Generally, the former districts are gaining a higher share of white students than the latter. The proportion of African American students was two to three times higher in declining-enrollment districts than their numbers in high-growth districts (Frankenberg & Orfield, 2012). A typical white suburban student in 2006-2007 attended a school that was 75% white, while the typical African American student attended school that was 34% white and a typical Hispanic student attended a 31% white school (Fry, 2009). Taken together, these data are evidence that sorting is occurring in a patterned way that suggests several distinct types of suburban districts clustered according to various social, economic and geographic attributes.

The metropolitan research literature is not lacking in the number of suburban taxonomies to choose from. These analyses mostly employ cluster- and discriminant-analysis methodologies to differentiate between types of suburban municipalities. Focusing on the rise of African American suburbanization in the 1970s, Lake and Cutter's (1980) seminal study identified six categories of suburban communities: "central city spillover, dormitory, outer industrial, metropolitan rural, subsidized, and mixed use. Population density, land use characteristics, and distance from a central city were the factors used to assign communities to categories in this typology" (p. 181). Mikelbank (2004) evaluated suburbs using race, wealth and employment, finding 10 types of suburbs that can conceptually be grouped into four clusters that he termed *White bedroom, manufacturing, suburban successes,* and *working-diversity*. Hanlon, Vicino, and Short (2006), using the variables of wealth, manufacturing, race and country of origin, classified suburbs into five types: *rich, poor, manufacturing, African American*, and *immigrant*. Vicino et al. (2007) followed up the previous typology by adding the criteria of occupation, education, and family structure, thereby adjusting the five types into *MidAmerican, affluent, places of poverty,* *immigrant gateways*, and *African American middle class*. Lang (2008), using the county as a unit of analysis, incorporated the variables of growth rate, population and housing density, and commuting, which were not considered by others. He classified counties into *core, inner suburb, mature suburb, emerging suburb* and *exurb.* Finally, Orfield and Luce (2013) classified suburbs in the 50 largest metropolitan areas based on racial composition and level of urbanization to describe types: *Predominately white, Predominately nonwhite, Diverse,* and *Exurbs.*

While each of these typologies add insight and have been used effectively to explain and understand segregation processes, their emphasis on residential patterns limits their utility in understanding school segregation. Students are not synonymous with residents and district boundaries are not coterminous with municipal boundaries. Also, the racial composition of local schools is often less reflective of the surrounding neighborhood than some emphasize (M. Orfield & Luce, 2013; Richards, 2014). Moreover, the resources and strategies available to municipalities differ from those of the school districts serving them (Diem, Welton, Frankenberg, & Holme, 2016). Therefore, an alternate typology is needed to address these differences between educational and municipal jurisdictions.

Myron Orfield (2002) was the first to proffer a typology of schools differentiable from the aforementioned residence-based typologies. Using cluster analysis, he focused on factors strictly related to resources, since a community's schools usually represent the largest share of local tax expenditures. On the supply side, he included variables that indicated a suburb's ability to raise tax revenues, either directly or indirectly (e.g., poverty levels, age of housing, population growth and density). On the demand side, he looked at a number of variables related to the demographic composition of the student population. Using these criteria, Orfield identified six suburban types, three of which he labeled "at-risk." Although differing in marked ways from each other, these at-risk suburbs were all poorer, meaning that not only were their abilities to raise revenues inhibited by their low tax base, their poorer student populations had relatively greater needs.

Building on Orfield's typology, Frankenberg (2011a) also found six clusters of suburban schools across the nation but differed from Orfield, whose typology examined each district's jurisdictional total population. Frankenberg, using only school-aged population characteristics, placed 2,364 suburban districts into one of these categories: *Developing immigrant meccas* (n=142), *Exclusive enclaves* (n=703), *Countywide districts* (n=13), *Exurbs* (n=1,102), *Inner-ring transitioning* (n=75), and *Satellite cities* (n=305). Not considering resource availability as Orfield did, she focused on school variables of racial concentration and racial change as well as income levels over a seven-year period. Each of these types differed by race/ethnicity composition and change, poverty level, and size, with their contrasting attributes being both expected and unexpected. The *inner-ring suburbs* had the largest decrease—three percent—in white student population and no *inner-ring* district contained a single segregated white school, i.e., a school with over 90% white students. These same districts also had decreases in both segregated minority schools and in high poverty schools. "[T]hese trends suggest that while dramatic transitions were occurring, as of 2006–07 at least, they had not created significant concentrations of low-income or minority students" (p. 39). *Satellite cities* also saw a significant drop in their white populations (about 2%) and a noticeable increase in both minority segregated schools and high poverty schools. Likewise, *countywide* school districts had a sharp rise in extreme poverty schools and had the highest portion of minority-segregated schools (over 90% nonwhite). *Developing immigrant meccas* experienced considerable racial change along with a sharp increase in the number of extreme-poverty schools. Given that these districts also had a high percentage of segregated white schools, districts of this type, which averaged 17 schools per district, may be experiencing the greatest segregative effects due to within-district fragmentation. However, this prediction is premised on these types of schools experiencing, not only percentage increases in their minority populations, but also net increases in *total* enrollments. Increases in within-district fragmentation are predicated on overall population growth causing districts to further subdivide and adjust their existing attendance boundaries as they add more schools to accommodate the influx of students. The simple factor of overall enrollment increase is a missing variable in these current school district typologies, yet it is one of the most salient features of many, but not all, of the nation's suburbs. While Frankenberg understandably focuses on racial composition and change in her typology, as these are necessary to describe segregation's manifestations and impacts, a school typology that omits overall enrollment growth provides only a partial picture of suburban districts. For example, not knowing the overall increase in enrollment may lead to a misinterpretation of racial compositional changes. There are a number of ways that the 8.61% decrease in the percentage of whites enrolled in developing immigrant meccas districts can occur. It is possibly due solely to a large in-migration of minority students, or the exodus of white students, or some combination of increases and decreases of both populations. Of the 100 largest metropolitan areas, 32 of them had suburbs losing white residential population. This is a substantial number but by implication the 68 other areas gained white population (Frey, 2011). A caveat here is that this statistic is only for residential populations of all ages and may not be indicative of gains in school populations. Overall growth for a district, regardless of changes in income or racial compositions, presents its own challenges for a district of any type and thus should be considered as a factor in any suburban school typology. I argue that this is more true now, a decade later, than when Frankenberg's typology was developed. In the 2006-7 school year that Frankenberg used for her second endpoint, suburban enrollment had increased to roughly 38% of all public school students (Snyder et al., 2016). According to the same NCES publication, the number of children in suburban schools now stands at over 40%, a numerical increase of 1.3 million new suburban students when the overall school-aged population in the U.S. rose only 569,000. Those growing districts acquiring many new students will respond to the challenges in various ways (Diem et al., 2016; McDermott, Frankenberg, & Diem, 2015), commonly by building new schools with adjusted attendance boundaries, which increases fragmentation (Frankenberg et al., 2017; Siegel-Hawley, 2013). The consequences of this dynamic is the focus of the present study.

Neighborhood Schools Policies

Certain other requisite factors, in addition to increases in school-level fragmentation, must be present within a school district in order for fragmentation to influence segregation. Foremost among these necessary factors is a school assignment policy that sends children to their local schools. The vast majority of districts having more than a single school per grade level employ some form of neighborhood school plan in their assignment procedures. Monarrez (2018a) estimates 95% of school districts nationwide use residence as the basis for school assignments in some way leading to roughly 80% of all students attending their neighborhood school (Grady, Bielick, & Aud, 2010).

Neighborhood schools policies, which explicitly tie residence to school assignments, have been identified as having reciprocal causal relationships with residential segregation. The demographic composition of residents in a school's catchment area is closely aligned with the makeup of the school population attending that local school. However, this demographic alignment may not be one-to-one depending on a number of elements. First, the characteristics of the total population may differ from the families of the school-aged children in that neighborhood. Second, some districts offer parents the option for their children to attend another school in the district via open enrollment or liberal transfer policies. Open enrollment/transfer policies (including acceptance into public magnet schools) vary on the conditions under which a child can forego attending the local school. Additionally, local schools may not contain all the neighborhood children if some parents homeschool their own children or send them to a private or charter school. Grady et al. (2010) estimate that two percent of urban children and around one percent of suburban children are homeschooled, while the rates for charter school enrollment for urban and suburban children is roughly 23 percent and 12 percent respectively.

School Choice

The current study assesses the effects on segregation when a school district increases the number of attendance zones under the assumption that the children in the district attend their local schools. Therefore, changing the attendance boundaries will alter the composition of those district schools affected by boundary adjustments. The range of school choices just mentioned can complicate this assumption. Thus, the effect that various educational options available to parents has on school segregation needs to be considered.

Proponents of school choice argue that offering parents various options can or will decrease segregation through the application of market forces (Chubb & Moe, 1988; Coleman, 1992; Friedman, 1955; Ogawa & Dutton, 1997). The counter arguments made by some educational scholars focus on the manner in which activist parents—mostly white and possessing both greater economic resources and social and cultural capital—have unequal access to the most desirable schools. As a result, these choice regimes exacerbate the problem they are ostensibly meant to address (Abernathy, 2002, 2006; André-Bechely, 2005; Frankenberg & Kotok, 2013; Henig, 1994; G. Orfield & Frankenberg, 2013). One study assessing the degree to which school choices affect the racial composition of neighborhood schools (albeit for urban rather than suburban districts) confirms these critiques of various choice "reforms." Saporito and Sohoni (2006) concluded that, absent school choices such as charter or magnet schools, public schools "that have private and/or magnet schools within their catchment areas have disproportionately fewer white children than do schools without nearby private or magnet schools" (p. 96). Similarly, Bischoff and Tach (2018) found that, out of a nationwide sample of urban and suburban school districts, 15 percent had an elementary-age racial mismatch of more than 10% between the composition of the school population and the corresponding residential makeup. Decreased white enrollment in the public schools was associated with the presence of both magnet schools and private schools within an attendance zone, particularly in areas containing high racial diversity. The presence of a charter school, however, seemed to have no connection to racial imbalance.

Neighborhood Schools as a Segregation Tool

Neighborhood schools policies were popular in the South as a strategy to maintain segregation in the post-*Brown* era but many highly segregated districts had to avoid this practice under court ordered desegregation. Even in segregated cities in the North, whites preferred neighborhood schools as a means of excluding nonwhites from local schools without having an appearance of overt discrimination. Employing a neighborhood-school-policy discourse has the advantage of sounding race-neutral by maintaining that local schools are in the best interest of all children, regardless of race. In Chicago during the 1960s and 1970s, white parents rallied around neighborhood schools in opposition to open transfers, which were supported by a majority of African American parents (Rury, 1999; Rury & Mirel, 1997). Boston's contentious desegregation period also had white grassroots advocacy groups using similar discursive language in their battle against forced busing (McDermott et al., 2015). When both African Americans and whites in St. Louis protested against the school district's reassignment policy intended to achieve racial balance, only the white children were exempted, allowing them to stay at their local school, while the African American children were bused out of their neighborhoods (Wells, Baldridge, Duran, Lofton, et al., 2009). As courts lifted mandatory desegregation injunctions, many school districts in the South reverted back to neighborhood school assignments, reversing the previous gains in racial balance reached prior to unitary status (Elmer, 2017; Frankenberg & Lee, 2002; Goldring, Cohen-Vogel, Smrekar, & Taylor, 2006).

The re-enactment of neighborhood schools in unitary districts has led to the reemergence of racial segregation and appears to contradict the prohibitions decreed in the *Keyes* (1973) decision. Under *Keyes*, if strict adherence to a neighborhood schools plan could be foreseen as perpetuating or exacerbating segregation, the resulting segregation was deemed to be *de jure* (M. Orfield, 2015). However, the judicial pendulum has swung back when the Supreme Court, in their *Parents Involved in Community Schools* (2007) decision, placed restrictions on using race as a criterion when trying to address racial imbalances, whether extant or predicted. Currently, many school districts tend to shy away from using race at all as a variable in assigning students to schools out of legal and political expediency (Bartels & Donato, 2009; Wells, Baldridge, Duran, Grzesikowski, et al., 2009). It may appear quite natural to many people that students should attend schools close to home, which is a preference expressed by both white and African American parents, although not in equal proportions: 87% for whites and 48% for African Americans (Farkas & Johnson, 1998). Often, the public assumes that when children attend local schools there is greater community attachment and sharing of resources, along with increased parental involvement and social capital (Goldring et al., 2006). There is a prevalent belief, supported by evidence, in the power of the community to affect the educational outcomes of the children within the local school (Bell, 2009; Chetty, Hendren, & Katz, 2016; Erickson & Highsmith, 2018; Owens, 2010; Sharkey & Elwert, 2011; Sharkey & Faber, 2014). Goldring et al. (2006) maintain that "[t]he community is now seen as a source of human, financial, and social capital to support student learning. This shift situates the family, the school, and the neighborhood as interdependent systems that together are responsible for socializing the next generation of America's children" (p. 337). As one diverse school district, in justifying their neighborhood schools policy, succinctly averred, "Neighborhood schools help connect a community with the school system" (Olathe, 2005).

Placing the preference for neighborhood schools within an ostensibly race-neutral or "color blind" discourse masks the potential segregative impact of assigning children to nearby schools. Simply put, if the residents of a district are segregated then the schools will be likewise. However, the causal direction just implied masks the reciprocal interactions between housing and school assignment. True, schools are segregated because neighborhoods are segregated (Massey & Denton, 1993), although not always to the same degree. Schools have been found to be more segregated than their residential catchment areas (Saporito & Sohoni, 2006, 2007; Tarasawa, 2012). Moreover, this mismatch between a school's nonwhite composition compared to the residential catchment area increases as the percentage of nonwhite residents increases (Noreisch, 2007; Tarasawa, 2012).

After the observation that residential segregation begets school segregation, the reverse causal connection was subsequently observed by social scientists (Dougherty, 2012; Dougherty et al., 2009; Erickson & Highsmith, 2018). The fact that school segregation contributes to residential segregation also reached the attention of the courts:

> People gravitate toward school facilities, just as schools are located in response to the needs of people. The location of schools may thus influence the patterns of residential development of a metropolitan area and have important impact on composition of inner-city neighborhoods. … Such a policy does more than simply influence the short-run composition of the student body of a new school. It may well promote segregated residential patterns, which, when combined with "neighborhood zoning," further lock the school system into the mold of separation of the races. (*Swann v. Charlotte-Mecklenburg Bd. of Ed*, 1971, pp. 20-21)

This mechanism of residential sorting uses school racial composition as a signal to house purchasers of local school quality, contributing to what is often labeled as “white flight” (Boustan, 2010). Siegel-Hawley (2011), in comparing metro areas with and without robust desegregation plans, found that, within districts committed to desegregation, there was a decoupling between where a child lived and where that child attended school. In these districts where residence did not determine school assignment, there was evidence of declines in housing segregation. Frankenberg (2005), comparing desegregation implementations of Mobile, Alabama and Charlotte, North Carolina, determined that the less rigorous desegregation efforts of Mobile explained its higher housing segregation compared to Charlotte’s lower levels of segregation. Referencing another study by Diana Pearce (1980), Frankenberg posits that the interruption of the housing/school attendance nexus leads to more integrated neighborhoods. “If school desegregation is fully implemented on a metropolitan level, it actually stems white flight” (p. 179).

Fragmentation

"White flight" is an impediment to desegregation since white populations are able to remove themselves from school jurisdictions containing high numbers of students of color. This reality necessitates a discussion of how political fragmentation enables the sorting of groups into separate places and how sorting impacts racial segregation. With the elimination of overt forms of racial exclusion, such as Jim Crow laws and redlining practices, many scholars maintain that a new form of racism has emerged in which "non-racial" policies aim to maintain the social, political and economic system of white domination and privilege (Bonilla-Silva, 1997, 2015; Holme, Diem, & Welton, 2013). Boundary lines comprise one part of this structure of racial subordination. Gregory Weiher (1991) argues that, as the formerly legal means of housing exclusion were banned, neighborhoods were no longer strong enough indicators of the racial makeup in a local area. Boundaries between political units, such as municipalities and school districts, became an easily identifiable marker of the types of neighborhoods and schools prospective residents would encounter, and thus provided a mechanism to achieve some preferred level of racial uniformity.

Weiher (1991) defines political fragmentation as "the proliferation of governments across American society and geography. [Fragmentation] denotes the division of urban areas among hundreds of overlapping, autonomous political units, each with an array of powers..." (p. 4). Numerous social researchers have produced an immense amount of literature examining political fragmentation in metropolitan areas, primarily considering both municipalities (Aurand, 2007; Carruthers & Ulfarsson, 2002; Farrell, 2008; Kelleher & Lowery, 2004; Kim & Jurey, 2013; Miller, 2002; Morgan & Mareschal, 1999; Schneider, 1986; Stansel, 2005) and school districts (Alesina, Baqir, & Hoxby, 2004; Ayscue & Orfield, 2015; Bischoff, 2008; Crowder et al., 2012;

Diem, Siegel-Hawley, Frankenberg, & Cleary, 2015; Frankenberg et al., 2017; Holme et al., 2013). Weiher points out that, unlike Europe, the United States is perhaps the most fragmented nation in the world. "Fragmentation speaks to the essence of our national character, is perhaps the best indication of what we value, and explains a great many social and political outcomes" (p. 2). Of these outcomes, racial segregation is of the greatest concern for Weiher and he contends that political fragmentation both allows and causes segregation primarily through sorting mechanisms.

Weiher partially agrees with sorting theories originating with Tiebout (1956) wherein a resident chooses to live in a particular jurisdiction out of preference for an affordable bundle of public goods. "The consumer-voter may be viewed as picking that community which best satisfies his preference pattern for public goods. … The greater the number of communities and the greater the variance among them, the closer the consumer will come to fully realizing his preference position" (p. 418). Those writing from a Tiebout perspective are concerned with issues of allocative efficiency and equality and locate the mechanism of sorting in the institutions operating within the jurisdictions. According to Tiebout, each jurisdiction offers a supply of public goods at a price, usually the cost of purchasing a home in that area, which prospective residents use to make their relocating decisions. However, appealing to the immutable laws of the market elides the normative considerations of the sorting process. "The market is primarily an instrument of status discrimination, whatever ostensibly economic functions it may perform" (Weiher, 1991, p. 19).

Stemming from the observation that the instability of integrated neighborhoods cannot be explained by a race-neutral preference by whites for a certain slate of public goods, various "tipping" models have been proposed (Clark, 1991; Schelling, 1971; Taub, 1984). Schelling's model (1971) is predicated on whites having lower tolerance levels for other races than in the reverse direction. When a few non-whites purchase homes in the unit area, some whites with a low threshold of tolerance begin to move out creating vacancies for residents of color to move in making the area even less white. This starts a feedback loop wherein more whites with slightly higher tolerance thresholds move out, creating still more vacancies for nonwhites to take up. In this cyclic manner, a unit area is tipped from all white to all non-white. Schelling refers to this mechanism of tipping as the “bounded neighborhood model” (Schelling, 1978, p. 155), which implies that a spatial unit with boundaries is a prerequisite. It may seem that the existence of bounded areas is a given not worth mentioning, however, boundaries form the core of Weiher’s model. Tiebout sorting and the related tipping models have consumers applying information in the expression of personal preferences through their purchasing/moving behaviors. The problem Weiher has with these models, as well as with Hirschman’s (1970) *Exit, Voice, Loyalty* model, is that they assume that consumers possess full and equal access to the information needed for preference expression. These theories do not stipulate how that information is provided nor how it is structured. According to Weiher, the primary piece of information needed for decision-makers is the boundary, without which the idea of moving-into or moving-out-of an area has little meaning.

Boundaries send important signals and can serve as proxies for a host of other attributes movers often assume exist within those boundaries, e.g., racial composition and property values. However, boundaries have often been given little consideration by some scholars testing tipping models. Schelling (1971) assessed white’s racial tolerance using hypothetical neighborhoods, while Clark (1991) conducted phone interviews using an ill-defined concept of “neighborhood.” Banzhaf and Walsh (2013) employed concentric circles as their operational definition of "communities" and the much cited Card, Mas & Rothstein (2008) based their test of Schelling on socially meaningless Census tracts. Tipping models, however, require discrete spatial units that can potentially be tipped—a place must have boundaries or else it is not a "place." For Weiher "boundedness" is an important psychological concept with behavioral implications and thus he sees residential boundaries, such as municipalities and school districts, as causal because they provide unambiguous information. Weiher argues that "[i]n order to achieve some correspondence between preferences and objective conditions in particular places, settlers require information…. [but] settlers are likely to possess limited resources and to face heavy information costs…. [thus] formal boundaries provide a basis for thinking of places as different from one another, the first step in acquiring information about places…. [and as such] political boundaries provide the structure that is prerequisite to the generation of information that movers need" (pp. 40-41). Formal boundaries provide a clarity to the distinctiveness of places and, with that distinctiveness, there is an implicit expectation that any sorting occurring on a racial, ethnic, or socioeconomic basis will be supported by those boundaries, whereas informal boundaries between neighborhoods do not possess the social salience necessary for a common, undisputed definition of place to develop.

For Weiher, boundaries are functional beyond the demarcation of distinct sections of land. Boundaries couple geography with political authority, for one, as well as performing economic and social functions. A highly fragmented metropolitan area allows differentiation to develop between the various political jurisdictions—what Weiher calls "eccentricity" and which he contends is an ineluctable consequence of fragmentation.

Sorting occurs through the complementary processes of exclusion and recruitment. Political fragmentation is ostensibly race neutral since boundaries are not based upon the racial makeup of an area nor are there laws requiring residents to live in certain places according to their race. Through recruitment and exclusion, groups who are most able to activate the political and social processes within a jurisdiction express their preference for prospective settlers in a manner congruent with Charles Tilly's (2005) concept of "opportunity hoarding", which he sees as operating within and across types of social boundaries, including spatial boundaries, to produce inequalities between groups. For Tilly "social boundaries interrupt, divide, circumscribe, or segregate distributions of population or activity within social fields" (p. 133).

Tilly details five mechanisms through which boundaries are formed and changed: encounter, imposition, borrowing, conversation, and incentive shift (Tilly, 2004), yet spends very little time describing how these apply to formal, physical boundaries—the type most people think of when the term boundary is used—such as the ones under consideration in this present study, namely municipal, school district, and school attendance zones. "Imposition" comes the closest when applied to the process of redrawing school attendance zones but the term implies a lack of agency attributed to those captured within the newly formed sections. That being said, Tilly's theory of boundary mechanisms is applicable when boundary changes disrupt the established racial, economic, and social mix of local schools (Alesina et al., 2004; Diem et al., 2016; M. Orfield, 2015; Wells, Revilla, Jennifer Jellison, & Atanda, 2004) since boundary formation and change, for Tilly, is the essence of politics. "Public politics invariably involves creation, activation, and transformation of visible us-them boundaries, as well as reversal of those processes: destruction, deactivation, or restoration of us-them boundaries" (Tilly, 2005, pp. 173-174).

Weiher's theory begins with extant boundaries and neglects the formation process, except to ascribe the fragmentation of the American landscape to the "pursuit of parochial interests" seeking to avoid interference from "overarching units of government representing the interests of a more heterogeneous sample of the public" (Weiher, 1991, pp. 165-166). A fuller explanation for the impetus to fragment the areas surrounding central cities and the inequality thus arising, can be found in the political economy literature (see Saiger, 2010). As cities aged, development waned and higher taxes were needed to sustain redistributive services. Wealthier whites—"connaisseurs" in Hirschman's terms (Hirschman, 1970)—exited for the suburbs to escape congestion, pollution, crime and taxes. The fact that they had an exit option was due to local, state, and federal government policies in housing and transportation, among others, (Rothstein, 2017) that provided city residents wishing to vote with their feet the "relevant ballot" (Rury & Mirel, 1997, p. 80) to do so. The result of the multitude of individual moves was a political power shift at the state level from central cities to the suburbs (Rury & Mirel, 1997).

> When redistributive policies begin to outweigh developmental activities, according to the logic of this model, an urban system can begin to change dramatically. For instance, developmental interests (both organizations and the social groups associated with them) will leave the central city at a faster pace (and will be replaced by fewer such elements). This, of course, can be seen as an important dimension of what has happened with the process of suburbanization (Rury & Mirel, 1997, p. 86).

School Shopping

Many families who left urban school districts were responding to the deteriorating quality of inner city schools and the higher reputation that suburban schools had for less behavioral issues and more qualified teachers, all at a cheaper cost. The *Milliken* decision all but guaranteed that the separation would be permanent. As residents left the central cities and new settlers arrived to the metropolitan areas from other parts of the country, the wealthier mostly-white families wanted “quality” schools for their children but had to determine what “quality” meant, what level of “quality” could they afford, and how could they obtain the information needed to decide where to purchase their home—the price of admission to a “quality” school. The political boundaries forming the fragmented suburban ring surrounding central cities allowed for Tiebout choices to be exercised. The agents of recruitment, in Weiher’s terms, were real estate agents and local government officials, usually working together, though sometimes conflicting, to enhance the reputation of their communities to attract city residents (Dougherty, 2012; Wells, Baldridge, Duran, Lofton, et al., 2009). These coalitions also practiced exclusion to prevent African Americans from purchasing homes within their locales. In Connecticut, “in the late 1960s and early 1970s, real estate agents steered African American homebuyers into Bloomfield and white homebuyers outward to Avon and West Hartford, by preying on white anxieties about racially mixed schools” (Dougherty, 2012, p. 211). The salient point in this example is that each of these school districts has well-defined, permanent boundaries conveying meaning to suburban homebuyers allowing them to express their preferences where they could afford to do so.

While it is true that districts’ boundaries were not formed manifestly upon the racial composition of residents, the greater school availability, both across districts and within districts, interacted with settler preferences to create racial segregation by residential location (Alesina et al., 2004; Hoxby, 2000a; Urquiola, 2005). Bischoff (2008) argues that this interaction between school fragmentation at all levels and residential preference leading to segregation arises from three basic intertwined causes: “(1) People may have a ‘taste’ for segregation and political boundaries help them to realize this goal. (2) People choose their residence based on socioeconomic, or class based, factors such as the quality of public goods, appearance of housing units, transportation infrastructure, or availability of commercial establishments…. (3) People use demographic composition as a proxy for quality of public goods within a jurisdiction" (p. 186).

Parents are hesitant to admit that the local school's racial makeup is a factor in selecting a particular residential location (Holme, 2002) yet their home-purchasing behavior confirms this to be true (Saporito & Lareau, 1999). Henig's (1990) study of magnet school choice found parents avoiding racial and socioeconomic isolation. Glazerman (1997) revealed that high test scores had secondary value compared to own-race preferences. Parents may express preferences for diversity to interviewers when in practice they seek schools with greater racial/ethnic homogeny (Weiher & Tedin, 2002). Likewise, parents, by a large majority, stated valuing test scores over student demographics, yet, in their online search of prospective schools for their children to attend, they filtered for race first (Schneider & Buckley, 2002). Liebowitz and Page (2014) found movers who shifted from one attendance zone to another regarded race as a stronger signal for a quality school than test scores. Some argue a "taste" for segregation is not the primary driver for selecting whiter schools and neighborhoods but rather race serves as a proxy for nonracial attributes thought to be associated with high-minority neighborhoods, attributes such as poverty, crime and low-quality schools (Harris, 2001; Taub, 1984). However, Billingham and Hunt's (2016) study supports the first of Bischoff's causes as subsuming the other two, as they found strong support for their "pure race" hypothesis over "racial proxies" i.e., test scores and older school buildings, a result also supported by Schneider et al. (1998).

Privileged whites value a high degree of school district fragmentation, allowing them the necessary boundaries to exercise opportunity hoarding (Frankenberg & Kotok, 2013; Hanselman & Fiel, 2017). In the Wells et al. study *Why Boundaries Matter* (2009), multigroup segregation was analyzed across highly fragmented Long Island, New York. Large disparities in racial composition and access to resources occurred between multiple levels of bounded units—between districts, between schools within districts, and between classrooms within schools. They concluded that the multiple boundaries allowed wealthier white parents to hoard all types of resources from children with darker skin and less affluence. "[T]he educators in this district face fierce opposition from the powers that be …to extending such opportunities and expectation to less advantaged children. In this way, the story of how and why boundaries matter plays out within the walls of single schools and not across school district lines. This proximity is important though…. For some, this proximity makes them more anxious about maintaining the boundaries; for others, it is a sign of their fragility" (pp. 78-79). In a nationwide study of multigroup segregation by fragmentation in metropolitan areas, Farrell (2008) concluded a causal role for well-defined boundaries. "The results of this study…add to a growing body of evidence that residential segregation is increasingly a function of formal political boundaries rather than neighbourhood differences …. Given that jurisdictions largely determine the distribution of resources and services within sprawling metropolitan areas, municipal distinctions are more consequential than those of census-defined tracts" (p. 490).

The vulnerability expressed by whites in the Wells study suggests a pressure to segregate (for which boundaries are employed) stemming from rapid demographic changes in once mostly-white locales. As noted previously, the last forty years has seen such rapid growth in African American and Hispanic student populations in suburban schools that suburban districts now enroll more Hispanic, Asian, and African American students combined than do central city schools (Frankenberg & Kotok, 2013; G. Orfield & Frankenberg, 2008). Viewing this trend with the highly fragmented landscape of suburban public schools, we see patterns of white flight from inner-ring suburbs and successful efforts to establish and protect white enclave districts and individual schools within diversifying districts, accomplished with the requisite condition of well-defined boundaries (Crowder, Hall, & Tolnay, 2011; Frankenberg et al., 2017; Lichter & Brown, 2011). As suburbs grew in number and the racial/ethnic diversity of suburbs rose, school segregation for African Americans increased between school districts while Hispanic segregation from whites was more prominent within districts (Reardon & Yun, 2001). This asymmetry can be attributed to regional differences in school districts in the northeast, where more African Americans reside to a greater extent in suburbs and where the school districts are smaller and more numerous. By contrast, in the west and south, where the districts are larger in area, within-district fragmentation is greater. When district boundaries are doing most of the fragmenting, then between-school segregation is lessened—a result supported by Reardon and Yun's findings that Hispanics are most suburbanized in the south and west where countywide school districts are more prevalent (see also Ayscue & Orfield, 2015).

A Question of Causal Direction

Are whites taking advantage of *already existing* fragmentation in order to isolate themselves within jurisdictions that they can control or, on the other hand, could demographic and economic shifts in suburban populations spur *more fragmentation* as a way by which white elites could enact opportunity hoarding? Alesina, Baqir, and Hoxby (2004) investigated the causal direction between racial and economic heterogeneity and the number and size of municipalities, school districts, and school attendance areas. They reason first that homogeneous areas benefit from larger economies of scale. However, if greater heterogeneity could arise from a larger jurisdiction then there may be a trade-off. Taking a Tiebout perspective, the researchers ascribe two basic avoidance motives to white actors that may increase fragmentation. First, people have preferences for local goods and taxes and they avoid making joint decisions with people who have different preferences. Multiple, smaller school districts would obviate redistributive pressures from residents with unlike preferences. Second, people may want to avoid interacting with those outside their group. If avoidance of racial or economic heterogeneity is the foremost motive then homogeneity may be accomplished through less expensive school attendance boundaries rather than more costly school districts.

> In short, if the number of school attendance areas responds to heterogeneity controlling for the number of districts, it is likely that a heterogeneous population has heterogeneous preferences or an unwillingness to interact, not merely an urge to avoid redistribution. We can get similar evidence by looking within districts: does a district with a more heterogeneous population divide itself up into more attendance areas, all else equal? (p. 368).

Evidence for an affirmative answer to this question came in the finding that a district is likely to have more attendance areas if it has greater racial/ethnic and income diversity. The fact that a two-standard-deviation increase (45 percent increase) in Hispanic heterogeneity is associated with 23 percent more attendance areas sheds light on Reardon and Yun's (2001) finding of greater within-district segregation for Hispanics compared to African Americans, and is consistent with Tilly's theory of boundary formation. Alesina et al. (2004) conclude that "[t]he trade-offs generated by Hispanic ethnic and religious heterogeneity are apparently too weak to affect districts, but strong enough to affect attendance areas" (p. 369).

Inter- and Intra- District Fragmentation

Past studies examining fragmentation's contribution to racial segregation have most often used the school district as the unit of analysis rather than the smaller local school attendance boundaries (Alesina et al., 2004; Ayscue & Orfield, 2015; Bischoff, 2008; Clotfelter, 1999; Diem et al., 2015; Frankenberg, 2009; Frankenberg et al., 2017; Holme & Finnigan, 2013; Reardon &

Owens, 2014; Richards & Stroub, 2014; Zhang, 2011). From Weiher's framework, school districts provide the type of hard jurisdictional boundaries allowing more efficient recruiting and exclusion. This jurisdictional inviolability, made possible in large part by the *Milliken v. Bradley* case (Clotfelter, 2006; Tefera, Frankenberg, Siegel-Hawley, & Chirichigno, 2011), has enabled both resource hoarding and racial and economic "eccentricity" (Jargowsky & El Komi, 2011; Lareau, 2011; Siegel-Hawley, 2011; Weiher & Tedin, 2002). In support, Ayscue and Orfield (2015) state, "In US society, space within metropolitan areas, divided by invisible school district boundary lines and attendance boundaries lines within many districts, defines and perpetuates different worlds of opportunity. Decisions made long ago have created lines of profound and lasting difference" (p. 6).

Social closure operating along lines separating districts are more dominant than the segregative processes occurring within district borders (Fiel, 2013). Other recent research on public school segregation confirms that sorting of students into separate school systems is now more prominent than sorting between schools within the same system (Clotfelter, 2004; Holme & Finnigan, 2013; Owens, 2016; Owens, Reardon, & Jencks, 2016; Reardon & Yun, 2009). The cleavage by district lines is so stark that, even excluding urban districts, many of the nation's metropolitan areas have some suburban districts with 90-100 percent white enrollment along with other districts in the same metro area that are 90-100 percent nonwhite. (Frankenberg & Orfield, 2012).

Racial imbalance between districts results mostly from differential movements of individuals and families settling into long-established borders. School districts have relatively stable boundaries not subject to frequent consolidation, creation, or secession, although recently the latter—secession—has been of some dubious concern. Frankenberg et al. (2017) claim that "[i]n recent years, new school district boundaries have proliferated…" (p. 449) citing two attempts in Alabama and Louisiana that have yet to occur before they examine one of the few successful splits. In all, only 47 new school districts have actually seceded from an existing district (EdBuild, 2017)—mostly in the south where race is a salient factor (Frankenberg, 2009; Frankenberg & Taylor, 2017)—out of a total of roughly 13,000 independent school districts nationwide (Snyder et al., 2016). The fact that so few new districts have successfully formed from existing ones speaks to the aforementioned high cost of achieving social closure through groups of residents staying put and changing the boundaries surrounding them, rather than moving within new boundaries, at least at the school district level. However, a more malleable set of boundaries—school attendance zones—may be susceptible to this form of manipulation.

Politics of Attendance Zone Redistricting

While school district perimeters are generally immutable in the face of mobile populations, school attendance zones often undergo annual adjustments when student enrollments expand or shrink (Holme et al., 2013; Wiley, Shircliffe, & Morley, 2012). The redrawing of attendance boundaries disturbs the status quo and is often perceived by local elites as threatening the suburban way of life that they feel their home purchases have entitled them to. The frequency of school attendance boundary disruptions can be attributed to the raw growth of student populations, which stretch the carrying capacity of local schools. The usual response in these cases is to add new schools near the neighborhoods experiencing the greatest residential gains. When raw growth is coupled with increased racial/ethnic and economic heterogeneity, local boundary lines become political battle lines. Studies examining the politics of school attendance boundary change, while detailing the *proportional* shifts in subgroup enrollments, seem to deal with *overall* growth with assumed stipulation. The requisite for new schools is attributed to an unquantified “rate of growth” (Holme et al., 2013, p. 22), which is not factored into the causal discussion of issues surrounding attendance zone fragmentation—a component this present study specifically addresses.

Reactions by local elites to joint numerical and demographic hikes can be interpreted through the lens of Tilly’s (2004) consequences of boundary changes:

- “authorities draw lines among social sites where they did not previously exist;
- that boundary increases in salience as an organizer of social relations on either side…” [or has *immediate* salience in the case of school attendance zones]
- “actors on at least one side respond to the boundary’s activation by engaging in coordinated attacks on sites across the boundary; and
- actors on at least one side engage in coordinated defense against those attacks” (pp. 226-227).

Case studies of school districts undergoing internal boundary adjustments confirm this process. As districts become increasingly diverse, racially and economically, white parents instigate this “attack-defense sequence” by striving to alter the attendance boundaries, initiate transfer policies, or site new school buildings, which will allow their children to attend whiter schools. Since school assignment based on residential location is the most prevalent assignment policy in the U.S., battles over changing attendance lines often dominate the suburban political landscape (Caldas & Bankston III, 2001; Diarrassouba & Johnson, 2014). In one of the fastest growing districts in Texas, Holme et al. (2013) note “[t]he political issue that caused the most difficulty for central office leaders was the redrawing of school attendance boundaries” (p. 22). White affluent parents in a Minnesota suburb threatened to secede from the district when new elementary school boundaries resulted in drastic changes to the schools’ racial diversity (Diem et al., 2016; Smith, 2010). School board meetings in Loudan County, Virginia, discussing proposed attendance zones to be implemented the following school year, were disrupted by hundreds of concerned white parents (Richards & Stroub, 2015). Even when boundary changes fail to make the local news, white parents often express concerns that new boundaries will expose their children to poorer nonwhite classmates (*Boundary change process*, 2013).

Much of the resistance from high-status parents comes couched in terms of concern that school quality will suffer if lower-income Hispanic and African American students are allowed in the same school as their children. These parents mobilize politically, pressuring administrators and board members to maintain the racial and economic imbalance currently in their favor (Parcel, Hendrix, & Taylor, 2016; Shaffer, 2011; Wiley et al., 2012). Commonly, these highly-involved white affluent families successfully influence school officials to delineate attendance zones in order to segregate students by advocating for ostensibly race-neutral neighborhood schools (M. Orfield, Luce, & Finn, 2010; Saporito, 2017a; Siegel-Hawley, 2013) that impede district leadership's efforts to decrease segregation.

> Such efforts, we found, were thwarted by elite (middle-class and mostly White) parents who pressured administrators to draw attendance boundaries in a way that furthered segregation. Similar resistance has been documented by researchers studying change in diverse school districts: these studies have found that when reformers seek to challenge inequitable structures, they often meet up against intense resistance by local elites (Holme et al., 2013, p. 59).

"Gerrymandering" of Attendance Zones

The examination of how school attendance zones are configured to suit the privileged has been a relatively recent subject of inquiry. These studies consider how the shapes of the attendance areas, whether they are compact or irregular, impact the racial and economic isolation of school-aged children into separate schools. Noting the dependence of school segregation on the spatial arrangement of racial groups in residential neighborhoods, each study argues either for or against irregularly shaped attendance zones as a culprit in worsening segregation levels above those found in the residential communities they serve.

It is well documented that residential areas surrounding most schools are comprised of families and individuals of similar race and income (Ong & Rickles, 2004). Some argue theoretically that when a compact neighborhood catchment area is drawn in close proximity to the school, that school will exhibit little diversity. If a district seeks diversity, then a more irregularly shaped zone reaching into more diverse neighborhoods will counter the proximal residential segregation (Goldring et al., 2006). However, some recent case studies of diverse school districts find the "gerrymandering" of attendance zones allows whites to exclude poorer and non-white students from whiter, more affluent schools. (M. Orfield, 2015; M. Orfield et al., 2010; Siegel-Hawley, 2013). The popular press also echoes this reasoning, often noting how local attendance zones have been constructed to achieve racial segregation (Chang, 2018; Robberson, 2012). The term "gerrymander" connotes both spatial and volitional aspects of a delineated political region. Siegel-Hawley (2013) says gerrymandering occurs when districts draw attendance boundaries "in such a way as to intensify racial segregation, often through the creation of oddly formed or discontinuous zones" (p. 581). This definition seems to conflate impact with intent although the latter could be reasonably inferred for the particular school district she scrutinized. When an outside contractor proposed five options for the attendance area of a new high school in Henrico County, VA, the school board drew their own adjusted boundary from one of two committee-recommended options in response to white affluent residents' threat to flee the district. Citing evidence that districts draw racially unbalanced attendance zones, Richards (2014) also places the impact on segregation in the forefront of her conception of gerrymandering: "by carving up the area of a district in ways that are not racially neutral, 'gerrymandered' boundaries may provide an additional layer of stratification that exacerbates existing patterns of residential segregation" (p. 3) but in an aside, the author conjectures just the opposite may occur—that gerrymandering attendance zones could help alleviate residential segregation. Never addressing intent, Richards chooses deviation from maximum compactness of an attendance zone to operationalize "gerrymandering" Employing a nationwide sample of thousands of attendance boundaries, she concludes that "attendance zones are particularly gerrymandered to segregate in districts experiencing rapid racial/ethnic change….irregular boundaries may occur in response to rapid diversification in formerly homogeneous White communities" (p. 33). A subsequent study by Richards and Stroub (2015) strongly concludes: "we find that attendance zones are highly gerrymandered…and are becoming more gerrymandered over time" (p. 1). Curiously, Richards and Stroub report a finding that seems to contradict their overall conclusion and that seems to confirm the theoretical argument that compact zones should be more segregative on average than more irregular zones. "[D]istricts with more gerrymandered boundaries are substantially less segregated than those with less gerrymandered boundaries…" (p. 22)—a result consonant with other recent investigations that find that attendance boundaries are not drawn irregularly in an effort to make them racially homogeneous.

Historically, southern districts under court orders to desegregate employed gerrymandering as one of the strategies meant to achieve racial balance in their schools (Liebowitz & Page, 2014). Since the intent to desegregate by drawing irregularly shaped attendance zones is explicit, the use of the term “gerrymandering” to describe the process is unproblematic as the dual criteria of irregular shape and intent are met. However, if a district drew non-compact attendance boundaries designed to separate children by race, then that objective would likely remain covert or else risk running afoul of anti-segregation laws, not to mention broader public approval. Therefore, assessing intent would need to be made indirectly and tentatively. To avoid this issue, other studies probing the connection between attendance boundary shape and segregation have avoided the term “gerrymandering” since any preference to segregate is not explicit. Instead, these studies have focused on the relation between degree of irregularity in shape and the level of racial and economic imbalance between schools within the same district (Monarrez, 2018a; Saporito, 2017a, 2017b; Saporito & Van Riper, 2016; Sohoni & Saporito, 2009).

The studies by Salvatore Saporito and his fellow researchers counter the conclusion drawn by Richards (2014) that “on average, attendance zones are gerrymandered in ways that exacerbate racial/ethnic segregation” (p. 34) and confirm the theoretical logic that if attendance zones are compact then those school districts will exhibit a comparable level of racial segregation as that found in the residential community. “While the evidence does not show that school district personnel draw compact attendance zones to intentionally segregate students by race, compact zones often contribute to that result” (Saporito & Van Riper, 2016, p. 14). By actually measuring the shapes of attendance zones—something Richards failed to do—both Saporito (2017a) and Monarrez (2018b) demonstrate that districts with the most irregularly-shaped zones had significantly higher racial diversity in their schools than that found residentially. Not surprisingly, a study of income segregation similarly concluded that “the more irregularly shaped a school district's attendance zones are, the lower its level of income segregation is likely to be" (Saporito, 2017b, p. 1366).

***Exit, Voice, Loyalty* and Changing School Attendance Boundaries**

When families with school-aged children shop for homes they are also picking schools since roughly 95 percent of students in the U.S. are assigned to schools via residential location (Monarrez, 2018a). Because neighborhood school plans are the predominate assignment policy, parents assume that the ability to purchase a home assures them access to the local school and factor this consideration into housing costs (Dougherty, 2012; Rowe & Lubienski, 2017; Schneider et al., 1998). From the beginning of suburban planning by real estate developers, the local school was envisioned as the focal point of suburban neighborhoods. The fact that these "neighborhood units", as Erickson and Highsmith (2018) labeled them, were historically highly segregated enclaves was not a mere artifact of larger social forces, but rather an intentional feature shaping racial segregation throughout the American landscape. "The school-centric neighborhood unit conjoined ideas about housing, schooling, and race, and then forged these ideas into a powerful mechanism of segregation" (Erickson & Highsmith, 2018, p. 23). Given the compelling interplay between settlers shopping for homes and shopping for schools, a question arises as to how homeowners react when there is a disruption of existing school assignments. The various responses by homeowners to the alteration of school boundaries can be usefully viewed from Albert Hirschman's (1970), Exit, Voice, and Loyalty framework.

In his seminal work, Hirschman makes a profoundly simple argument regarding how customers or citizens respond to an organization when dissatisfied with a good or service provided by that organization. He proffers two non-mutually-exclusive alternatives: Exit, wherein one ceases to purchase or consume from that organization and then leaves to seek a better alternative elsewhere, and Voice, which refers to the communication of displeasure with the current level of quality of the product or service. Hirschman envisions a third variable, Loyalty, as a mediator between exit and voice. Loyalty, he hypothesizes, makes exit less likely and increases the probability of voice being exercised. Furthermore, voice's efficacy is increased by the possibility of exit being held in check for the time being by loyalty.

The present study asks whether the mere geometric act of increasing the number of school attendance zones alters the level of racial imbalance within a district's schools. This question makes a broad and nontrivial assumption that the current residents remain relatively stationary during the process and do not respond to this disruption by *exiting* their newly formed boundaries shortly after their enactment. If homeowners move soon after reassignment to different schools then the effect of increasing spatial fragmentation on segregation would be confounded by short-term residential mobility. Asking the question from a Tiebout/Hirschman theoretical perspective: will families with school-aged children exercise their exit option in response to redistricting by resorting into attendance zones more aligned with their racial preferences?

This question of whether being rezoned into a more racially diverse school affects white households' residential decisions has not been directly assessed. However, two studies took advantage of a natural experiment that altered school assignment policies after the Charlotte-Mecklenburg school district (CMSD) was granted unitary status. During the 30-year period of court-ordered desegregation, CMSD adopted the Finger Plan, which included highly gerrymandered residential attendance zones designed to promote racial integration. In 2005, after the unitary status declaration, CMSD reverted to a neighborhood schools policy. Liebowitz and Page (2014) assessed whether this policy "shock" motivated white families to relocate to more racially isolated attendance zones. While the researchers' larger findings somewhat affirmed this behavior.

> White families, overall, were very stable in their residential choices, with only 5% to 10% of those with elementary school students moving across attendance zone boundaries in a given year. In addition, non-White movers were marginally more likely to move to Whiter neighborhoods after the changed assignment policy. These moves would serve to counterbalance some of the segregative choices White families made during these years (p. 697).

In another study of CMSD using GIS methodologies, Monarrez (2018b) concurred that White mobility was limited after the implementation of neighborhood school assignments, "finding high residential compliance rates and little real estate valuation effects stemming from sudden changes in attendance boundary policy" (p. 2) adding that, given the 85 percent residential compliance rate over a decade, "the main analysis in this study is robust to endogenous residential sorting, especially considering the relative frequency of SAB changes" (pp. 38-39).

Would current residents move in response to changes in school attendance boundaries? These studies suggest that white residents are not compelled to move in response to boundary changes even when they are rezoned into more racially/ethnically diverse schools. From an EVL perspective, they may not like the changes and resort to the voice option in an attempt to arrest what they perceive is a decline in school quality (Hirschman, 1970). However, they are far more likely to remain loyal afterwards by maintaining their current residences rather than exiting to a less diverse neighborhood. Considering the implications for this study, if school attendance rezoning increases segregation through fragmentation, then any gains in racial/ethnic imbalance between schools is more likely than not to persist, at least in the near future.

Conclusion

Schools are more than educational institutions. For many families, schools are the organizational focal point of everyday life, shaping the patterns of social interactions of children and parents alike. When educational and social activities are restricted by race and class then privileged children are the primary beneficiaries of adequate funding, parental involvement, small class sizes, positive peer effects, higher expectations, teacher quality, better facilities, and opportunities accessed through informal networks. In spite of the removal of many forms of legal discrimination, racial, ethnic and economic segregation persists, perpetuating the unequal educational and social contexts that children of different races and ethnicities experience in their daily lives.

These unequal contexts no longer fit neatly into the stereotypes of "chocolate city and vanilla suburbs" In cities, Hispanics now outnumber African Americans, who are now more likely to live in a suburb than in a central city (Frey, 2011). The rapid pace of minority settling in suburbs is occurring unevenly, leading to great demographic differentiation among suburban municipalities and school districts. Various typologies have been posited to make sense of the numerical gains and shifts in diversity. Because of their overall growth and increasing racial diversity, this current study predicts that boundary changes in two types of suburban school districts—*developing immigrant meccas* and *countywide districts*—will experience the greatest segregation effects attributable to increased fragmentation.

Boundaries lie at the nexus of demography and geography. School assignment by residential location reinforces and deepens residential segregation when other-race avoidance is factored into home purchasing decisions (Glazerman & Dotter, 2017). As a result of the *Milliken* decision, locating within a particular school district virtually guarantees that one's children will not be classmates with children from another district. "[T]he connection between fragmentation and segregation is interactive; fragmentation activates, or enables, racial differences in preferences or resources to dictate residential location" (Bischoff, 2008, p. 185)

Metropolitan areas that are the most fragmented by school district also exhibit higher segregation between districts owing to Tiebout/Schelling sorting processes. Whereas district boundaries are a relatively stable feature of metro areas, school attendance zones are much more fluid and, while within-district segregation has decreased, segregation by school attendance boundaries still accounts for a meaningful share of total school segregation. The reccuring shifts in school attendance boundaries allow for a temporal investigation of these political boundaries as mechanisms of segregation.

Boundaries are perhaps the most salient feature of the suburban terrain and school attendance boundaries, like district boundaries, carry information signaling quality and racial composition, allowing for differentiation—or "eccentricity" in Weiher's terms—through the operation of recruitment and exclusion. As with district lines, school attendance boundaries are accessed by home seekers desiring to settle into distinct places and their alteration potentially disrupts the meanings they formerly conveyed. This disruption can trigger "attack-defense" sequences (Tilly, 2004) as elites vie to maintain hoarded resources against redistributionist attempts.

School attendance boundaries are most susceptible to manipulation owing to their instability and lower cost of change, since there is no need to create jurisdictional infrastructure as would be needed when establishing a new school district. Whereas local elites have disproportionately more power, they take advantage of existing fragmentation and encourage additional fragmentation when it benefits them (Alesina et al., 2004; Monarrez, 2018b; Saporito, 2017b) but when fragmentation threatens to disturb the status quo, especially when increases in racial and class diversity are the anticipated results, elites protest and otherwise pressure political leaders. Some researchers maintain that political pressure by elites promotes increased segregation through gerrymandered school attendance zones. However, subsequent analysis indicates the opposite: more compact catchment areas are associated with greater segregation. This finding implies that further fragmentation would yield still higher segregation. As to the question of whether elites will exit after a reapportionment process that increases racial diversity, the existing evidence is tentative but seems to point to minimal residential resorting.

In growing districts adhering to a neighborhood schools policy, school attendance zone fragmentation is unavoidable as new schools are added. When race and class are salient, elites resist and manipulate. The resulting increase in segregation might be attributed *solely* to political maneuvering unless the independent geometric effects of redistricting upon segregation levels are assessed. Once those independent fragmentation effects are established, any additional increases in segregation could then be attributed to the ability of white elites to successfully influence the political process.

Chapter 3: Methods

This study seeks to identify the independent effects that school attendance zone fragmentation has on racial/ethnic segregation between schools within growing and diverse school districts. It predicts that in those districts whose racial and ethnic groups are spatially clustered residentially, there can be significant increases in between-school segregation due solely to proportional increases in school zone fragmentation.

School districts face a number of decisions when the growth of student populations stretches their present capacities. If, as is often the case, district leaders respond by adding new schools, they will site those buildings and determine new catchment areas for each additional school, thus precipitating a reapportionment of school-aged children among both new and extant schools via redrawn attendance boundaries. District planners are typically guided by a number of principles when allotting children to schools and face a number of trade-offs when formulating new attendance zones. These planners usually seek (a) to minimize transportation time and distance, (b) to reduce the effects on staff and disruptions of feeder school relationships to the upper grades, (c) parity in enrollment numbers between other schools, and (d) to remain below school capacity in the long term, making further boundary changes less likely (*Boundary change process*, 2013). With these competing demands, it is not surprising that balancing the racial/ethnic composition across schools often takes a backseat when new catchment areas are specified. Under these conditions, a growing and diversifying school district can find its schools increasingly segregated as the district becomes more fragmented. While they are mute on causal mechanisms and without measuring increasing fragmentation, Reardon et al. (2012) observed how "[s]egregation levels grow fastest among elementary schools, which typically draw from smaller (and therefore more homogeneous) catchment areas under neighborhood-based assignment plans, and slowest among high schools" (p. 899).

Case Study of Fragmentation Effects on Segregation

The following example of a single Midwestern district shows how segregation between schools can rise due solely to increased fragmentation. To reiterate, it is the contention of this present study that the effects of a neighborhood-schools policy on segregation has a component that is independent of changing demographic proportions in the population. When new schools are added, the fixed area of the overall district is subdivided into more and increasingly smaller and thus increasingly more homogeneous units. When any variable is dispersed across an area unequally—race and ethnicity in this case—the act of increasing segmentation alone is sufficient to cause greater inequality between subunits without any other changes being necessary.

The growth of the Bainbridge school district

In order to illustrate this process, the following is a detailed analysis of a single school district showing the methods employed in the national sample and revealing the consequences that greater fragmentation has on between school segregation. This analysis of the Bainbridge school district preceded the investigation of the national sample of districts, which comprise the bulk of this study, and the results from this one district indicate that the effects for fragmentation observed in Bainbridge schools may be observed more broadly. Applying an analysis to a single district enables a clearer explication of the methods employed in the national sample. The town of Bainbridge comprises roughly 90 percent of the total area of the Bainbridge school district and the town is classified as a "diverse" suburb under Orfield and Luce's (2013) typology. The shift from a "predominately white" suburb occurred sometime between the 2000 and 2010 decennial censuses (Table 3.1) while, during that same decade, the overall population increased by 35 percent.

Table 3.1

Racial and Ethnic Composition of the Town Of Bainbridge

Race	2000 percent of total population	2010 percent of total population
White only	85.20%	76.10%
Black or African American	3.70%	5.30%
American Indian & Alaska Native	0.40%	0.40%
Asian	2.70%	4.10%
Some Other Race	2.60%	4.10%
Two or More Races	1.80%	3.00%
Hispanic	5.40%	10.20%

From U.S. Census, American Factfinder, 2012.

While adding nearly 500 students per year since the start of the current millennium, the Bainbridge school district is now one of the largest in the state, serving more than 30,000 students, of which roughly 28 percent qualify for free or reduced lunch, up from 10 percent in 2000. Due to this rapid overall growth, Bainbridge operated 35 elementary schools in SY2015, 16 more schools than the 19 it operated in 1990. Bainbridge adheres to a “neighborhood schools” policy, assigning children to schools based upon residential location and maintaining a very limited transfer policy, much as the 95 percent of all multi-school districts do (Monarrez, 2018b).

Outline of methodological approach

The basic approach to assess the independent effects due to fragmentation is first to take two school attendance boundary configurations at two different target times and assign school-aged children to schools under both boundary configurations. These two projected school populations at each time are drawn from a single spatial dataset containing residential locations aggregated at the US Census block level. This necessarily fine-grained residential dataset contains racial/ethnic compositions for the smallest areal units—census blocks—within the larger school district boundary. After all children are assigned to a school at each target time into the respective boundary configuration, the level of segregation between schools for both configurations is calculated and compared in order to note any increase or decrease in segregation due solely to the spatial partitioning process.

Data and methods

The first step in linking the place of residence to school attendance zones was to obtain school attendance boundaries in geographic information systems format. A geographic information system (GIS) is a computer-based framework or tool for investigating and displaying spatial data. Data are organized in layers of information for the purpose of visualizing and/or analysis of spatial relationships, patterns, and trends. The elementary school (grades K to 5th) attendance boundaries were obtained directly with permission from the Bainbridge district planning manager for all school years from 1987 to 2012. Because of the availability of detailed boundaries spanning multiple decades, three target times, ten years apart, were chosen to assess the effects of fragmentation: 1990 (19 schools), 2000 (27 schools), and 2010 (34 schools). Next, the spatial dataset of the residential locations of school-aged children needed to be constructed. The GIS dataset of census blocks can be pictured as a blank map of geometric shapes—

polygons—void of any descriptive information about the residents living there. "Filling" each block with the age and racial composition of the residents of each block required joining tabular data containing demographic information to the corresponding spatial block using matching index values in both the spatial and tabular datasets (figure 3.1). The spatial and demographic data files both originated from the 2010 U.S. decennial census (2010 Census: SF 1a - P & H Tables) and were downloaded from the IPUMS-NHGIS database (Manson et al., 2018).

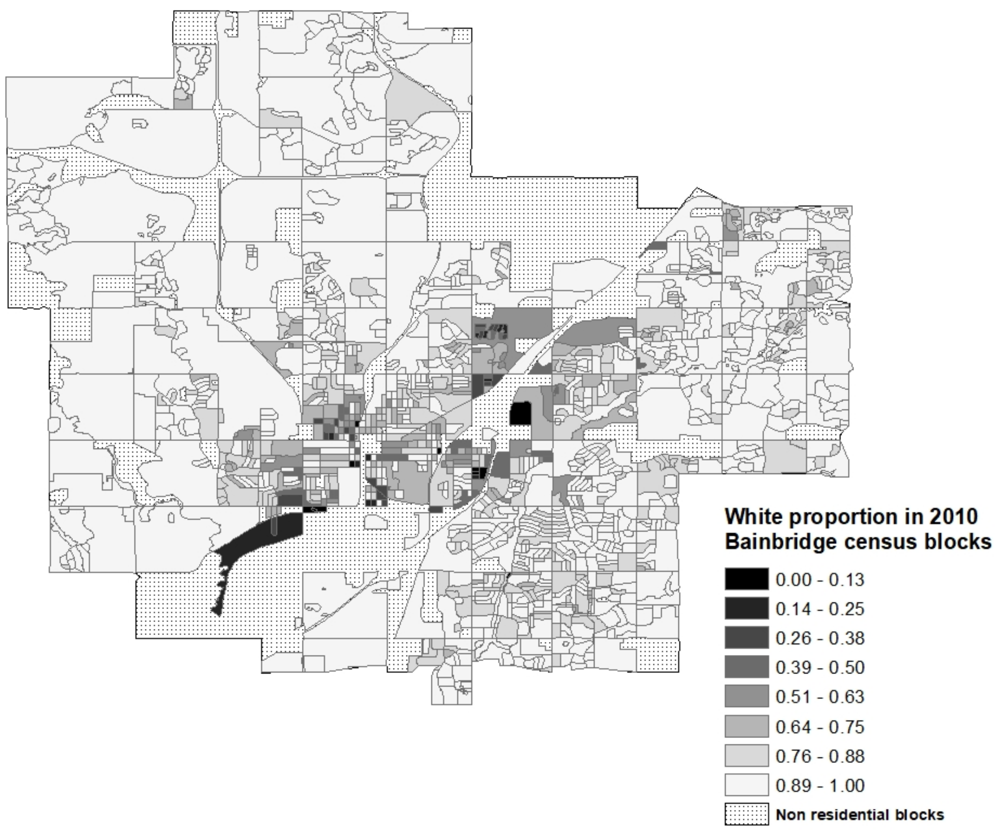

Figure 3.1. 2010 Census blocks within Bainbridge school district shaded by percent of white residents.

Census blocks are the smallest areal unit for which the U.S. Census Bureau gathers and reports decennial census data. The necessity of using these smallest units stems from the slight geographic changes that may occur when attendance boundaries are adjusted, often altering the catchment area of an existing school by only a few blocks. Former studies of school attendance boundaries have not attempted to measure the effects of these marginal spatial/temporal changes, looking instead at the composition of each school attendance boundary at a single time or comparing the total district diversity across some time period (Monarrez, 2018a; Richards, 2014; Richards & Stroub, 2015; Saporito, 2017a, 2017b; Saporito & Sohoni, 2006; Siegel-Hawley, 2013; Sohoni & Saporito, 2009). One drawback of using these smallest units is the paucity of demographic detail available at the block level. For race and Hispanic origin there is only one age delineation—age 18 and over. Subtracting from the total population yielded the under 18 year old population, which this study deems "school-aged children" for apportioning purposes. Encountering a similar problem using a nationwide sample from the Census Bureau's 2000 SF1 block-level data, Sohoni and Saporito (2009) downplayed any differences in racial proportion by age, finding "the racial percentages across ages are nearly identical within school districts" (p. 576).

Since this study seeks to determine whether the single process of subdividing a school district into more and smaller school attendance areas increases racial/ethnic segregation among the district's schools, it is necessary to eliminate the variable of student migration. This is done by keeping the residential locations of children artificially constant from one target time to the next. From a single spatial dataset of residential locations (figure 3.1), a projected school population will be apportioned to each school by assigning to each school all the school-aged children residing in the census blocks within each school's attendance zone. The apportioning process can be illustrated with an example from one of the school attendance zones in Bainbridge, shown in figure 3.2.

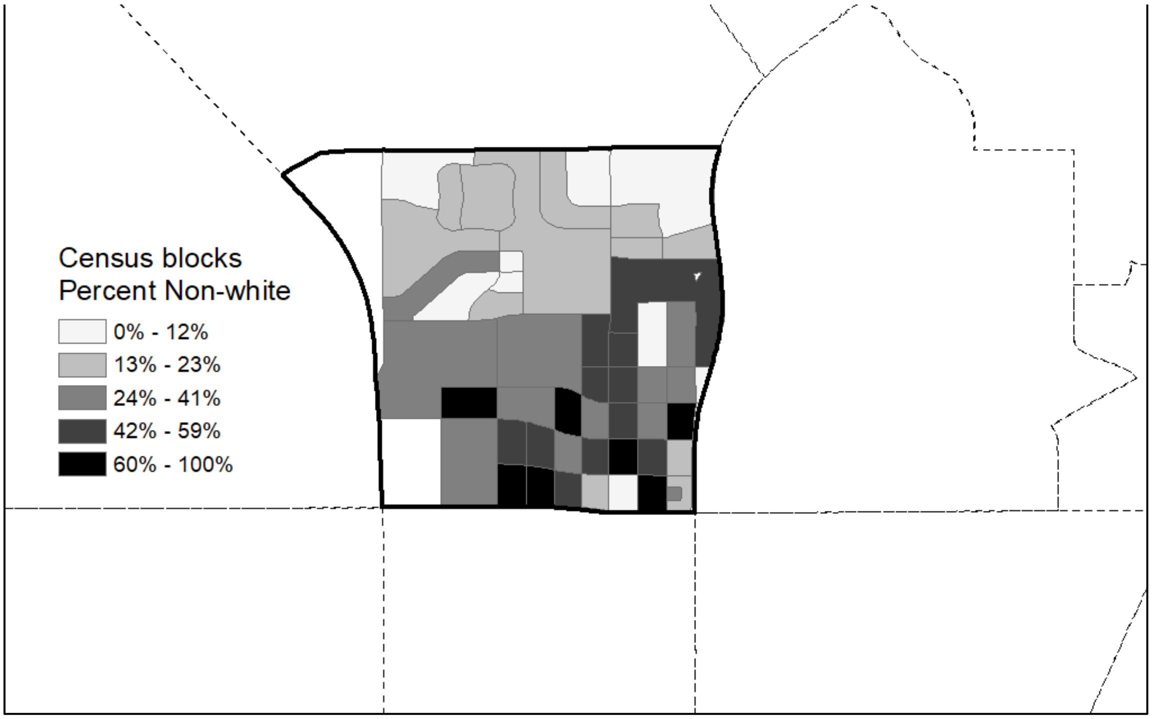

Figure 3.2. Census blocks within one school attendance zone in the Bainbridge school district.

The actual school attendance zone is outlined in bold with adjacent school attendance boundaries indicated by dotted lines. Within the attendance zone shown are 50 census blocks containing the racial/ethnic makeup of the school-aged children residing therein. These demographic data are aggregated and the racial/ethnic group sums are assigned to the zone as its projected school population. Likewise, this apportionment process is repeated for every school attendance zone in the district for each of the three target years—1990, 2000 and 2010—producing three sets of projected school populations, one for each decade. The aggregated racial/ethnic composition for the attendance area shown in figure 3.2 was imputed, from the year 2000 residential census data, to be 31.8% non-white while the actual non-white population for this particular school, as reported by the state department of education for the 2000-2001 school year, was 35.1%.

The racial/ethnic makeup was operationally defined as consisting of three exhaustive and mutually exclusive categories: *White,* composed of non-Hispanic whites, *Black*, containing black and African Americans including black Hispanics, and *Hispanic*, consisting of Hispanics not self-identifying as also black or African American. According to the definitions used by the U.S. Census bureau in 2010, *white* is "a person having origins in any of the original peoples of Europe, the Middle East, or North Africa. It includes people who indicate their race as "White" or report entries such as Irish, German, Italian, Lebanese, Arab, Moroccan, or Caucasian" (U.S. Census Bureau, 2012, pp. B-7). *Black* is "a person having origins in any of the Black racial groups of Africa. It includes people who indicate their race as "Black, African Am., or Negro" or report entries such as African American, Kenyan, Nigerian, or Haitian" (U.S. Census Bureau, 2012, pp. B-7).

The terms "Hispanic," "Latino," and "Spanish" are used interchangeably. Some respondents identify with all three terms, while others may identify with only one of these three specific terms. People who identify with the terms "Hispanic," "Latino," or "Spanish" are those who classify themselves in one of the specific Hispanic, Latino, or Spanish categories listed on the questionnaire ("Mexican," "Puerto Rican," or "Cuban") as well as those who indicate that they are "another Hispanic, Latino, or Spanish origin." People who identify their origin as Hispanic, Latino, or Spanish may be any race. (U.S. Census Bureau, 2012, pp. B-3).

The "total population" then consisted of the sum of the three racial/ethnic categories. Other racial/ethnic categories, representing roughly seven percent of the population, were excluded from the analysis.

There remained one additional methodological decision regarding the imputation of racial/ethnic compositions to each school attendance area. A few of the census blocks straddled a boundary between two attendance zones. When this occurred, the question became one of deciding how to apportion the census block's school-aged population to one or both of the attendance zones. Following a procedure past studies have employed (Bischoff & Tach, 2018; England, 2014; Monarrez, 2018a; Saporito et al., 2007), every block was assigned to a single school attendance zone by asking if the block's centroid—the block's geometrically central point—was located within the school attendance zone.

Assessing the degree of segregation under each boundary configuration was accomplished by calculating Theil's Entropy Index, also known as Theil's "*H*" or the Information Theory Index (Theil, 1972), which can measure segregation for multiple groups. Theil's *H* is a measure of "evenness" or how evenly distributed students of each racial/ethnic group are distributed across the district's school attendance zones. Theil's *H* compares the average deviation between a group's proportion within each zone to that group's proportion within the district as a whole; or more succinctly, "the measure of the ratio of within unit diversity to total diversity" (Reardon & Firebaugh, 2002, p. 46).

The multigroup entropy index (*H*), measuring the district's overall diversity, is calculated from entropy scores for each school attendance zone and from the district's overall entropy score. The entropy score measuring the overall diversity for the entire district is defined by the formula:

$$E = \sum_{m=1}^{M} (\pi_m) \, ln\left(\frac{1}{\pi_m}\right)$$

where π_m refers to each racial/ethnic group's proportion in the district's total population and *M* is the number of racial groups. When expanded out to show all three racial/ethnic groups—black, white, and Hispanic—district entropy would be calculated by the formula:

$$E = (\pi_B)ln\left(\frac{1}{\pi_B}\right) + (\pi_W)ln\left(\frac{1}{\pi_W}\right) + (\pi_H)ln\left(\frac{1}{\pi_H}\right)$$

Next, E_i is calculated for each school attendance zone, giving each zone an entropy score—its measure of racial/ethnic diversity:

$$E_i = \sum_{m=1}^{M} (\pi_{mi})\, ln\left(\frac{1}{\pi_{mi}}\right)$$

where π_{mi} refers to the proportion of group *m* in the population of school *i*.

From the entropy scores for each school, E_i, the Entropy Index (*H*) is normalized by both the district's total population, *T,* and its entropy score, *E*. The Entropy Index (*H*) is calculated using the formula:

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

where t_i is the overall population of each school zone *i*. "*H* is the weighted average deviation of each [school zone's] entropy from the [district-wide] entropy, expressed as a fraction of the [school district's] total entropy" (Iceland, 2004, p. 8). If all racial/ethnic groups are distributed evenly across all schools, *H* has a value of 0, meaning complete integration, and if each school contains only one racial/ethnic group, the value of *H* is 1, meaning maximum segregation (Iceland & Weinberg, 2002).

A number of other measures of evenness have been used to measure segregation, the most widely used being the Dissimilarity Index. *H* is preferred here because it can measure segregation between more than two groups simultaneously leading to its increased use in studies investigating racial imbalance. Reardon, Yun, and Eitle (2000) compared *H* to other multigroup measures finding correlations with *H* ranging between 0.85 and 0.96, concluding that using another metric would indicate similar levels of multigroup segregation.

Indications of a fragmentation effect

By calculating *H* for each of the three boundary arrangements, it can be seen whether greater fragmentation, i.e. the number of school zones increases from 19 to 27 and then to 34, indicates an independent effect on segregation. The effect would be "independent" because all projected school populations were obtained from the same source residential data. The only variable from one time to the next is the number, size, and shapes of the three boundary configurations.

Theil's *H* was computed for three of Bainbridge's school boundary configurations across two ten-year intervals following the methods implemented in the STATA –seg– package by Sean Reardon (1999). Holding the residential source layer constant and varying only the spatial structure of school zones from one decade to the next yielded gains in *H* for all comparison groups as the number of school zones increased (Table 3.2).

Table 3.2

Entropy index (H) across years and number of school attendance zones in Bainbridge school district.

Year	1990	2000	2010
School attendance zones	n=19	n=27	n=34
Multigroup *H*	0.0700	0.0769	0.0785
Black-White *H*	0.0345	0.0397	0.0402
Hispanic-White *H*	0.0897	0.0958	0.0981

Inasmuch as the residential dataset from which the racial/ethnic compositions were extracted remained constant, the increases in diversity can only be attributed to geometric processes. Figure 3.3 shows the Bainbridge boundary configurations at each target time with the white populations apportioned to each zone from the same block-level residential map. Two features are important to consider in understanding the increases in *H* across the years as reported in table 3.2. The first notable feature is the close similarity of the shaded regions. This is due to the fact that the same residential layer served as the source feature from which all the racial/ethnic compositions of each school attendance zone were imputed. The total areas for the darkest and lightest shadings remain fairly constant. This similarity is born out in table 3.3 where the average white proportion for all school attendance zones increases only slightly.

Table 3.3

Descriptive statistics of the white population in attendance zones of the Bainbridge school district under each boundary configuration

		Proportion white			
Year	*n*	minimum	maximum	mean	S.D.
1990	19	.573	.931	.795	.112
2000	27	.573	.939	.821	.113
2010	34	.573	.953	.838	.110

The roughly equally shaded areas from one map to the next leads to the second important feature of these maps, namely what is dissimilar: the number and average size of the school zones comprising each of the shaded regions. Of the five shaded categories, the top two indicate the highest proportion of white children while the lower two categories indicate the schools with the lowest proportion of white students.

From 1990 to 2010, when the total number of school attendance zones increased from 19 to 34, the schools with the lowest proportion of white students grew from four to five (table 3.4)—an increase, but by itself not remarkable. What is more important, but perhaps not as conspicuous, is that the number of schools with the highest proportions of white students rose from 10 to 25. (The middle category slightly decreased from five to four.) By the single act of cutting up the same residential layer into smaller and more homogeneous units of analysis, measured segregation increased meaningfully without the overall complexion of the district changing. When changes in within-district segregation is reported in the research literature, the influence of increasing fragmentation on measured segregation is either unaccounted for, unrecognized, or otherwise ignored (for instance Mickelson, 2014, p. 161). This study predicts that increases in measured segregation due to greater fragmentation are not unique to Bainbridge but will be observable on a large scale across the nation.

Table 3.4

Number of elementary schools in the Bainbridge school district with relatively low, medium, and high proportions of white students

		Percentage of white students		
Year	*n*	Below 70%	70% to 80%	Above 80%
1990	19	4	5	10
2000	27	4	6	17
2010	34	5	4	25

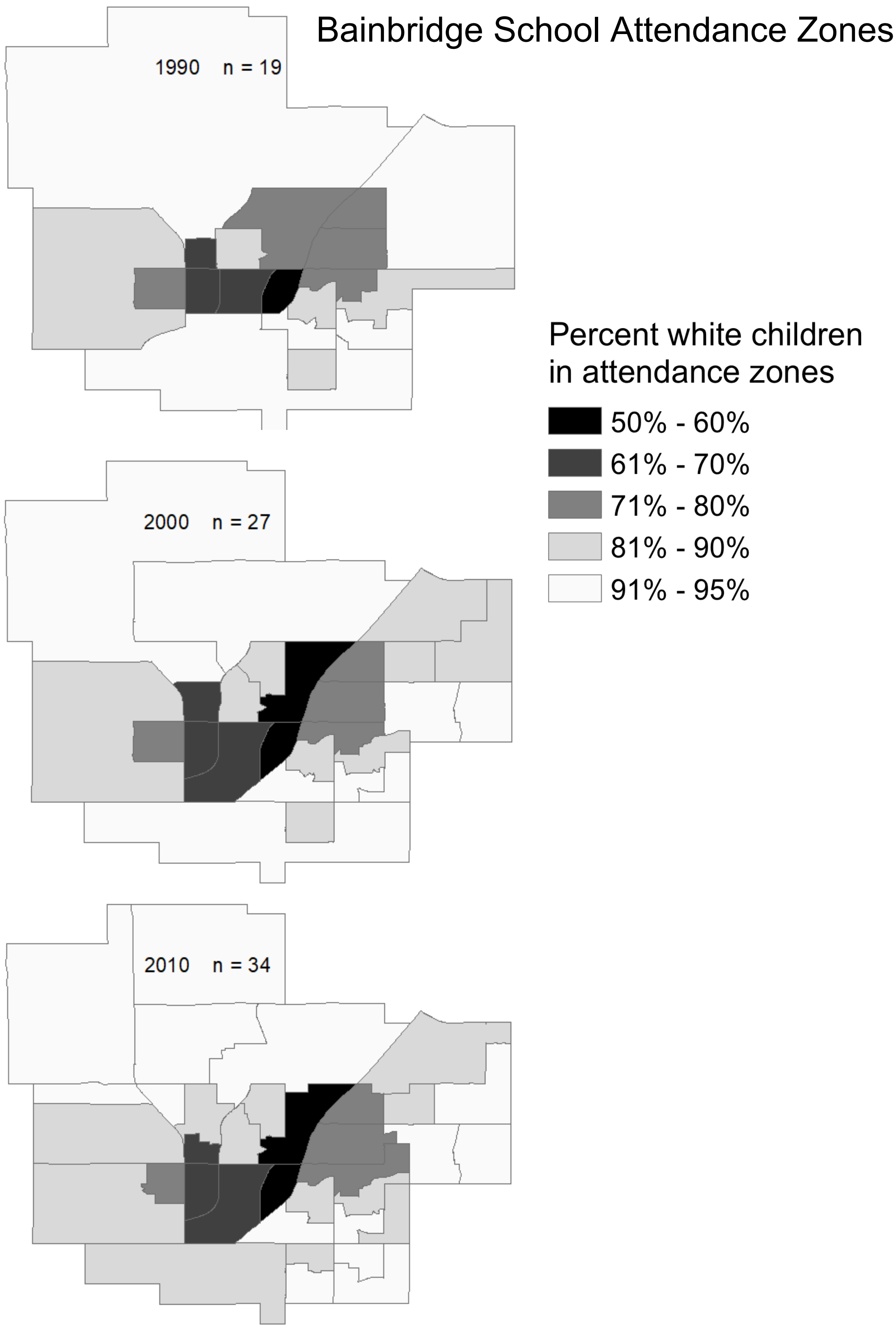

Figure 3.3. Bainbridge school attendance zones for each of the three target times shaded with percent of white students apportioned from census blocks.

Investigating Fragmentation Effects at the National Level

Arguably the leading researcher examining school attendance boundaries' impact on segregation, Salvatore Saporito, called for studies going beyond the scrutiny of a single district. "Despite the need for systematic studies that examine a large sample of attendance zones, most existing studies draw conclusions based on inspection of a few zones. … What is needed is research examining a large sample of attendance zones embedded in a large number of urban school districts" (Saporito & Van Riper, 2016, p. 6). It would not have been possible, until recently, to investigate fragmentation effects by school attendance boundary due to the absence of a database of school attendance boundaries for a large number of districts. For years, the U.S. Department of Education's National Center for Educational Statistics (NCES) has made school district boundaries available for most, if not all, of the nation's school districts starting in 1989 and continuing up to the present. This has enabled between-district comparisons, but within-district investigations were not possible until the SABINS project. The School Attendance Boundary Information System (SABINS) is an NSF-funded project of the Minnesota Population Center and the College of William and Mary that provided the first database of kindergarten through 12th grade school attendance boundaries for selected areas in the United States beginning in SY2009-10 ("School Attendance Boundary Information System (SABINS): Version 1.0," 2011). These data are available in GIS formats and, for this study, were imported into ArcGIS 10.6 for analysis. Due to limited funding, not all public local education agencies (LEAs) were targeted with requests for documentation of their school attendance zones. Of the over 13,000 LEAs in the nation, more than half of all school-aged children reside within roughly 800 LEAs. These districts were the focus of the SABINS project. On the other end, 60 percent of all LEAs in the U.S. are what are termed "*de facto*" school districts, meaning there is only one school at each grade level serving the children of the entire district. Approximately 20 percent of all U.S. children attend a de facto school.

The SABINS database contains complete school attendance boundaries for all public schools in three states—Delaware, Minnesota, and Oregon—along with around 600 districts within the largest Metropolitan Statistical Areas (MSAs) containing most of the largest districts in the country. These SY2009-10 SABINS districts, containing over 38,000 schools, formed the pool from which the school attendance boundaries for the first target time were selected.

The school attendance boundary layer for the second target time was derived from a related but separate database. Subsequent to the SABINS project, NCES conducted the School Attendance Boundary Survey (SABS), which attempted to collect school attendance boundaries for public schools in all 50 states and the District of Columbia. To increase the likelihood of observing fragmentation effects, it is best to choose target times spanning the greatest number of years. The latest publicly available SABS boundaries cover SY2015-16.

The SY2009-10 SABINS districts and the SY2015-16 SABS districts were intersected to yield two target layers containing mutually inclusive school districts for both target times. This short span of six years is less than ideal for examining the effects of fragmentation due the reduced likelihood that many districts would add multiple schools resulting in consequential boundary changes. For instance, the Bainbridge school district contained 33 elementary schools in the SY2009-10 SABINS data and 35 elementary schools in the SY2015-16 SABS data.

The SABINS/SABS intersection was filtered further by excluding de facto schools as well as smaller, less fragmented school districts. Following Monarrez (2018b), this study is restricted to districts administering at least five elementary schools in SY2015-16. Both SABINS and SABS denote schools by the grade levels they contain and neither ascribes a label to schools such as “primary” or “elementary.” In this study, the operational definition of an “elementary” school is a public school possessing at least one third-grade classroom. In their investigation of school attendance boundaries, school choice, and segregation, Bischoff and Tach (2018) also operationally define “elementary” schools at the third grade level. Using ArcGIS 10.6, I intersected SABS and SABINS with a filter for the number of elementary schools, obtaining roughly 500 school districts in the SABINS/SABS intersection possessing five or more elementary schools in SY2015-16.

In order for school attendance boundaries to have a segregative impact on children, districts with an “open enrollment” policy were filtered out of the sample. An open enrollment district allows a child to apply to attend a school outside his/her local catchment area. Additionally, many districts that had a large number of magnet and charter schools that enrolled children from across the district were culled from the data. Typically, magnet and charter schools distort the distribution of children into schools according to residential location—a requirement necessary for fragmentation to have a segregative effect. Of the remaining districts with five or more “neighborhood” elementary schools, two were excluded because of an apparent error in the SABINS database. From the application of these filters came a nationwide sample of 484 school districts in 39 states (Figure 3.4).

Figure 3.4. Non-“open enrollment” school districts with five or more elementary schools in SY2015-16 included in the SABS database.

Assigning Demographic Attributes to School Attendance Boundaries

One of the main hypotheses of this study is that alterations of school attendance boundaries themselves can have an independent effect on racial/ethnic segregation net any change in residential patterns either preceding or subsequent to the boundary alterations. In order to test this conjecture, the assignment of children to local schools based upon residential location for each target time must be extracted from a single resident population layer. Duplicating the same procedure used in the Bainbridge case study, 2010 U.S. census SF1a block-level data was the residential layer used when apportioning children to schools. This entailed a two-step process. First, using ArcGIS 10.6, the racial and ethnic population counts available from the US Census in tabular format were joined to the spatial census block units. Now that each residential census block contained racial/ethnic counts of school-aged children, projected school populations were obtained by attributing to each school attendance zone all children residing in census blocks having block centroids contained by the attendance zone. The racial/ethnic categories were operationally defined in the same manner as in the Bainbridge case, which meant that some children not fitting into one of the three categories were excluded—Asians, Native Americans, and multi-race children comprised roughly seven percent of the total under-18 population.

Reassigning data from one geographic layer to another, such as ascribing residential attributes to school attendance zones, can lead to errors if the polygonal boundaries between the two layers are not completely contiguous. If a school attendance boundary cuts across a census block, the issue becomes one of deciding how much of the block's population should be apportioned to each school zone. Other researchers studying the relationships between school attendance zones and segregation have used various areal interpolation methods but only one study (Saporito et al., 2007) has sought to assess the relative accuracies of these different methods. Saporito et al. (2007) described and tested four ways of reassigning attributes from one zonal system to another. Similar to this study, they reassigned school-aged residents from census blocks into local school attendance boundaries for the school districts in the largest 25 MSAs. In doing so, they found that school attendance zones completely contained roughly 95 percent of all intersected census blocks (SD=3.33%). They conclude that assigning the attributes of a census block to a larger areal unit—school attendance zone in this case—according to whether the centroid of the census block is contained by the larger unit leads to very little error when they were able to compare this method with known actual values of the larger unit. Discrepancies between population apportionment by centroid method and known populations only increase meaningfully when units larger than census blocks, such as block groups or census tracts, are used in reassigning demographic attributes to school zones.

Clustering

A major prediction of this study is that increased fragmentation, meaning the redrawing along with the addition of new school attendance zones, will differentially affect between-school segregation depending on, not only the *amount* of residential separation of racial/ethnic groups, but also on *particular arrangements* of spatial units primarily occupied by each group. Within-district segregation will be altered, net other factors, when a new attendance boundary configuration shifts the previous racial/ethnic proportions between two or more schools. Changes in segregation will not occur if the previously undivided section is racially homogeneous. Measured segregation remains unvaried if large swaths of either minority or majority populations are subdivided by new attendance lines. Cutting through a large homogeneous area would merely create two new sectors with racial proportions roughly equal to each other. Atlanta city school district in Georgia illustrates this notion (figure 3.5). Given the large African American population in the southwest portion of the district compared to their scarcity in the north, a new school added in the midst of either region would result in new school zones containing racial proportions similar to existing compositions due to the *large* racially homogeneous residential areas—large, that is, in comparison to the size of the typical school attendance zone in the district.

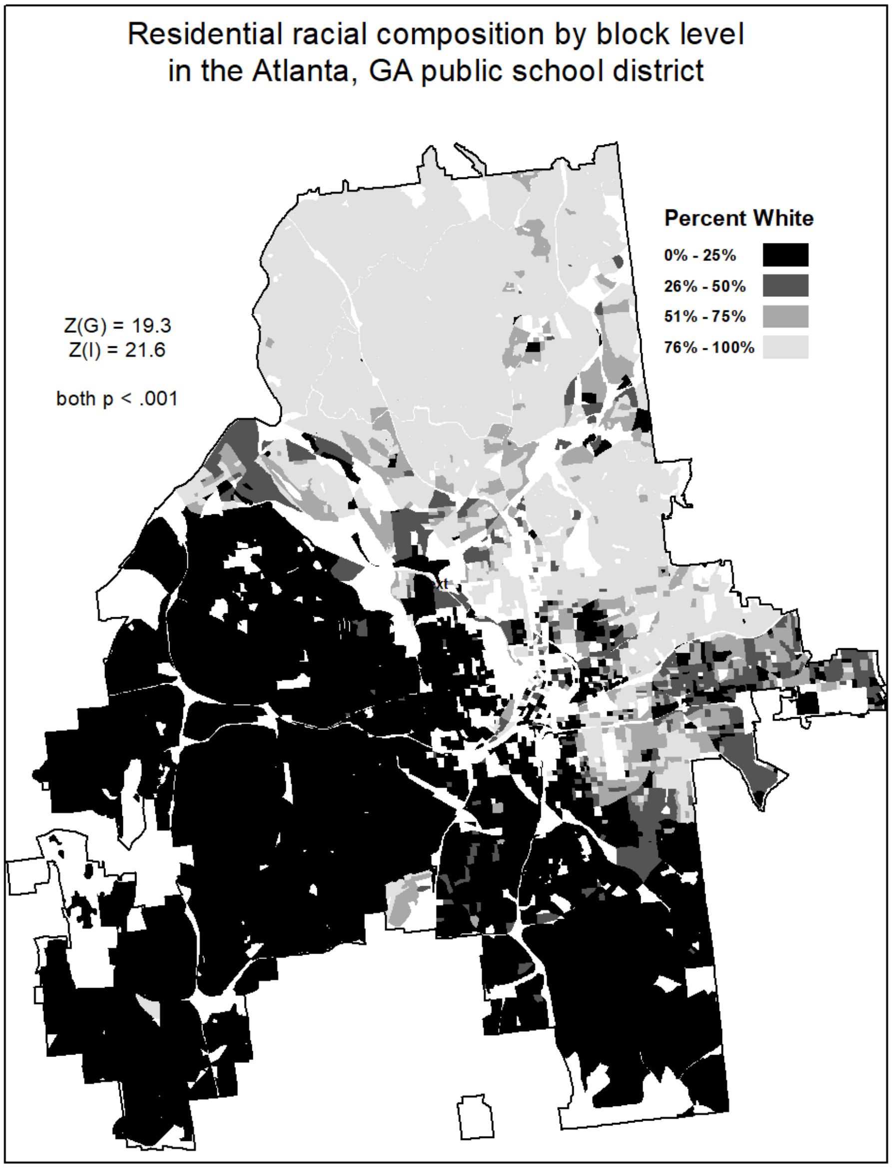

Figure 3.5. Bifurcated racial landscape yielding high values for both Getis-Ord G and Moran's I.

On the other extreme, consider a district containing many small but racially concentrated residential neighborhoods *dispersed* across the district. In this situation, a counter-intuitive outcome may result. Measuring overall residential segregation on the dimension of evenness could yield a high value but drawing a new school attendance zone may not result in greater racial/ethnic differences between the schools. This outcome is due to what has been labeled the "checkerboard" problem where each square on the checkerboard contains only one color. Using the individual squares as the unit of analysis would yield maximum segregation on the evenness dimension. Yet, if one makes an arbitrary cut across the board, the two sections will each contain roughly the same ratios of the two colors (see Fossett, 2017, p. 131).

Between these two extremes lie patterns of spatial residential segregation that are susceptible to the effects of increasing fragmentation. The difficulty in measuring this middle ground pattern across hundreds of districts is that it requires employing summative measures for entire districts that will distinguish the two extremes from intermediate patterns.

What is a cluster?

Local areas containing higher numbers of one group compared to another are generally referred to as clusters. Capturing their number, size, concentration, and spatial arrangement within the larger region of analysis is difficult using a single summative statistic for any given region. Unlike in this study, most spatial research considering clustering as a segregative factor typically examines only one to a few regions that can be visually inspected on a case by case basis (England, 2014; Etienne, 2006; Torres & Bichir 2009). When sample sizes exceed a dozen or so then researchers are concerned only with whether clustering is high or low (Catney, 2017). I have found no examples in the segregation literature of general methods used to capture the size, intensity, or arrangement of clustering for large sample sizes using a single global index. Nonetheless, residential patterning of racial/ethnic groups is central to the prediction of finding fragmentation effects. In order for changes in school attendance boundaries to impact school segregation, new boundaries must separate children differentially according to race and ethnicity. This can only occur if these children live in racial/ethnic clusters. From an implementation and conceptual standpoint, identifying and describing clusters can be thorny (Hennerdal & Nielsen, 2017). When like features are found in close proximity or when groups of features with similar values are found together then clustering occurs. Clustering as a concept seems intuitive and is a common notion in many spatial investigations beyond segregation research. However, “it is often applied in a very imprecise and confusing manner” (Wong, 2014, p. 49). Massey and Denton (1988), when introducing clustering as one of segregation’s five dimensions, illustrate this semantic ambiguity when they defined clustering as “the extent to which areal units inhabited by a particular group adjoin one another or cluster in space” (p. 293). As a general statement of clustering, this depiction is enough to start the conversation but cannot serve as an operational definition. Yet, for unspecified reasons, Massey and Denton stop there, leaving many questions unaddressed. What qualifies as “inhabited by a particular group”? Is 50% minority sufficient or must the proportion approach 90%? Furthermore, not all areal units may share a boundary, perhaps a rail line or interstate separates these units. Are they considered adjoining if no other inhabited area intervenes? How many and of what size do aggregated units need to attain in order to be considered a cluster?

Massey and Denton (1988) recommended the Spatial Proximity Index (SPI) as their preferred metric without addressing these and other issues. SPI measures whether members of the minority and majority groups live closer to one another on average than they do to members of the other group (White, 1983). If this occurs then SPI is greater than 1.0 indicating clustering. However, a simple color gradient, in which the color gradually changes from one color to another, would yield a SPI greater than 1.0 without any visible clustering.

Reardon and O’Sullivan (2004) collapsed Massey and Denton’s five dimensions into two distinct continua by placing isolation and exposure at opposite ends of one continuum and clustering and evenness as opposites on the other. They considered a fifth dimension of Massey and Denton—centralization—as less descriptive of recent patterns of segregation in the U.S. and thus excluded it entirely.

The evenness/clustering dimension describes the spatial distribution of groups throughout the region and is independent of the overall groups' compositions. The exposure/isolation dimension is dependent on overall groups' compositions in the region as it denotes the likelihood that members of different groups reside near each other. In view of the deficiencies in SPI, Reardon and O'Sullivan (2004) propose a series of spatial evenness/clustering indices that have not been generally accepted nor widely implemented and, therefore, will not be employed in this study. Rather, in this study, the degree of residential clustering within school districts will be estimated using measures of spatial autocorrelation. For more on why spatial autocorrelation is preferred over SPI and a discussion on some of the issues when using spatial autocorrelation to measure clustering see Appendix 3-A.

For this study, two spatial autocorrelation statistics, Moran's I and Getis-Ord-G[3], will be computed for each school district at the residential block level and interpreted concurrently to

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[3] Moran's *I* formula:

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j} z_i z_j}{\sum_{i=1}^{n} z_i^2}$$

where z_i is the deviation of an attribute for feature *i* from its mean $\left(x_i - \bar{X}\right)$,
$w_{i,j}$ is the spatial weight between feature *i* and *j*,
n is equal to the total number of features,
and S_0 is the aggregate of all the spatial weights:

$$S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{i,j}$$

estimate the degree and pattern of clustering. Both indices compare the strength of correlation between nearby features for all areal units and report a summative value for spatial autocorrelation that can be compared to a random distribution of feature values in order to assess the statistical significance of the reported value. Each method provides different information regarding the nature of any spatial autocorrelation.

For Moran's *I*, values are considered clustered if the differences in values between the target feature and neighboring features is less than the differences in values between the target feature and all features. Moran's *I* only determines if features of like values occur together—the presence of clusters—not whether those clusters are composed of high values or low values.

In order to discern whether the clusters in a region are composed of majority or minority populations or perhaps both, Getis-Ord-*G* is calculated. *G* measures the concentration of either high or low values across the entire region. A high *G* score indicates the presence of "hot spots" or concentrations of high values (high minority clustering). A low *G* score indicates the presence of "cold spots" or concentrations of low values (high majority clustering). Getis-Ord-*G* does not do well in distinguishing between areas where, on the one hand, there are both hot and cold spots from areas where there are no clusters present at all. The *G* statistic is a relative rather than an absolute measure, meaning that the statistical significance of a *G* value is not known unless it is compared to the expected *G* value for a random distribution. *G* values, as well as Moran's *I* values, can be converted to *z*-scores for either significance testing or for comparing the relative magnitude of clustering between districts. In this study, a significant negative *z*-score for *G*

Getis-Ord *G* formula:

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{i,j} x_i x_j}{\sum_{i=1}^{n}\sum_{j=1}^{n} x_i x_j}, \forall j \neq i$$

indicates the presence of high white clustering and a significant positive *z*-score indicates high non-white clustering. For Moran's *I*, a random spatial distribution of the variable of interest, i.e. non-white residences, yields a value close to zero. If Moran's *I* is positive and significant then that is take as evidence of either white and/or non-white clustering. If negative and significant then the distribution of the variable of interest is considered dispersed across the study region.

Using both Getis-Ord *G* and Moran's *I* concurrently for the purpose of estimating the amount and nature of non-white clustering for each school district is recommended (Getis & Ord, 1992; Tao, 2016) as a way to overcome the shortcomings of each index separately, such that together they give a richer picture of the complexion of clustering.

The character of clustering in a district adds contingency to the overall prediction of this study, namely that an increase in the number of school attendance zones, which requires the redrawing of two or more school attendance boundaries, will increase segregation when boundary lines shift small groups of children of different races and ethnicities into separate schools. This is less likely to happen when the overall racial composition in a district is distributed homogeneously or randomly ("0-0" for $z(G)$ and $z(I)$ in table 3.5) and likewise if minority groups are dispersed ($z(I)$ is moderately negative). On the other hand, districts with extremely high residential spatial autocorrelation ("HH" in table 3.5), as is the case in the Atlanta public school district (Figure 3.5), might experience less effects of school attendance boundary fragmentation on account of there being two large clusters rather than multiple smaller clusters, i.e., a more "splotchy" landscape. Multiple clusters of minority members in relative proximity to majority clusters ("HL" in table 3.5) would allow differential separation of minority neighborhoods from majority ones when school attendance boundaries are redrawn.

Table 3.5

Standard Normal Variates for G and I Under Varying Circumstances

Situation	*z*(G)	*z*(I)
HH	+ +	+ +
HM	+	+
MM	0	0
Random	0	0
HL	–	– –
ML	– *	–
LL	– –	+ +

Note:
HH = pattern of high values of *x* within *d* of other high *x* values.
M = moderate values.
L = low values.
Random = no discernible pattern of *x*s.
+ + = strong positive association (high positive Z scores) + = moderate positive association.
0 = no association.
*This combination tends to be more negative than HL.

Adapted from Getis, A., & Ord, J. K. (1992). The analysis of spatial association by use of distance statistics. *Geographical Analysis*, 24(3), p. 198.

Justification for the use of both spatial autocorrelation indices requires their values to be sensitive to various spatial configurations and not merely to global disparities in racial/ethnic composition. An example of a measure where this is not the case is the most commonly used measure of racial segregation, the Dissimilarity Index (D), which measures the aspatial dimension of *concentration-evenness* but does not describe the spatial *clustering-exposure* dimension. To illustrate D's insensitivity to spatial patterns, Brown and Chung (2006) present eight different hypothetical patterns of segregation where each cell ("neighborhood") has 100% Black or 100% White residents (Figure 3.6). Each pattern yields a D of 1.0 and, even if the proportion of each cell was less than 100%, D would be less than 1.0 but would not deviate from one pattern to the next.

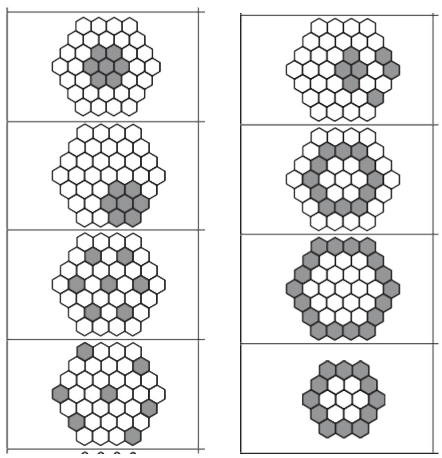

Figure 3.6. Eight different patterns of segregation. Reprinted from "Spatial segregation, segregation indices and the geographical perspective" by Brown, L. A., & Chung, S.-Y. , 2006, *Population, Space and Place*, *12*(2), p. 127.

Using a similar idealized landscape (Figure 3.7), Wong (2014) showed that single measures of spatial autocorrelation may be able to distinguish between some cluster arrangements but not others and also how edge effects may alter index values. Using Join Count statistics[4], a method for measuring clusters of categorical variables, Wong was able to detect differences in some clustering patterns but not all. For instance, patterns 4, 5, and 6 vary by how spread out each group-of-four clusters are, yet each pattern yields the same join count *z*-score. In the context of this study, if these areas represented resident neighborhoods, it is more likely that two clusters in pattern 4 would be within the same school attendance boundary than two clusters in pattern 6.

[4] Join Count is used for nominal variables. Each target feature's join count is determined by dividing the number of adjacent features that have the same nominal value as the target feature by the total number of adjacent features.

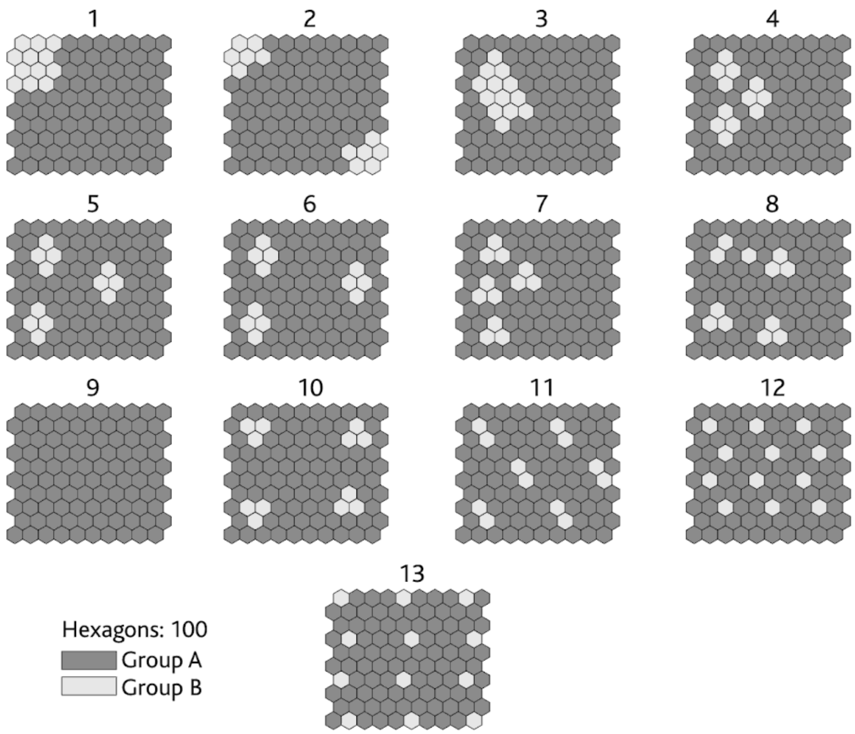

Figure 3.7. Thirteen two-group hypothetical landscapes ranging from extremely clustered (1) to extremely dispersed (13) patterns. Reprinted from "Using a general spatial pattern statistics to evaluate spatial segregation" by Wong, D. W., 2014, in C. D. Lloyd, I. Shuttleworth, & D. W. S. Wong (Eds.), *Social-spatial Segregation : Concepts, Processes and Outcomes*, p. 52.

In the only example I could find employing two spatial autocorrelation indices to distinguish between types of spatial patterns, Wong (2011) combines Moran's I and the Geary ratio into a single measure he called MW—M refers to the attribute matrix and W to the weights matrix. Wong notes that this combination index, if used with a distance weighting matrix instead of the more common binary weighting matrix, is more sensitive in detecting certain types of clustering patterns. In figure 3.8, the Moran's I and Geary ratio together can detect the very close proximity of very high and very low values seen in landscape iii. If only one measure was used then the Geary ratio would not distinguish between ii and iii and Moran's I would not distinguish between iii and iv. A configuration of type iii would be more susceptible to the effects of school attendance boundary fragmentation at the interface of the high and low clusters. The use of MW to detect certain clustering patterns is promising but has not been tested by others besides Wong and he recognizes that "[t]he statistical ramifications of including attribute weights in the expanded framework are not clear yet, and investigating the statistical properties with different attribute weights specifications is an obvious direction of future research" (p. 337).

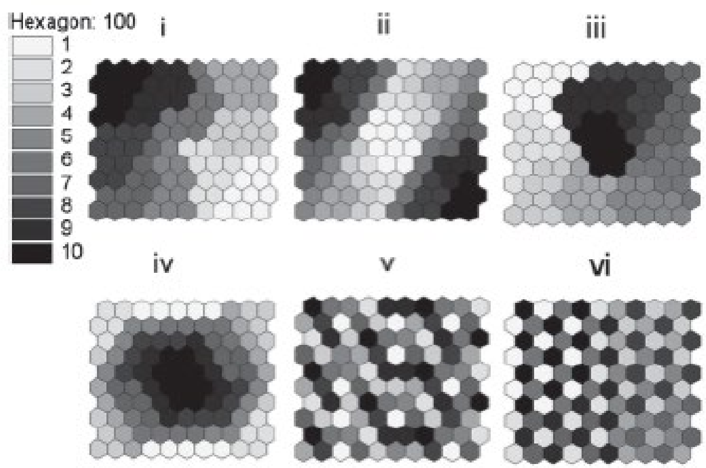

Figure 3.8. Six hypothetical landscapes with values ranging from one to 10 by an increment of one. Reprinted from "Exploring spatial patterns using an expanded spatial autocorrelation framework" by Wong, D. W., 2011, in *Geographical Analysis, 43*(3), p. 332.

Heeding Getis and Ord's (1992) and Tao's (2016) recommendations to use both Moran's Index and Getis-Ord's General index together, I constructed a series of idealized segregation patterns similar to the previous examples in an attempt to detect how the two indices would respond to changes in cluster size and proximity. Various two-group configurations were tested and compared, and a sample of five of these patterns is shown in figure 3.9. Districts exhibiting significant clustering, as evidenced by both higher z(I) and z(G) scores (patterns 1-4 in figure 3.9 and in table 3.6) are predicted to be more susceptible to the effects of fragmentation. This prediction is illustrated by comparing the two school zone configurations where the second configuration shows the addition of a new school zone in the center of the district. For patterns 1 through 4, all minority populations occupy a higher proportion of their new attendance zone compared with their previous zones under the first school boundary configuration. However, minority populations, which may be concentrated but smaller and more dispersed, such as pattern 5, would not significantly alter the racial/ethnic compositions of school zones as fragmentation increases.

Table 3.6

Moran's I and Getis-Ord General statistics for five idealized two-group patterns in figure 3.9

Configuration	Moran's Index	*z*-score	Getis-Ord G	*z*-score
1	0.618	**9.578**	0.0125	**6.936**
2	0.798	**12.329**	0.0128	**9.088**
3	0.572	**8.891**	0.0123	**6.004**
4	0.278	**4.415**	0.0118	**2.676**
5	-0.0391	-0.420	0.0112	-1.593

Note. All *z*-scores for patterns 1 through 4 significant at 99% level. *z*-scores for pattern 5 not significant at 95% level

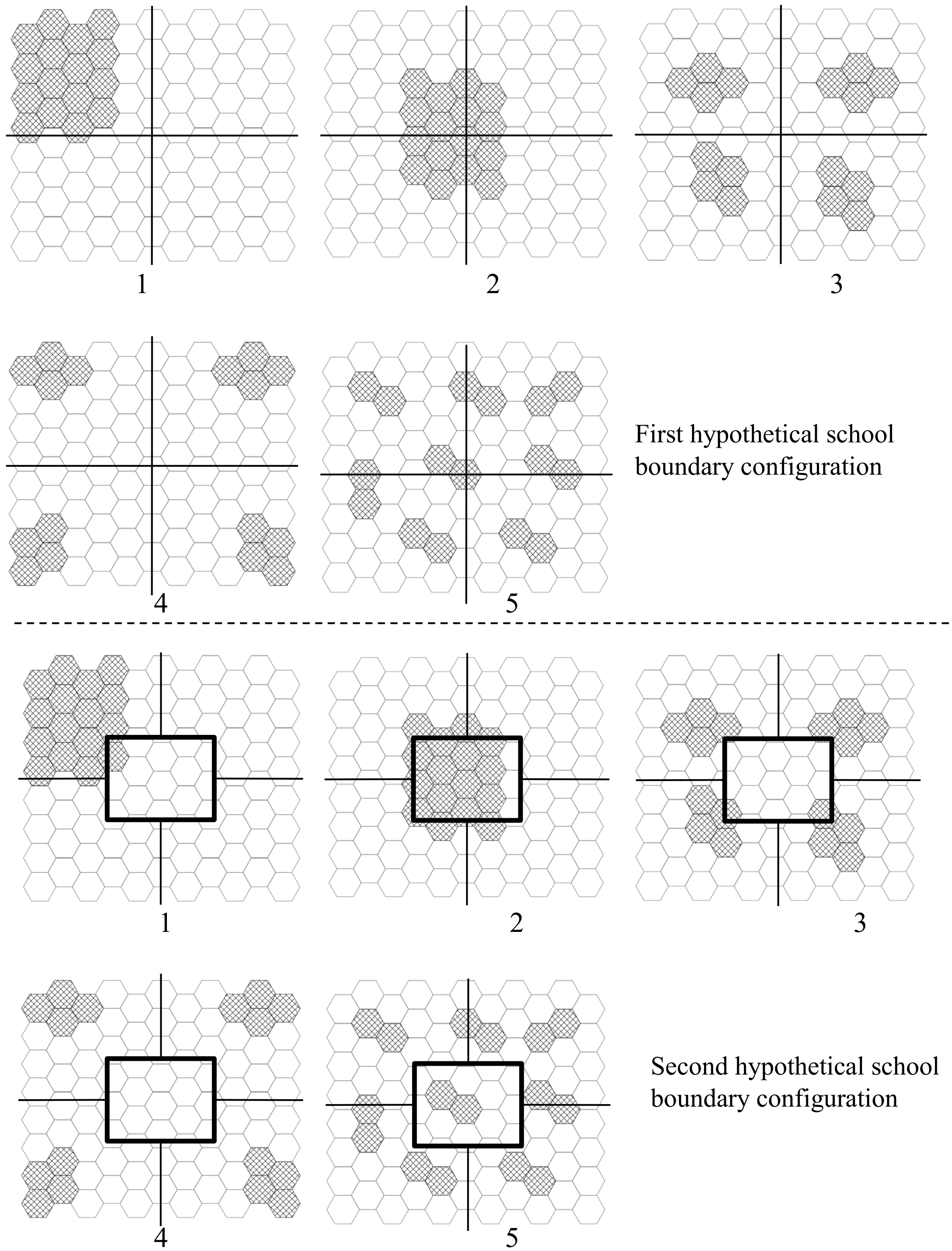

Figure 3.9. Five idealized two-group segregation patterns under two hypothetical school zone configurations—constructed by the author to test Moran's I and Getis-Ord G concurrently.

A Corollary Prediction

This study maintains that increasing the amount of school attendance zone fragmentation in a district with a diverse and clustered residential area is sufficient to increase the racial/ethnic imbalance between schools. By implication, it is expected that overall racial/ethnic composition will *not* correlate with changes in between-school segregation. In figure 3.9, all five patterns contain the same number of majority-minority units, meaning each hypothetical school district has the same overall racial/ethnic composition. Yet, when looking at the set of five segregation patterns in the second school boundary configuration, one can readily see that due to clustering and fragmentation there would be varying amounts of unevenness between the schools. Some would have minority populations spread out among multiple schools while other patterns would have one school almost exclusively attended by minority children.

Defining the Neighborhood

Every method of analyzing patterns and clusters of features examine two aspects: the difference between feature values and the spatial relationship between the features. In other words, every index of spatial autocorrelation compares the value of the target feature to the values of nearby features and does so for all features in the study region. The meaning and the statistical significance of all spatial autocorrelation indices are highly contingent on what other features within a study region are considered "nearby" each target feature, *x*. This is usually referred to as *x*'s neighborhood and considerable thought must go into how the neighborhood is operationally defined within the context of the questions being investigated. As summarized previously, there are numerous measures of spatial autocorrelation and each one captures an aspect of the spatial relationships between features and, likewise, there are a multitude of methods used to define the neighborhood, some are generally accepted and common, and others that have been more recently proposed are meant to address shortcomings of previous definitions. This has led Lloyd et al. (2014) to observe, "'Neighborhood' is a contested and problematic concept and, because of this, there are a variety of possible definitions and meanings" (p. 66). As with the choice of which spatial autocorrelation measure to use, defining the boundaries of the neighborhood depends upon the nature of the segregation problem being analyzed. Flores (2009) captures the scope of considerations when defining the neighborhood:

> [N]eighborhoods are socially and physically defined. The size and shape of areal units will vary from place to place according to the characteristics of the natural and constructed environment and the forms of local, political, economic, and social interaction…. In practice, the selection of the areal units is often arbitrary, since it depends upon the availability of data. Nonetheless, researchers should consider that areal units of different sizes might lead to different conclusions. The most appropriate size will depend on the outcome under analysis and other considerations. (p. 28-29).

A neighborhood can be defined with some distance metric, often called a "bandwidth." The choice of radius can affect the values of clustering indices that, when recognized, can offer a view of segregation operating at different scales (Hennerdal & Nielsen, 2017; Reardon et al., 2008). Fixed-distance methods may assign all features that fall within the radius equal weights, usually a one, or may apply a distance-decay function, where more distant areal units within the radius are assigned a weight value less than one, as is the case when performing geographically weighted regression (GWR) (England, 2014; Harris, Fotheringham, & Juggins, 2010).[5]

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[5] Weight values for each areal unit are stored in a spatial weights matrix. The weight matrix defines the specific neighborhood for each unit in the study region. Distant areal units not defined to be in the neighborhood are assigned a zero and neighboring units are given a value greater than zero and less than or equal to one depending upon the relative influence each is

Proximity-based measures, such as GWR, and other global and local spatial autocorrelation indices calculate each target unit's index value by multiplying the spatial weights matrix by a matrix containing the values of each areal unit for the particular attribute being investigated (e.g., median income). The resulting values are used as inputs into the spatial autocorrelation measure being used (Mitchell, 2005). Using a fixed distance to define a neighborhood is straightforward but can have some drawbacks when investigating segregation, chief among them being that varying population densities may result in neighborhoods of vastly different population sizes. One approach around this problem is to define neighborhoods based upon equal populations (Feitosa et al., 2007; Östh, Malmberg, & Andersson, 2014; Saporito, 2017a). While preferable in most cases where population densities vary widely across study regions, this method is computationally demanding even on a small scale as Lee et al. (2008) attest: "proximity functions based on population density or travel time could help build social distance into our approach, although implementation of these metrics remains daunting" (p. 785). Arguably the foremost investigators of segregation by school attendance zones, Saporito and Van Riper (2016) conceded that constructing areas of equal populations for the purpose of analysis would be time and resource prohibitive for studies at a national scale:

> Determining how much attendance zone shape contributes to racial segregation is an immensely complicated analytical issue that has bedeviled statisticians, geographers, and political scientists for decades. It is not possible to truly determine whether a school district has "maximized" racial integration or segregation across attendance zones. It is not even possible to determine if, for example, racial segregation in actual zones is greater than one

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defined to have on the target unit. The target unit itself may have a value of zero or one depending on the SA measure being used and depending upon the nature of the spatial phenomenon under investigation.

would expect by chance. This would require generating a large set of randomly drawn, equi-populous and compact zones for every school district" (p. 17).

Perhaps the simplest and most common definition of a neighborhood is adjacency—often used when areal units are contiguous polygons (Brown & Chung, 2006; Wong, 2005). Census-defined units have a high degree of continuity from the block group on up. However, for the smallest census-defined units—blocks—contiguity between residential areas is often disrupted by major roadways, waterways, and other natural and humanly constructed physical features. Since this study analyzes the effects of small fragmentation changes, the use of these smallest units is unavoidable, making a strict adjacency-based definition of neighborhood problematic. Block-level geographies of the US Census contain a substantial number of non-residential areal units that may or may not signify the presence of barriers to social interaction of school-aged children (e.g., see figure 3.10). School attendance boundaries for elementary schools are typically drawn with the intent to minimize these barriers. All too often, studies fail to recognize these features when defining neighborhoods for spatial measures. Instead, they make an assumption that Euclidean distances are all that matter, implying that the entire study region is a flat featureless plane with few if any impediments to social interactions. But impediments do exist and can be natural features, such as hills, rivers, valleys, ridges, and lakes that "establish the broad contours within which other, human-generated influences on segregation operate" (Lee et al., 2008, p. 786). These human-generated features include "the transportation grid, (2) housing policies and practices (e.g., zoning, actions of lenders and real estate agents), (3) the degree of fragmentation among school districts, municipalities, and similar jurisdictions, [and] (4) the spatial distribution of employment nodes and nonresidential land uses" (Lee et al., 2008, p. 786). These natural and humanly-constructed restraints impose limitations when one estimates school attendance zone segregation. Only one study of school attendance zone segregation has seemed to recognize these limiting factors (Saporito, 2017a): “some children who are nearest ‘as the crow flies’ may not interact since a major geographic impediment (e.g., a river) lies between them. Residential racial segregation is probably underestimated in some school districts since many local environments cross physical barriers such as rivers—and attendance zones typically do not draw children from either side of such barriers” (p. 305).

Defining a spatial autocorrelation neighborhood to include only adjacent blocks would take these natural barriers into account since the Census Bureau assigns block numbers to nonresidential features such as business areas, railroads, bodies of water, major highways and some forested land. However, not all nonresidential blocks bar easy movement between residential areas. As an example, figure 3.10 shows residential blocks shaded in gray hues separated by a nonresidential strip of white. This nonresidential strip, which is very familiar to the author, is a street paralleling a stream with a bike path in between them leading from the north and south past a small group of stores. School children from both sides of this narrow strip attend the same schools and ride together on the same trail. If only adjacent blocks were considered for clustering measures then residents on opposite sides of the strip would be considered non-interacting.

Figure 3.10. Residential blocks shaded in gray. White areas are nonresidential blocks. (SocialExplorer.com, 2019).

A measure of spatial autocorrelation using an adjacency-based definition of neighborhood would thus underestimate the degree of spatial autocorrelation in this area. Therefore, it cannot be assumed that all nonresidential census blocks inhibit children from attending the same school.

Including the blocks that pose physical barriers and excluding the others that do not is a solution suggested by Lloyd (2014) who introduced and developed the concept of a "friction surface" when deriving weights for spatial autocorrelation measurements. "Friction" is associated with the degree of effort or cost required to travel from one spatial unit to the next. This ideal approach would be quite useful for the present study but, unfortunately, would require more information about the school districts than is readily available and, moreover, would be computationally prohibitive.

Studies measuring spatial autocorrelation using census-defined units from block groups on up to the State level often define a unit's neighbor by adjacency—either having part or all of a shared border and including touching corners. For geographic units above block level this presents little problem since there are no nonresidential units above the block level. However, defining neighbors by adjacent boundaries at the block level would isolate some residential blocks from each other when otherwise they would be considered adjacent when aggregated into spatial units at a higher scale. Should nonresidential blocks be included as neighbors of residential blocks or ignored when measuring clustering? The question only matters if nonresidential blocks somehow influence school attendance boundary changes and serve to reduce social interactions between residential blocks. Some, if not all, of the more isolated blocks have reduced interactions with their nearest neighboring residential blocks, but perhaps not as reduced as a simple adjacency definition would indicate.

Figure 3.11 shows some fairly isolated residential blocks within the Bainbridge school district. Even if these blocks shared the exact same demographic makeup as their nearest neighboring residential blocks, by using a strict adjacency criterion to define neighbors they would not contribute to a global measure of spatial autocorrelation, resulting in an underestimation of the spatial autocorrelation level for the district. In response to this potential for underestimating spatial autocorrelation, the present study will expand the adjacency criterion to additionally include near, but not adjacent, blocks by applying a *k*-nearest-neighbor approach—the parameter *k* being the number of the nearest census blocks to the target block, whether they be residential or nonresidential.

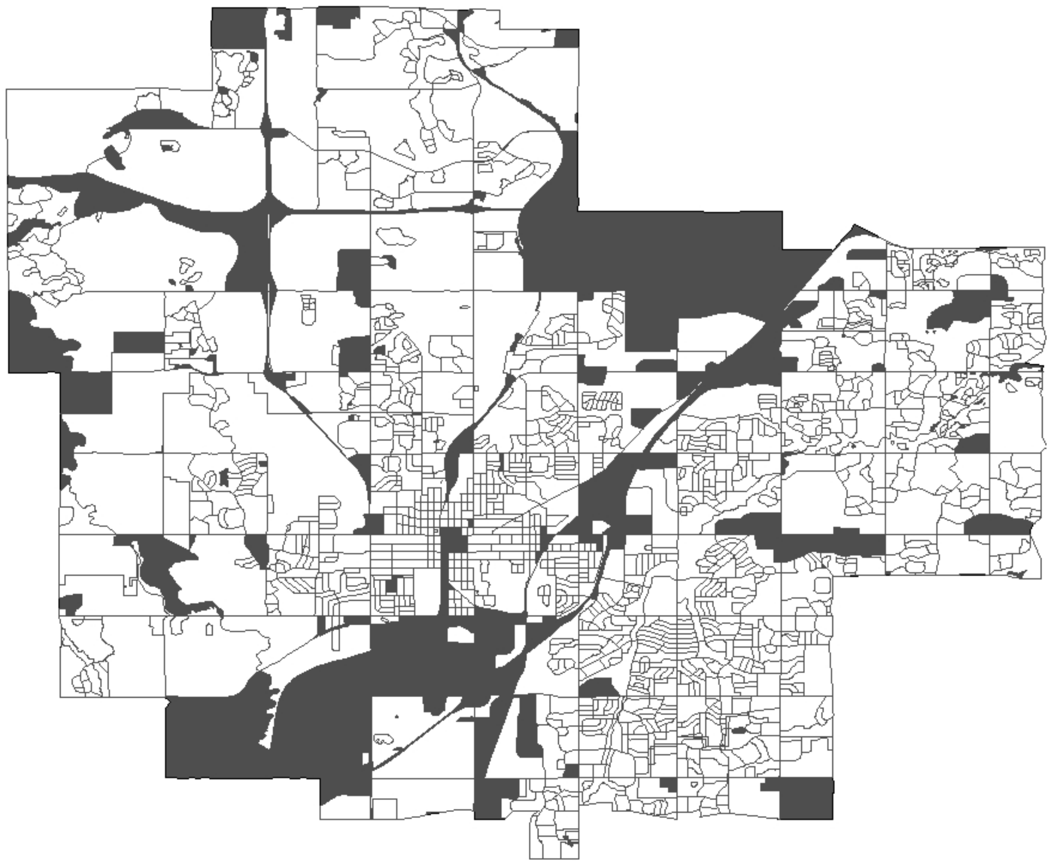

Figure 3.11. Census blocks in the Bainbridge school district. Non-residential blocks shaded in gray. Notice some residential blocks are completely isolated and others have few immediate neighbors.

The *k*-nearest-neighbor method of determining neighborhoods was used by Östh et al. (2014) and Hennerdal and Nielsen (2017) to address the disparities of scale between various areas within the study region. A critical determination to be made in this study is how many nearby blocks to include in the neighborhood definition so that consistency is maintained for all school districts across the entire nation ensuring that appropriate comparisons can be made between districts. Recognizing how crucial neighborhood size is to the measurement of spatial autocorrelation, O'Sullivan and Wong (2007) recommend that

> the optimal bandwidth should not be so small that some census units include no neighbors. On the other hand, the bandwidth size should not be too large to include too many neighbors. One possible approach to determining an appropriate bandwidth would be to use the average nearest-neighbor distance among all polygon centroids. A variety of approaches might be used, based on ensuring that some minimum numbers of neighbors are included within the kernel bandwidth applied to each centroid (p. 162).

Considering that all residential blocks, whether isolated or not, will be assigned to at least one school in every district, every block should contribute at least a portion to the measure of clustering while bearing in mind that more isolated blocks will exert less influence. The method chosen for this study is to define the neighborhood of each block as the 12 nearest blocks, whether they be residential or nonresidential, and using centroid to centroid distance to determine nearness. The rationale for defining a neighborhood in this way is based on the idealized square grid, much like a checkerboard, where every square unit has eight squares either adjacent or touching on its corners. It would be computationally challenging to select only the nearest populated blocks and, furthermore, that definition would not compensate for the degree of isolation of populated blocks bordering unpopulated ones.

The total number of census-defined blocks in the entire United States is 6,461,804, of which roughly two million are not populated. The median value of unpopulated blocks per state is 31.1% (Bureau of the Census, 1994). In the 484 school districts in the present study, 1,305,637 blocks are populated and 684,075 have zero population for an average of 34.3% unpopulated blocks per district. Given the roughly two to one ratio of populated to unpopulated blocks, it is assumed that the "typical" block would have eight populated blocks as neighbors. Spatial weights matrices defined as the nearest 12 blocks were formulated for each school district using the Generate Spatial Weights Matrix tool in ArcGIS. These matrices were inputs, along with the racial/ethnic compositions of each block—the attribute matrices—into both the High/Low Clustering (Getis-Ord General G) tool and the Spatial Autocorrelation (Global Moran's I) tool of ArcGIS, which calculated these spatial autocorrelation index scores and corresponding *z*-scores for each school district.

Predictive Models

From the national sample of 329 school districts analyzed in this study, only a portion increased the number of elementary schools within the time frame considered. Others reduced the number of elementary schools or remained unchanged, leading to three broad fragmentation categories: *growing* districts, *shrinking* districts, and *constant* districts. To reiterate, this study predicts segregation will rise when a racially/ethnically diverse school district undergoes increased fragmentation. *Changing fragmentation* is defined simply as the difference in the number of school attendance zones within a district from SY2009-10 to SY2015-16. A district was classified as *diverse* if its residential area contained more than 15% white and more than 15% non-white children. Furthermore, in order to assess changes in boundary arrangements, school districts also needed to be included in both school attendance boundary databases—the SABS SY2009-10 and the SABINS SY2015-16. Out of over 12,000 school districts contained in the SABINS SY2015-16 database, 329 met the criteria of being diverse, having open enrollment[6], administering at least five elementary schools, and were included in both databases.

The following OLS models were run separately for both growing and shrinking districts but not for districts that remained constant, since they experienced no change in overall

[6] One criterion to being labeled "open enrollment" was that a district could not have more than 10% of their elementary schools classified as charter or magnet schools.

fragmentation. The response variables—the changes in segregation as measured by Theil's entropy index, *H*—were calculated for each growing and shrinking school district for the three racial/ethnic comparison groups: white-black, white-Hispanic, and white-black-Hispanic (or *multigroup*).[7]

Additionally, global spatial autocorrelation values, indicating the levels of white and nonwhite clustering within each school district, were formulated using Moran's Index, *I*, and the Getis-Ord General index, *G*, along with the corresponding *z*-scores for each index.[8] *Z*-scores were used in the models rather than the raw index values for reasons previously stated (see discussion of table 3.6).

The regression equations took the form:

$$\Delta H_{igc} = \beta_F \Delta F_{igc} + \epsilon \qquad (1)$$

$$\frac{\Delta H_{igc}}{H_{0igc}} = \beta_F \Delta F_{igc} + \epsilon \qquad (2)$$

$$\Delta H_{igc} = \beta_F \frac{\Delta F_{igc}}{F_{0igc}} + \epsilon \qquad (3)$$

$$\frac{\Delta H_{igc}}{H_{0igc}} = \beta_F \frac{\Delta F_{igc}}{F_{0igc}} + \epsilon \qquad (4)$$

$$\Delta H_{igc} = \beta_F \Delta F_{igc} + \left(\beta_I I_{igc} + \beta_G G_{igc}\right) + \epsilon \qquad (5)$$

$$\frac{\Delta H_{igc}}{H_{0igc}} = \beta_F \Delta F_{igc} + \left(\beta_I I_{igc} + \beta_G G_{igc}\right) + \epsilon \qquad (6)$$

$$\Delta H_{igc} = \beta_F \frac{\Delta F_{igc}}{F_{0igc}} + \left(\beta_I I_{igc} + \beta_G G_{igc}\right) + \epsilon \qquad (7)$$

$$\frac{\Delta H_{igc}}{H_{0igc}} = \beta_F \frac{\Delta F_{igc}}{F_{0igc}} + \left(\beta_I I_{igc} + \beta_G G_{igc}\right) + \epsilon \qquad (8)$$

Figure 3.12. Models estimating the relationship between segregation and fragmentation

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[7] While the constant districts, by definition, have no numerical change in the number of school attendance zones, they may nevertheless exhibit differences in *H* due to shifting attendance boundaries during the time span examined. However, since by definition constant districts have zero fragmentation changes, any observed changes in segregation cannot be correlated with absent fragmentation changes.

ΔH_i is the difference in the Theil entropy index values for school district *i* between SY2009-10 and SY2015-16. H_{0i} is the Theil index in district *i* in the starting school year SY2009-10. ΔF_i is the difference in the number of school attendance zones in district *i* between SY2009-10 and SY2015-16 and F_0 is the number of school attendance zones in district *i* for SY2009-10. Subscript *g* refers to one of the three racial/ethnic group comparisons: white-black, white-Hispanic, and white-black-Hispanic (multigroup). Subscript *c* is the category school district *i* is assigned to: growing or shrinking. Change in segregation was operationalized in two ways: first, absolute change was the simple numerical difference in *H* between the two time periods, ΔH, and then by its proportional change was the ratio of absolute change in segregation to its starting value, $\frac{\Delta H}{H_0}$. Change in fragmentation was likewise operationally defined as ΔF and $\frac{\Delta F}{F_0}$.

Each of the numbered models (figure 3.12) actually represents six distinct regression equations—one for each of the two changing categories, *c*, by each racial/ethnic group comparison, *g*. Constant districts, since they had no changes in overall fragmentation, were not included in any model.

The relationships between the predictor variables of fragmentation and clustering and the response variable of segregation were estimated using OLS regression with simultaneous entry of both predictor variables. The first four OLS regressions tested the relationships between segregation changes and changing fragmentation without including clustering. Subsequently, the clustering variable was introduced into the last four models to ascertain whether any of the variance in segregation could be attributed to clustering. The two measures of spatial autocorrelation were together operationalized as the single variable of *clustering* and, as such, were entered together as a block in the models that included clustering (models 5 through 8).

Reiterating the focus of this study, only a subset of these regressions are predicted to be found positively related at the 0.05 level of statistical significance. *Proportional* increases in segregation, $\frac{\Delta H}{H_0}$, should correspond to *proportional* increases in fragmentation, $\frac{\Delta F}{F_0}$, especially when clustering, *I* and *G*, are factored in. This implies that models (4) and (8) should show the highest positive correlations in growing school districts for all three racial/ethnic group comparisons. *Absolute* changes in both fragmentation, *F*, and segregation, *H*, are not expected to correlate because of the variability in the number of elementary schools each district administers. For example, a district with 30 schools that adds two schools would likely experience relatively less disruption to its total boundary configuration than a district with five schools would experience when adding even one more school.

Predictions for Shrinking Districts

The central hypothesis in this study concerns growing districts and how the dynamics of boundary changes in these districts may affect segregation between schools. This study makes no predictions for those districts that eliminated schools during the examined time period. The expectations is that, as school districts decrease the number of elementary school they oversee, their school attendance boundaries will undergo some consolidation, thereby placing some students together in schools when previously they had been separated. The overall changes that a proportional decrease in fragmentation has on proportional segregation due to consolidation are expected to be consistent with the results seen from growing districts, namely, decreases in segregation should follow decreases in fragmentation in shrinking districts. Whether or not these differences rise to the level of statistical significance is not speculated given that the dynamics of district consolidation has not been examined in this study.As mentioned in the previous chapter, overall racial/ethnic group size is not predicted to correlate with changes in between-school segregation. To determine the validity of this prediction, two sets of Pearson correlations will be calculated for all racial/ethnic group comparisons in both growing and shrinking districts. These correlations will assess whether the proportion of blacks or whites or Hispanics in a district is related to any changes in segregation for all three comparison groups: white-black, white-Hispanic, and multigroup.

Chapter 4: Results

This chapter first outlines some of the attributes of the 329 school districts in this study, finding that there were a few more districts that reduced the number of their elementary schools than districts that remained the same size. Growing districts—the focus of this study—were the smallest, but still sizable, group. These three categories of districts were usually found together within the same metropolitan areas, with shrinking districts tending to be older and central-city districts, while growing and constant districts were more often suburban and exurban districts.

The main hypothesis of whether proportional fragmentation changes are related to increases or decreases in segregation is answered in the affirmative for African Americans, but no for Hispanics. Greater nonwhite residential clustering was hypothesized to be predictive of proportional increases in segregation. This was not the case. Over 90% of all districts were significantly clustered and, thus, the clustering variable failed to distinguish between districts. Nonwhite clustering was higher in districts having a large share of African American residents. In contrast, the proportion of Hispanic residents in a district was unrelated to nonwhite clustering. This result implies that African Americans could be more concentrated residentially in relationship to whites than Hispanics are to whites, perhaps explaining why the fragmentation effect was found for African Americans, but not for Hispanics.

Description of School Districts in the Study

The focal prediction of this study is that the simple geometric act of partitioning a school district into more and smaller school attendance zones is sufficient to increase overall segregation between schools. This hypothesis is predicated on those school districts undergoing boundary changes meeting certain criteria. In order for school attendance zones to sort students, the districts must adhere to a neighborhood schools policy, meaning there is no open enrollment allowing large numbers of students to attend other schools outside their assigned attendance catchment area. Relatedly, the district must be largely absent of magnet and charter schools drawing students from across the district. Additional restrictions limited the sample in this study to school districts administering five or more elementary schools—defined as containing at least one third grade classroom— in SY2015-16 and be racially/ethnically diverse—having no less than 15% white nor less than 15% non-white. Not all of the 329 school districts meeting these criteria added elementary schools. One hundred and nineteen school districts had no changes in their number of schools while 82 districts added at least one school and 128 decreased the number of schools they administered (table 4.1). The districts not experiencing changes in the number of elementary schools ("constant" districts) had fewer schools on average than either the "growing" or "shrinking" districts. An Analysis of Variance (ANOVA) of these means yielded a significant variation among the categories ($F(2, 327) = 19.63$, $p < .001$). A post-hoc Tukey HSD test showed that both the growing and shrinking districts administered a significantly higher number of schools than the constant districts ($p < .001$) but were not significantly different from each other.

Table 4.1

Descriptive statistics of Attendance Zones (SAZs) in all School Districts with at least five elementary schools

		SAZs in 2009-10	SAZs in 2015-16	Δ SAZs	Census blocks in district
All districts	Mean	34.25	32.92	-1.33	4225
n = 329	Maximum	516	463	10	46290
	Minimum	3	5	-58	245
Shrinking	Mean	**47.38**	42.61	-4.77	5826
n = 128	Maximum	516	463	-58	46290
	Minimum	6	5	-1	457
Constant	Mean	**18.04**	18.04	0	2393
n = 119	Maximum	64	64	0	12303
	Minimum	5	5	0	245
Growing	Mean	**37.27**	39.38	2.11	5117
n = 82	Maximum	204	210	10	38374
	Minimum	3	5	1	332

Note. For all districts, the median number of census blocks per school attendance zone was 134 in SY2015-16.

This study examines the effect that changes in fragmentation have on between-school segregation. Table 4.1, data column 3 shows fragmentation decreasing for shrinking districts on the order of almost five school attendance zones per district on average, which is a loss of slightly more than 10% of all school zones in the typical shrinking district. Many of these districts are older, central-city districts experiencing declining enrollment (figure 4.2). Many of the growing districts are adjacent to shrinking districts or in nearby surrounding areas. Growing districts grew by just over two school zones per district on average. Constant school districts were quite small compared to the other two types of districts, with less than half the number of school zones and total census blocks per district than either growing or shrinking districts. The mean number of census blocks for all school attendance zones was about 130 blocks per attendance zone for all districts and did not vary significantly between the three types of districts.

Segregation Profile for all School Districts

The projected school-aged population assigned to each school attendance zone for both target times was apportioned from the 2010 residential census block layer. This was accomplished by aggregating the school-aged population from all census blocks contained within the boundaries of each school zone (see figure 3.2). This summing process resulted in projected school populations, along with their racial/ethnic compositions, being assigned to each school zone.Using this imputed school population, which possessed demographic proportions, between-school racial/ethnic imbalance was assessed for each district using Theil's entropy index, *H* — first for the SY2009-10 attendance boundary configuration (time one) and then again for the SY2015-16 boundaries (time two). The differences in *H* between the two boundary configurations at the two times were calculated for each school district in order to measure the change in segregation due to shifting boundaries. Any differences in *H* between time one and time two were due solely to the changes in the boundaries of school attendance zones, since all projected school populations at both times were extracted from the same source residential layer, i.e. the 2010 census blocks.

Even though the number of elementary schools in some districts remained the same, that did not necessarily equate with unchanged boundaries during the intervening time period. Thus, most districts experienced changes in segregation from time one to time two due to boundary differences between the two school attendance layers from each target time. While not a central prediction of this study, it was anticipated that both growing and shrinking districts, by necessity, were likely to make the bulk of the changes to their school attendance boundaries owing to the addition or elimination of schools, and that these changes would manifest themselves in differences in measured segregation between the three district categories. Growing districts, having increased fragmentation, should see average gains in segregation. Shrinking districts should manifest decreases in segregation and constant districts should exhibit no significant change. ANOVAs were conducted on both the *starting* segregation levels (table 4.2) and on the *change* in segregation between the two target years (table 4.3).

Table 4.2

ANOVA of racial/ethnic comparisons in segregation (H) by school district category for 2009-10

Racial/ethnic comparison	District category	Mean	*F*	*p*	Tukey HSD
White-Black	Shrinking	.1329	20.667	.000	*Constant districts* significantly lower than the other two categories at p < .005
	Constant	**.0672**			
	Growing	.1101			
White-Hispanic	Shrinking	.0943	12.306	.000	*Constant districts* significantly lower than the other two categories at p < .05
	Constant	**.0577**			
	Growing	.0800			
White-Black-Hispanic	Shrinking	**.1165**	24.099	.000	All three district categories significantly different from each other at p < .01
	Constant	**.0617**			
	Growing	**.0886**			

The main takeaway from table 4.2 is that the ANOVA measuring segregation at the start of the study period in SY2009-10 for all racial/ethnic comparisons revealed higher mean values for both the growing and shrinking districts compared to the constant districts. These initial segregation levels form the baseline from which absolute changes and proportional changes in segregation will be compared. Shrinking districts are somewhat but not significantly more segregated at the start than growing districts for both white-black and white-Hispanic comparisons. This means that when comparing *changes* in segregation within growing and shrinking districts, beginning segregation levels should not substantially influence any differences found between growing and shrinking districts. The fact that constant districts are significantly less segregated than the other two types of districts is of less importance to this study since these districts evinced no fragmentation changes.

Table 4.3

ANOVA comparing changes in racial/ethnic segregation (ΔH) by school district category

Racial/ethnic comparison	District category	Mean	F	p	Tukey HSD
White-Black	Shrinking	-.00220	9.351	.000	Growing districts significantly higher than the other two categories at $p < .01$
	Constant	-.00034			
	Growing	**.00510**			
White-Hispanic	Shrinking	**-.00201**	5.755	.003	Shrinking districts significantly lower than the other two categories at $p < .05$
	Constant	-.00063			
	Growing	.00107			
White-Black-Hispanic	Shrinking	**-.00214**	10.293	.000	All three district categories significantly different from each other at $p < .05$
	Constant	**.00024**			
	Growing	**.00309**			

Looking at how segregation changed over the seven-year span (table 4.3), growing districts saw significant *increases* in white-black segregation on average while shrinking districts saw some white-Hispanic segregation *decrease*. Multigroup segregation changes were all significantly different from each other and followed the changes in the number of school attendance zones, as shrinking districts eliminated nearly five schools per district on average and growing districts gained roughly two schools per district (table 4.1). It is important to keep in mind that all changes in segregation are due to altered boundaries since projected school populations for both target times were derived from the same residential layer—the 2010 block-level census data. As predicted, segregation in shrinking districts declined and growing districts saw increases in segregation. This result supports the notion that as shrinking districts reduced the number of attendance zones, their zones on average became larger and more racially/ethnically heterogeneous than before. The obverse pattern for growing districts is also confirmed, namely as growing districts added attendance zones, their average size decreased making these attendance zones more racially/ethnically homogeneous (see Lee et al., 2008, p. 770). Constant districts, as expected, showed little change with no general trend toward increases or decreases.

Spatial Patterns

The school districts meeting the criteria for this study were located nationwide in 39 states and were almost exclusively concentrated in major metropolitan areas. There is no discernable national pattern when looking at the locations of school districts from each of the three categories just discussed (figure 4.1). School districts in this study were fairly evenly split among three broad regions of the country. Western districts (from Colorado and New Mexico westward) numbered 162 districts and contained 4515 school attendance zones in SY2009-10. In the south (North Carolina across to Oklahoma southward) 5114 school zones were contained in 145 districts and in the northern states, 177 districts with 3940 school zones met the study criteria. While the north region of the country as a whole has the most school districts compared to the other regions, a good many of the larger districts in the SABINS database administered multiple public charter and magnet schools, making them ineligible for analysis.

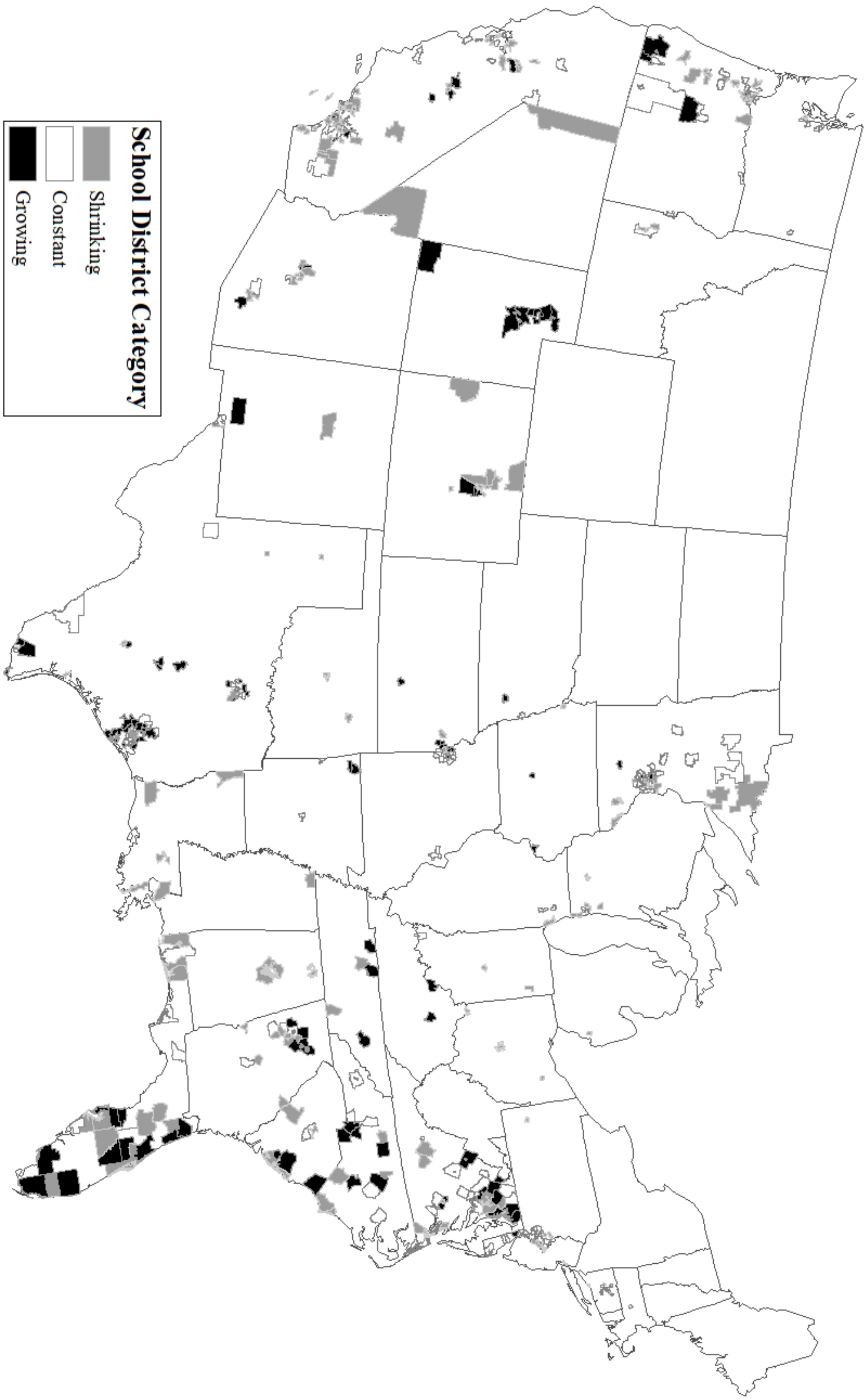

Figure 4.1. Locations of school districts in study shaded by category: growing, shrinking or constant.

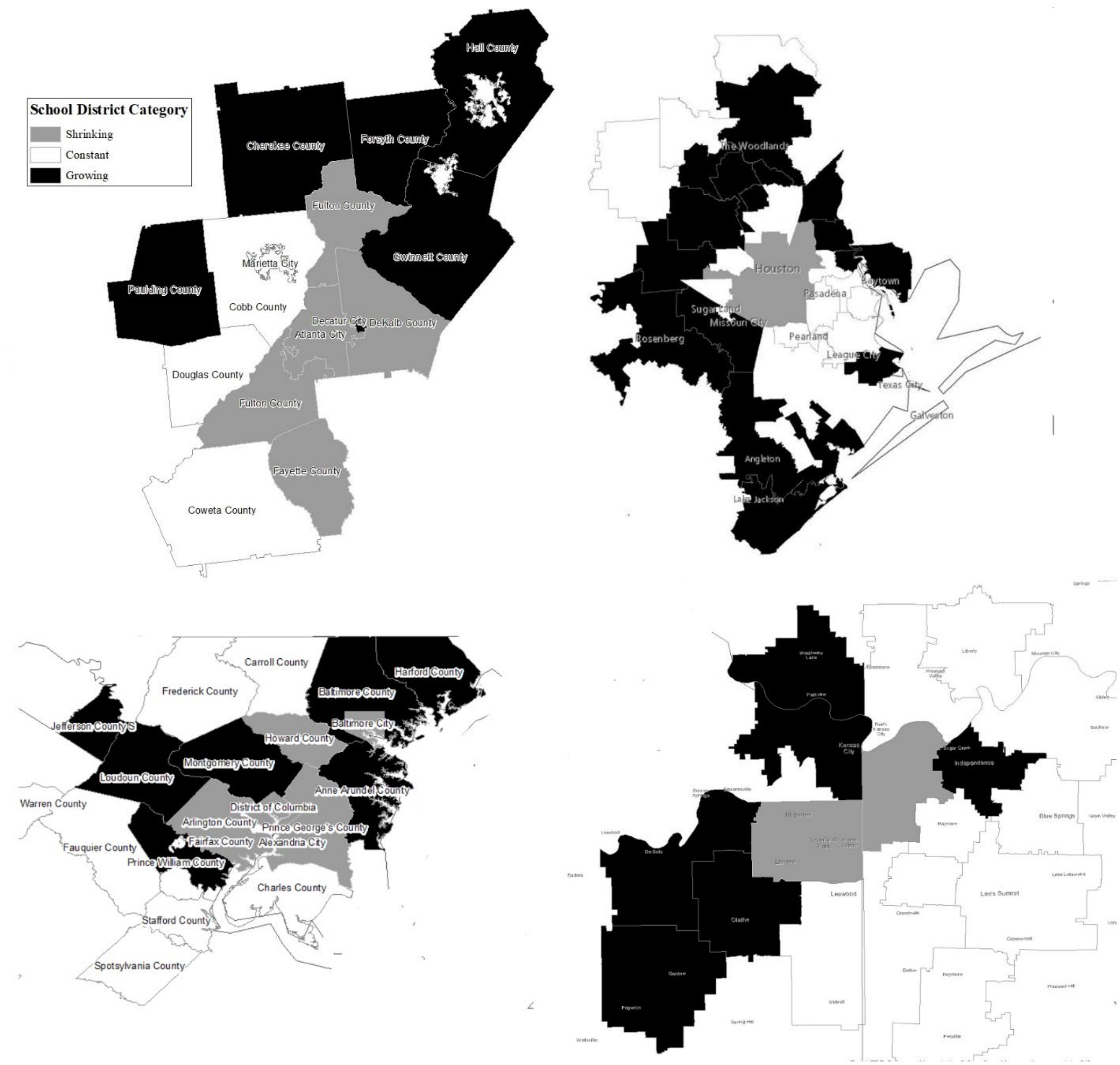

Figure 4.2. School districts growing, shrinking, or remaining constant in four metro areas: Atlanta, Houston, District of Columbia/Baltimore, and Kansas City. The districts shaded gray are older central-city districts that reduced the number of schools between SY2009-10 and SY2015-16. Districts shaded black adjoining and surrounding the central-city districts are newer suburban districts that added more schools due to increased enrollment. The districts shaded white maintained the same number of schools in that time period.

While no recognizable national patterns are apparent, when examined at the metropolitan level, some commonalities seemed to be evident. Figure 4.2 shows four metropolitan areas, each with older and mostly central-city districts losing elementary schools, while nearby newer suburban districts have either added new schools or remained stable over the seven-year timespan. These spatial configurations seemed less prevalent in the West, most notably around Los Angeles and San Francisco.

Test of Predictive Models

Does the partitioning process alone, occurring when new schools are added to growing districts, contribute meaningfully to increased segregation? If so, then as fragmentation rises so should increases in imputed segregation. This is the central question of this present study and four OLS models were used to test this hypothesis comparing both *absolute* and *proportional* changes in fragmentation (ΔF) to segregation (ΔH) for all three racial/ethnic comparison groups. H is calculated for each district by taking the projected school-aged population of every school attendance zone, imputed from the US census block-level data, and calculating the racial/ethnic imbalance between all zones within that district. The change in fragmentation, ΔF, is simply defined as the difference in the number of school attendance zones between SY2009-10 and SY2015-216.

$$\Delta H_{igc} = \beta_F \Delta F_{igc} + \epsilon \quad (1)$$

$$\frac{\Delta H_{igc}}{H_{0igc}} = \beta_F \Delta F_{igc} + \epsilon \quad (2)$$

$$\Delta H_{igc} = \beta_F \frac{\Delta F_{igc}}{F_{0igc}} + \epsilon \quad (3)$$

$$\frac{\Delta H_{igc}}{H_{0igc}} = \beta_F \frac{\Delta F_{igc}}{F_{0igc}} + \epsilon \quad (4)$$

Figure 4.3. Regression models 1 through 4. Model 4 contains the main hypothesis of this study: that proportional change in segregation is predicted by proportional changes in fragmentation. This relationship is not an artifact of absolute changes in either fragmentation or segregation, thus models 1 through 3 should not show significant relationships.

ΔH_i is the difference in the Theil entropy index values, *H,* for school district *i* between SY2009-10 and SY2015-16. A separate regression is run for each of the three racial/ethnic comparison groups, *g,* (white-black, white-Hispanic, and white-black-Hispanic or "multigroup") within both growing and shrinking districts, *c,* thus resulting in six separate regressions for each model. H_{0i} is the value of the Theil index in district *i* in the starting school year SY2009-10. ΔF_i is the difference in the number of school attendance zones in district *i* between SY2009-10 and SY2015-16 and F_{0i} is the number of school attendance zones in district *i* for SY2009-10. Absolute change, ΔH, was the simple numerical difference in *H* between the two target years. Proportional change, $\frac{\Delta H}{H_0}$, was the ratio of absolute change in segregation to the level of segregation at the start, H_0 , in SY2009-10. Change in fragmentation was likewise operationally defined as absolute change in fragmentation ΔF and $\frac{\Delta F}{F_0}$.

Each of the numbered models (figure 3.12) actually represents six distinct regression equations—one for each of the two changing categories, *c*, by each racial/ethnic group comparison, *g*. Constant districts, since they had no changes in overall fragmentation, were not included in any model.

Model 4 tests the primary hypothesis in this study, namely that when the fragmentation by school attendance zones increases by a given percentage, then between-school segregation also increases proportionately. As an example, if a school district with 20 elementary schools in SY2009-10 added two new schools, then fragmentation would increase by 10%. This implies that the average school attendance zone is 10% smaller than previously. The smaller units will draw from more homogeneous residential areas compared to the previously larger school attendance zones, especially if the residential areas are concentrated by race and ethnicity (i.e. clustered). If this is the case then it is predicted that segregation, as measured by Theil's *H*, will increase proportionately since attendance zones will be less internally diverse due to their reduced average size.

The other models are calculated to eliminate the possibility that the proportional change in segregation due to proportional change in fragmentation is merely an artifact of *absolute* changes in either variable. Model 1 regresses absolute change in segregation on absolute change in fragmentation. Models 2 and 3 test one absolute change with one proportional change. Again, Model 4 tests the central prediction of this study: that proportional changes in fragmentation alone raises relative levels of segregation. Considering that school districts varied widely in the number of elementary schools they had, none of the first three models, containing absolute change in either fragmentation or segregation, were predicted to yield significant results for any of the racial/ethnic group comparisons. Of the three categories of school districts, the two undergoing changes to fragmentation were labeled "shrinking" and "growing" districts and, accordingly, regressions were computed separately within each of these two categories.

Segregation is less likely when a district has low numbers of minority students. Accordingly, a certain level of racial/ethnic diversity was an important criterion for inclusion in the sample for each model. For this reason, only shrinking and growing districts having residential compositions between 15% and 85% non-white (the "middle 70%") were included in the regression equations.[9] While this study makes no theoretical conjectures regarding the effect of *decreased* fragmentation upon changes in segregation in the shrinking districts, the results from the regressions for these districts were expected to be consistent with the outcomes from the growing districts analysis. That is, if proportional *increases* in fragmentation leads to greater relative racial imbalance, then proportional *decreases* in fragmentation should result in proportionately lower levels of racial imbalance.

Table 4.4 shows the results of all four regression models for each set of racial/ethnic comparisons for *shrinking* districts. Results from models 1 and 2 are on the first row and models 3 and 4 on the bottom row.

From these results it appears that, as predicted, decreases in *absolute* fragmentation are unrelated to changes in either absolute or proportional changes in segregation. Model 1 in the top left regresses absolute change in fragmentation, ΔF, on the absolute change in segregation, ΔH. There are no significant relationships between either variable, which is also true for Model 2—absolute change in fragmentation does not predict proportional change in segregation, as expected. This is because adding a single new attendance zone in a larger district would have

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[9] Sets of regression models were conducted on the entire sample of both growing and shrinking districts regardless of diversity level and those results are included Appendix B.

less effect on overall attendance zone configurations than it would in a smaller one, where adding a new attendance zone may alter every other attendance zone's catchment area.

Model 3 showed that decreases in proportional fragmentation are slightly associated with decreases in absolute segregation for the white-black and the multigroup comparisons, counter to the predictions made. However, looking at the accompanying beta coefficients reveals that those changes are slight. For instance, Model 3 predicts that it would require about a 20% change in fragmentation to raise absolute white-black segregation by one percent and multigroup segregation by one-half percent.

Model 4, in the lower-right set of regressions, compares proportional fragmentation to proportional segregation, it shows a statistically significant relation between relative fragmentation decreases and reductions in proportional segregation for the white-black comparison only, but not for white-Hispanic or multigroup comparisons. This result indicates that when districts consolidate attendance zones, the average size of all zones increases. The new catchment areas are relatively more racially diverse on average than the previously smaller catchment areas. This serves to reduce the between-school racial imbalance, although this decrease in proportional segregation is small, as the amount of explained variance due to the proportional fragmentation change, as indicated by the adjusted-R^2values, is just around five percent.

Table 4.4

*Association between changes in segregation and changes in fragmentation—**Shrinking diverse school districts** (middle 70%)*

df (1, 127)	Change in segregation (ΔH)				Change in *proportional* segregation ($\Delta H/H_0$)			
	Racial/ethnic comparison group	adj. R^2	*p*	b	Racial/ethnic comparison group	adj. R^2	*p*	b
			Model 1				**Model 2**	
Change in fragmentation	White-Black	.018	.068	.000	White-Black	-.001	.912	.002
	White-Hispanic	-.001	.360	.000	White-Hispanic	-.007	.681	.001
	White-Black-Hispanic	.013	.106	.000	White-Black-Hispanic	-.004	.458	.002
			Model 3				**Model 4**	
Change in *proportional* fragmentation	White-Black	.119	**.000****	**.055**	White-Black	**.054**	**.005****	.410
	White-Hispanic	.012	.113	.018	White-Hispanic	-.003	.453	-.155
	White-Black-Hispanic	.042	**.012***	**.025**	White-Black-Hispanic	-.008	.831	.035

Note. * indicates statistical significance at the $p < .05$ level. ** indicates statistical significance at the $p < .01$ level.

Does Greater Fragmentation Increase Segregation?

Table 4.5 summarizes the test of the principle hypothesis of this current study (Model 4), namely, as growing diverse school districts add new schools, proportional increases in fragmentation correspond with proportional increases in segregation.

Just as it was for shrinking districts, *absolute* changes in fragmentation for growing diverse school districts are not significantly correlated with either *absolute* changes in segregation nor *relative* changes in segregation for any of the racial/ethnic comparison groups. This can be deduced by looking at the non-significant *p*-values for models 1 and 2 on the top rows of table 4.5. Again, this is as expected since adding a single school to a district that already has a large number of schools would not be as disruptive to the overall school-attendance-boundary configuration as would adding a single school to a much smaller district, which would likely see some boundary changes to most, if not all, of its school zones. In the latter case, shifting boundaries could move proportionately more children into different schools than they had previously attended, but in larger districts adding one new school would leave most children in their present schools.

For this reason, *proportional* changes in fragmentation, i.e. the number of additional schools divided by the number of extant schools in SY2009-10, are predicted to be more influential on changes in segregation—somewhat for *absolute* changes in segregation, but particularly for *proportional* segregation changes. These predictions are substantiated from the results of Models 3 and 4 in the bottom half of table 4.5 for white-black and multigroup comparisons, but not for white-Hispanic segregation. The significant correlations of the Model 3 regressions in the bottom left of table 4.5 indicate that proportional changes in fragmentation are associated with small changes in absolute segregation for African Americans particularly, but not for

Hispanics alone. However, the effect of this association is small. For example, interpreting the beta coefficients for Model 3 white-black segregation, a 10% increase in fragmentation, such as a district with ten schools adding one more school, would only produce an absolute increase in *H* of roughly 0.006, or only about 10% of what Reardon & Yun (2001) consider a meaningful increase in *H*.

Model 4 results (lower right set of regressions in table 4.5) indicate with very high probability that proportional white-black segregation will increase as relative fragmentation rises, as also does proportional multigroup segregation. This can be inferred from the adjusted-R^2 values of model 4. Almost 38% of the variance in proportional white-black segregation change can be explained by increases in proportional fragmentation. This is also true to a slightly lesser extent for white-black-Hispanic proportional segregation increases (~37%). The magnitude of this increase can be estimated by looking at the beta coefficients in the last column of model 4. This study also predicted a similar response of white-Hispanic proportional segregation to fragmentation increases, but instead the results suggest no linkage.

Since model 4 regresses percentage change in segregation ($\Delta H/H_0$) on the percentage change in fragmentation ($\Delta F/F_0$), b would indicate by what percentage *H* would increase for every one percent increase in fragmentation, *F*. The unstandardized coefficient in model 4 for the white-black comparison (b = 1.695) indicates that a 10% increase in fragmentation (roughly the mean for growing districts) would result in white-black segregation rising on average by 17%. Similarly, multigroup segregation would increase by about 16% in response to a 10% increase in fragmentation (b = 1.598). That similar effects were not observed for the white-Hispanic comparison implies that the spatial arrangement of Hispanic and white residents is much different at this scale than whites compared to African Americans.

Table 4.5

*Association between changes in segregation and changes in fragmentation—**Growing diverse school districts** (middle 70%)*

df (1, 81)	Change in segregation (ΔH)				Change in *proportional* segregation ($\Delta H/H_0$)			
	Racial/ethnic comparison group	adj. R^2	*p*	b	Racial/ethnic comparison group	adj. R^2	*p*	b
			Model 1				**Model 2**	
Change in fragmentation	White-Black	-.012	.929	.000	White-Black	-.012	.906	-.002
	White-Hispanic	-.007	.500	.000	White-Hispanic	-.007	.528	.003
	White-Black-Hispanic	-.012	.984	.000	White-Black-Hispanic	-.012	.867	-.003
			Model 3				**Model 4**	
Change in *proportional* fragmentation	White-Black	.085	.005*	.059	White-Black	**.378**	**.000****	**1.695**
	White-Hispanic	-.006	.458	-.004	White-Hispanic	-.005	.455	.061
	White-Black-Hispanic	.101	.002*	.026	White-Black-Hispanic	**.368**	**.000****	**1.598**

Note. * indicates statistical significance at the $p < .05$ level. ** indicates statistical significance at the $p < .01$ level.

The Role of Clustering

An additional prediction of this study is that increased fragmentation will differentially affect between-school segregation depending, not only on the amount of residential separation of racial/ethnic groups, but also on the particular arrangements of spatial units primarily occupied by each group. This study anticipated that in districts where racial/ethnic groups are more clustered, the level of segregation would intensify over and above the increases in segregation due to greater fragmentation alone. Changes in segregation will not occur if new attendance areas are cut from a residential region where racial/ethnic groups are evenly dispersed across the region. However, if a region contains many small but racially/ethnically concentrated residential neighborhoods, i.e. high clustering, then the subdividing process is more likely to separate children of different racial/ethnic groups from each other.

Clustering was measured with two indices of spatial autocorrelation, Getis-Ord G and Moran's I, on the proportion of nonwhite residents in the 2010 block level census layer. Spatial autocorrelation looks at the degree to which one feature is similar to other nearby features. If nearby features are more alike than distant features then spatial autocorrelation is positive. Otherwise, if nearby features are less like each other compared to distant features then spatial autocorrelation is negative. The percentage of nonwhite school-aged residents in each census block was the attribute of interest used by both indices of spatial autocorrelation for comparisons with the other features within a school district.

Models 5 through 8 duplicated models 1 through 4 in every way except that an additional variable was added to each model. Specifically, the additional predictor variable was the amount of nonwhite residential clustering present in a school district, as measured by the indices of spatial autocorrelation—Getis-Ord G and Moran's I. The *G* statistic is a relative rather than an absolute measure, meaning that the statistical significance of a *G* value is not known unless it is compared to the expected *G* value for a random distribution across a school district. For this reason, *G* values, as well as Moran's *I* values, can be converted to *z*-scores enabling their use for either significance testing or for comparing the relative magnitude of clustering between districts, as is the case in models 5 through 8. A low and non-significant *z*-score for either *I* or *G* would indicate in this study that whites and nonwhites were distributed randomly throughout a school district. A statistically significant *z*-score for *G* would indicate that either whites or nonwhites are clustered but it does not indicate which group is most clustered. A significant and positive *z*-score for Moran's *I* indicates nonwhites are closer to each other than they are to whites but may not show cluster patterns. If both $z(G)$ and $z(I)$ are positive and significant then the district has a nonrandom amount of nonwhite clustering (see figure 4.5 for the distribution of *z*-scores in this study).

Each of these models was an OLS regression using simultaneous entry of a fragmentation variable and the spatial autocorrelation variable entered as a block.

$$\Delta H_{igc} = \beta_F \Delta F_{igc} + \left(\beta_I I_{igc} + \beta_G G_{igc}\right) + \epsilon \quad (5)$$

$$\frac{\Delta H_{igc}}{H_{0igc}} = \beta_F \frac{\Delta F_{igc}}{F_{0igc}} + \left(\beta_I I_{igc} + \beta_G G_{igc}\right) + \epsilon \quad (6)$$

$$\Delta H_{igc} = \beta_F \frac{\Delta F_{igc}}{F_{0igc}} + \left(\beta_I I_{igc} + \beta_G G_{igc}\right) + \epsilon \quad (7)$$

$$\frac{\Delta H_{igc}}{H_{0igc}} = \beta_F \Delta F_{igc} + \left(\beta_I I_{igc} + \beta_G G_{igc}\right) + \epsilon \quad (8)$$

Figure 4.4. Regression models 5 through 8. These duplicate the regression models 1 through 4 (figure 4.3) with the addition of clustering as a predictor variable—the sum of Getis-Ord G and Moran's I in parentheses.

The districts exhibiting higher clustering, as evidenced by both higher *z*(I) and *z*(G) scores, were predicted to be more sensitive to the effects of fragmentation since small changes to school attendance boundaries could more easily separate minority children from majority children if the minority children were more tightly grouped. This prediction assumed that the districts in the study would exhibit a wide range of clustering patterns, with a good number of the districts having high *z*(I) but low *z*(G) and others showing the reverse. However, *z*(I) and *z*(G) scores showed high collinearity ($r = .961$, $p < .001$) making their dual entry into the last four models redundant (figure 4.5).

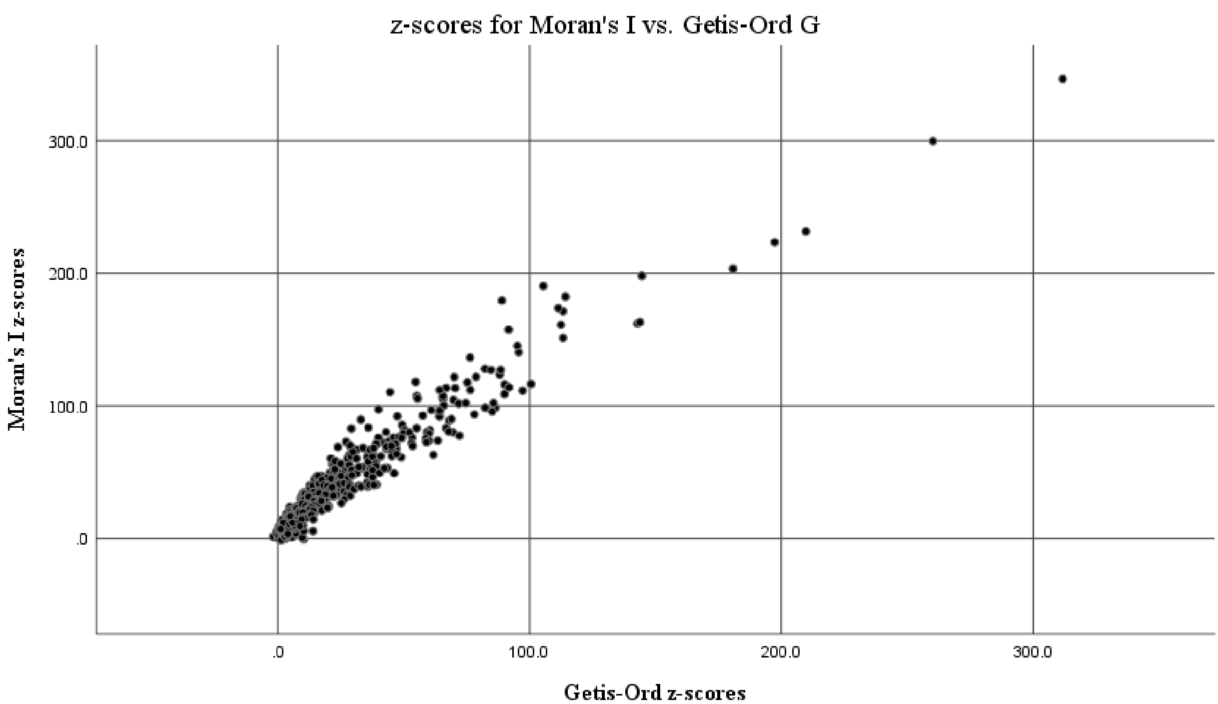

Figure 4.5. Collinearity of spatial autocorrelation indices.

The inclusion of clustering as a contributing factor to the effects of greater fragmentation assumed wide variance in clustering between districts, with a fair number of districts being significantly clustered and many others not significantly clustered. This was not the case. Even though there was variance in clustering among districts, most districts contained such a high degree of clustering that almost all *z*-scores for both indices were statistically significant at the .05 level: 93% for Getis-Ord G and 91% for Moran's I. The fact that most districts surpassed this threshold level of clustering, i.e. having a statistically significant *z*-score for both *G* and *I*, became evident when models 5 through 8 were estimated. When those models containing fragmentation *plus* clustering were computed—models 5 through 8— the results nearly duplicated the results of models 1 through 4, which were identical except they did not include clustering (see tables 4.4 and 4.5). Nearly all adjusted-R^2 values decreased due to the fact that the additional clustering variables contributed little if any to the explanatory ability of models 1 through 4 above what fragmentation alone predicted (tables B5 and B6 in appendix B).

A further analysis assessed the association of the clustering variables alone, i.e. *z*(I) and *z*(G), with changes in segregation, ΔH and $\Delta H/H_0$, and showed no significant relationships for any racial/ethnic comparison groups in any of the district categories (tables B3 and B4 in appendix B). The fact that the level of nonwhite clustering failed to predict segregation changes, either by itself or included with fragmentation as in the latter models, points to the single factor of fragmentation as the only "culprit" in this study responsible for the observed gains in racial/ethnic imbalance between schools.

This is not to say that clustering and segregation were unrelated, only that the *changes* in apportioned school segregation did not correspond to different levels of clustering in the residential layer. Since the projected composition of each school attendance zone was extracted directly from the block-level residential census layer, the racial/ethnic imbalance (Theil's *H*) between school zones should follow the racial/ethnic clustering ($z(G)$ and $z(I)$) in residential areas. This relationship makes theoretical sense since, according to (Reardon & O'Sullivan, 2004), clustering and evenness represent two poles of a single dimension of segregation. In order to show this connection between residential clustering and school zone segregation, an OLS model regressing school segregation on residential clustering was calculated: $H_{igc} = \beta_G z(G)_{igc} + \epsilon$, where school segregation, *H,* in each district, i, was regressed on the amount of nonwhite residential clustering present in the district, $z(G)_i$. A separate regression was computed for each racial/ethnic comparison group, g, in all of the district categories, *c*. The results of this regression summarized in table 4.6 further support what has been established in many studies, namely that school segregation—in this case within-district segregation—follows residential segregation. All *p*-values are less than 0.001 indicating that when residential clustering is high then schools drawing their populations from local neighborhoods will be correspondingly segregated to a similar degree.

Table 4.6

Evenness, (H), across schools vs. clustering, z(G), of residential census blocks

District category, *c*	Racial group comparison, *g*	r	*p*
All districts	White-Black	.773	.000
n = 329	White-Hispanic	.626	.000
	White-Black-Hispanic	.788	.000
Shrinking	White-Black	.797	.000
n = 128	White-Hispanic	.704	.000
	White-Black-Hispanic	.797	.000
Constant	White-Black	.675	.000
n = 119	White-Hispanic	.630	.000
	White-Black-Hispanic	.756	.000
Growing	White-Black	.671	.000
n = 82	White-Hispanic	.387	.000
	White-Black-Hispanic	.704	.000

Note. Evenness was defined as Theil's *H* in SY2015-16 for each school district. Clustering was defined as the Getis-Ord G *z*-score for the block level 2010 residential census layer.

Racial/Ethnic Proportions Related to Clustering

An interesting observation from looking at the adjusted R-squared values in table 4.6 is that, within all district categories, the amount of explained variance in segregation, *H,* due to clustering, *z(G)*, is lowest for the white-Hispanic comparison, especially in growing districts.

This suggests that nonwhite residential clustering is more of a phenomenon of African Americans than Hispanic residents. Are communities with higher proportions of African American children more racially/ethnically clustered than communities with high relative numbers of Hispanic children? To try to answer this question, an OLS analysis was conducted regressing residential clustering, *z*(*G*), on the proportion of both racial/ethnic groups (table 4.7).

Table 4.7

Association between residential nonwhite clustering and overall residential racial/ethnic composition in school district communities by district category[10]

	Racial/ethnic group	r	*p*
Shrinking	Black	.419	.000
n = 128	Hispanic	.111	**.212**
Constant	Black	.381	.000
n = 119	Hispanic	.106	**.250**
Growing	Black	.332	.002
n = 82	Hispanic	.060	**.589**

Note. Clustering was defined as the Getis-Ord G *z*-score for the block level 2010 residential census layer

The results indicate a lack of significant residential clustering between whites and Hispanics, meaning that higher proportions of Hispanic children in a district is not associated with greater nonwhite clustering (see bold, non-significant *p*-values in the last column of table 4.7).

[10] This same relationship between residential nonwhite clustering and proportion of both racial/ethnic groups could also have been estimated in a multivariate linear model with *racial/ethnic group* and *district category* as predictors of *residential nonwhite clustering*. At the $p < .001$ level, proportion of the Black population predicted 73.3% of the variance, while Hispanic group size only explained and additional 4.1% of the variance in residential clustering.

However, in all categories of school districts—growing, shrinking, and constant—when the relative number of African American children is high, there is a correspondingly greater level of racial/ethnic clustering, implying that in the school districts with more African American children, residential neighborhoods are less racially heterogeneous. On the other hand, districts with larger Hispanic populations are not characterized by residential clustering to the same degree.

Visualizing the nexus between clustering, racial proportions, and school segregation. As an aide in illustrating the spatial relationships between clustering, racial/ethnic composition, and levels of school segregation, consider the maps in figure 4.6. In the Baltimore/DC area depicted, there appears to be a relationship, albeit a weak one, between clustering (map 2) and whether or not a district is adding or eliminating elementary schools (map 1), as was previously noted. If one compares the degree of clustering to racial/ethnic proportions, there appears to be closer similarity between clustering (map 2) and the relative number of African American children (map 3) than with the degree of clustering compared to the proportion of Hispanic children (map 4)—indicative of the results in table 4.7. Comparing school level segregation between whites and African Americans (map 5) and between Hispanics and whites (map 6), the visual contrast between these two maps is not as severe as between their respective racial/ethnic proportions (maps 3 and 4). Furthermore, these school segregation maps (5 and 6) are generally similar to residential clustering patterns seen in map 2, with white-black segregation a bit closer in appearance to the clustering map (2) than white-Hispanic segregation (map 6)—a difference born out in the adjusted R^2 values in table 4.6 (see bold values in table).

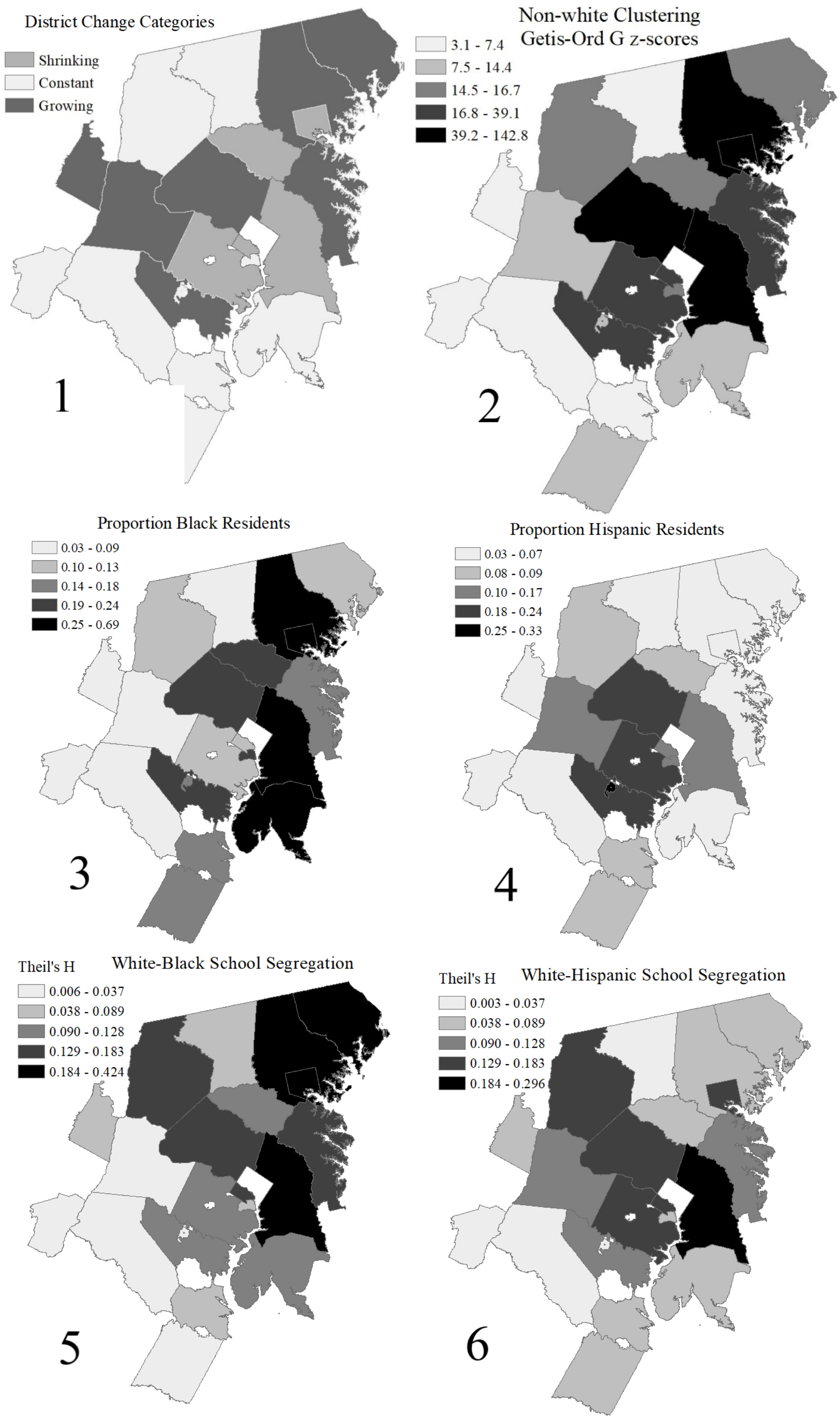

Figure 4.6. Racial/ethnic group comparisons for school districts in the Baltimore-DC area

Do Racial and Ethnic Proportions Matter?

Looking one last time at the six maps in figure 4.6, there is one additional variable correspondence needing to be assessed, if for no other purpose than to eliminate any potential connection. Could it be that overall racial/ethnic residential compositions influence changes in segregation independent of the spatial arrangement of the racial/ethnic groups? In other words, could one predict the changes in school segregation found in this study simply by measuring the size of the racial or ethnic group within a district? Does white-black proportions predict white-black segregation and does white-Hispanic proportions predict white-Hispanic segregation? This question can be visualized by comparing map 3 to map 5 and map 4 to map 6 and asking how closely does each map on the second row match the map directly below it. In other words, do overall racial/ethnic proportions predict changes in school segregation? Do districts with more black and Hispanic children experience greater segregative effects from changing fragmentation without needing to consider their spatial arrangements? A major argument of this study is that the *spatial concentration* of the various racial/ethnic groups is a precondition for differential sorting when school boundary lines are redrawn. Therefore, the aspatial variable of overall racial/ethnic composition of a district should have little to no effect on changing segregation. To test this, Pearson correlations were calculated between racial/ethnic proportions and changes in imputed school segregation in growing school districts (table 4.8) and in shrinking districts (table 4.9). There is only one slightly significant correlation at the .05 level in table 4.8—white-black segregation change with non-white percentage—indicating no substantial correspondence between the size of the racial/ethnic population and the degree of segregation change.

Table 4.8

Pearson correlations of residential racial/ethnic proportions and changes in imputed school segregation—Growing districts (n = 82)

School segregation	Residential racial/ethnic composition		
Change (ΔH) in	Non-white proportion	Black proportion	Hispanic proportion
White-Black	**.224**[*]	.159	.129
significance	*.043*	*.155*	*.249*
White-Hispanic	-.032	-.105	.037
significance	*.772*	*.348*	*.743*
White-Black-Hispanic	.152	.211	.018
significance	*.172*	*.057*	*.875*
Proportional change ($\Delta H/H_0$) in			
White-Black	-.003	.049	-.037
significance	*.976*	*.662*	*.744*
White-Hispanic	-.018	-.079	.035
significance	*.872*	*.479*	*.758*
White-Black-Hispanic	-.020	.083	-.077
significance	*.858*	*.460*	*.491*

Note. *significant at $p < .05$.

Table 4.9

Pearson correlations of residential racial/ethnic proportions and changes in imputed school segregation—Shrinking districts (n = 128)

School segregation	Residential racial/ethnic composition		
Change (ΔH) in	Non-white proportion	Black proportion	Hispanic proportion
White-Black	.021	-.092	.117
significance	*.813*	*.300*	*.188*
White-Hispanic	-.106	-.124	.019
significance	*.234*	*.162*	*.831*
White-Black-Hispanic	-.046	-.165	.123
significance	*.605*	*.062*	*.166*
Proportional change ($\Delta H/H_0$) in			
White-Black	.070	.012	.060
significance	*.433*	*.896*	*.500*
White-Hispanic	-.059	-.096	.037
significance	*.505*	*.283*	*.676*
White-Black-Hispanic	-.024	-.091	.069
significance	*.788*	*.309*	*.441*

Summary of Findings

This study asked the question: can the simple act of subdividing a school district into more and smaller school attendance zones increase racial/ethnic segregation among the district's schools? Eighty-two school districts were identified that met the criteria needed to answer this question. These schools were contained in both school attendance boundary databases—SABS and SABIN—collected at a six-year interval—SY2009-10 to SY2015-16—in which time each added at least one elementary school. Each district was large enough to administer at least five elementary schools and served a community that was racially and ethnically diverse. After school-aged children were assigned to school zones in both sets of boundary data based upon their residential location obtained from block-level census data, racial/ethnic segregation between schools was computed for both school years and differences in segregation between the school years were calculated. Since the same residential census layer served as the source data for projected school populations for each set of school attendance zones, all differences in school segregation between SY2009-10 and SY2015-16 are due solely to alterations in the attendance boundary configurations between the two times.

The main hypothesis of this study—that increased fragmentation alone increases segregation—held for white-black segregation but not for white-Hispanic segregation. As the number of school attendance zones within a district increased so did white-black imbalance between school zones. In growing, diverse school districts, proportional increases in fragmentation resulted in proportional increases in white-black segregation. The relationship was strong, both in the highly significant *p*-value and in the large effect size[11]. For every 10% increase in the number of school zones there was an estimated average increase in black-white segregation of 17% (see model 4 in table 4.5).

[11] In table 4.5 model 4, for black-white comparison, Pearson's r = .621. For a bivariate regression, (Cohen, 1988, p. 80) considers r >= .50 as a large effect size.

In order to grasp why white-black segregation increased to such a great extent while white-Hispanic segregation was unresponsive to increased fragmentation, it is necessary to understand how the geometric process of changing fragmentation acts upon a spatially uneven landscape. Fragmentation, as defined in this study, is the number of spatial units (school attendance zones) subdividing a region (a school district). Increasing fragmentation, i.e. adding more school attendance zones, shifts boundaries and draws new lines that separate children, who were once classmates, into different schools. By geometric necessity, adding more school zones requires that the average size of the zones to decrease. At this point nonwhite clustering becomes an essential variable interacting with changing fragmentation to cause an increase in racial/ethnic segregation. Generally, if an entire region was homogeneous with respect to a feature, then all partitioned units would contain roughly equal proportions of that feature. In this case, additional partitioning would result in no greater imbalance between subunits than existed before. However, if the feature of interest is distributed unevenly across the region, then additional partitioning would make the average size of the new units smaller than before. Some units will contain relatively more and some less of the target feature than was contained previously. In this way, increased fragmentation can only result in greater imbalance between units if the feature of interest is distributed unevenly across the region. The fact that smaller unit are more internally homogeneous resulting in greater between-unit heterogeneity has been recognized by other researchers of school boundaries and segregation (Alesina, Baqir, & Hoxby, 2004; Frankenberg, Siegel-Hawley, & Diem, 2017; Reardon, Yun, & Eitle, 2000; Saporito & Van Riper, 2016). While they noted the connection between existing fragmentation and segregation, this study is the first to examine how the process of fragmentation increases that segregation. The finding that African American segregation showed such large effects due to fragmentation, while

Hispanics showed none, strongly suggests that African American and Hispanic residents have qualitatively different spatial arrangements relative to whites.

This study did not separately assess African American clustering and Hispanic clustering relative to whites and relative to each other. Only white-nonwhite clustering was measured for each school district. As explained previously, in order to obtain separate clustering measurements would have required a large amount of computational resources—a tradeoff other recent researchers have also made (Fossett, 2017; Grubesic, Wei, & Murray, 2014; Rich, 2016; Saporito, 2017). Even though distinct values for African American and Hispanic clustering were not computed, that a difference exists in the spatial arrangements of each group relative to whites can be ascertained from the data at hand.

One analysis looked at how nonwhite clustering related to each group's degree of segregation from whites (table 4.6). When segregation was regressed on nonwhite clustering, a distinction between Hispanics and African Americans was observed. The strongest relationship was seen for African Americans compared to Hispanics, as evidenced by looking at the amount of explained variance (the adjusted-R^2 values). Within each district category, nonwhite clustering explains more of the variance in African American segregation compared to Hispanic residents. This is especially true in growing diverse districts. This result points to a qualitatively different spatial pattern for Hispanics and African Americans in relation to white residents.

A further analysis (table 4.7) comparing group size to level of residential clustering again showed a stark difference in the residential patterns of the two groups. The *p*-values in the last column of table 4.7 show the dissimilar response of clustering[12] to changes in group proportions. Districts with high numbers of African American residents were as clustered or were more

[12] "Nonwhite clustering" in this regression is the response variable responding to group size.

clustered than districts with small populations of African Americans. No such relationship was found for Hispanics. Differences in the size of Hispanic populations within districts showed no relationship with how clustered the nonwhite residents were. These results further reinforce the argument that in this study nonwhite clustering in relation to whites is a primary characteristic of African American residents and not of Hispanic residents.

Many racially and ethnically diverse school districts saw no changes in the number of schools (n = 119) and 128 school districts had decreases in enrollment, eliminated just under five schools per district on average. These shrinking districts saw significant *decreases* in segregation due to school zone consolidation but these changes were not of the same magnitude as growing districts.

Almost all of the diverse school districts in this study had statistically significant clustering of their non-white school-aged residents, but greater clustering was not associated with increases in segregation from fragmentation.

While the degree of non-white clustering was more prominent in districts with greater proportions of African American children (but not Hispanic children), there appeared to be no connection between proportions of Hispanics or African Americans in a district and changes in school segregation due to fragmentation. In other words, nonwhite clustering was higher in districts with more African Americans (not Hispanics), but higher clustering did not increase segregation—only greater fragmentation increased segregation. The fact that nonwhite clustering is greater in districts with high numbers of African Americans may indicate different spatial patterns for African Americans than for Hispanics in their respective residential arrangements with whites—an issue addressed in some detail in the next chapter.

Chapter 5: Discussion

Studies of school segregation—descriptions, antecedents, causes and consequences—fill the social science literature. Many chart historical developments after key court cases and legislation, while others examine temporal shifts in demographics stemming from migration dynamics. Some consider the effects of various school choice options and others consider residential factors such as zoning, housing and loan discrimination, transportation, poverty and other economic variables. In the compendium of causal variables identified and proposed, at least one variable had escaped notice until now: the effect of increasing fragmentation by school attendance boundaries. The present study extends the literature because it is the first to demonstrate that a previously unmeasured mechanism of segregation can account for a consequential portion of racial/ethnic imbalance between schools in growing and diverse districts—a mechanism that is the outcome of a rather simple geometric process.

Using a national sample, we can now estimate that when a diverse district that increases the number of schools by a mere ten percent (which mandates shifting school attendance boundaries) that district could expect to increase segregation between whites and African Americans by roughly 17%. The key point to keep in mind is that nothing else needs to change in order for segregation to rise. There need be no shift of the residential population in response to the boundary adjustments nor changes in any other policies, procedures, or processes.

The failure to observe a similar effect for Hispanics vis-à-vis whites may be due to dissimilar spatial arrangements African Americans and Hispanics each have in relationship to whites. When racial/ethnic residential clustering was measured, nonwhite clustering was much higher in communities with large numbers of African Americans. For the most part, communities with large Hispanic populations did not exhibit high levels of racial/ethnic clustering. In order for boundaries to separate groups, those groups must be spatially grouped. This appears to be true for African Americans living with whites more so than for Hispanics.

Supporting the finding that districts with neighborhood schools policies may increase between-school segregation merely by adding more schools is a corollary result: districts that lose enrollment may decrease segregation when they reduce the number of schools and thus consolidate school zones. Although the magnitude of the decrease in segregation is smaller[13], the strong statistical association between a decrease in the number of school zones and lower between-school segregation indicates the mechanism of fragmentation acts similarly in both directions.

Relationship to Previous Research on Between-School Segregation

Given the current racial/ethnic patterns in residential areas, the results just discussed indicate that new partitions within school districts can meaningfully increase the separation of whites from African American children; this effect is not seen between white and Hispanic children. That is not to say that white and Hispanic children are not segregated by school zones, but rather, the findings of this study show that white/Hispanic segregation is not exacerbated by increasing fragmentation within school districts. In order to make the argument that a *meaningful* amount of the change in segregation could be due to greater partitioning of school districts, the findings of this study must be evaluated in light of the results and conclusions of past research.

The primary goal of this study is to call attention to a mechanism of school segregation that has heretofore been unaccounted for in the research literature. By not considering the effect of

[13] For "shrinking" school districts, a 10% decrease in the number of schools resulted in about a 4% decrease in segregation, whereas "growing" districts that added 10% more schools yielded an estimated 17% increase in segregation (see model 4 in tables 4.4 and 4.5).

increased fragmentation, many important studies failed to present a fuller causal picture of school segregation. The following section will critique a few prominent studies that have examined racial/ethnic and economic segregation within school districts. By pointing out where fragmentation by school attendance zones could help better elucidate some of the research findings, I am in no way challenging the primary conclusions expressed in each study. My intention in this section is to make the argument that an understanding of fragmentation's effects could have enhanced each study's explanations of the manner in which segregation levels change within public school districts.

Magnitude of Fragmentation Effect

The main conclusion to bear in mind when assessing the relevance of this study in relation to other studies of school segregation is the strong relationship between the percentage increases in new school attendance zones and the accompanying rise in segregation between white and African American children. Looking at the last column in table 4.5 model 4 reveals that a *mere 10% growth in the number of new schools, such as a district with 20 schools adding two more, could lead to an average increase in between-school segregation of about 17% (b = 1.695).* This would occur without a single resident relocating into or out of any school zone. For school district planners and leaders who want to reduce segregation, their efforts to draw more racially balanced school zones as they are adding new schools may be "swimming upstream" against the effects of increased fragmentation.

Before considering other studies, another result from model 3 in the lower left panel of table 4.5 is relevant. Model 3 shows how absolute changes in segregation are affected by proportional increases in fragmentation. The unstandardized coefficient of b = .059 for the white-black comparison group means that if a district doubled the number of its schools, i.e. a 100% increase in the district's proportional fragmentation level, then racial imbalance, *H*, would have an average absolute increase of 0.06. Reardon and Yun (2001) determined that a 0.05 absolute increase in *H* would be a meaningful increase in segregation. While a doubling of the number of schools in a seven-year period is very rare, even a 10% increase in the number of schools could result, on average, an absolute increase of 0.006 in *H*, or about 12% of the amount needed to be considered meaningful. Other studies, as will be seen shortly, have found smaller effects on *H* associated with the main independent variables they examined.

Implications of the Fragmentation Effect for Previous Research

There are only a handful of recent studies examining changes over time in racial/ethnic segregation by school attendance zone. Richards and Stroub (2014), using a nation-wide sample of 366 metropolitan areas, compared levels of between- and within-district fragmentation between 2002 and 2010 with changes in racial/ethnic segregation using Theil's *H.* Finding overall trends towards consolidation rather than increased fragmentation in most metropolitan areas, they measured the average decrease in within-district white/non-white segregation of 0.004. Their measure of fragmentation duplicates Bischoff's (2008) formula, which factors in the number of districts in a metro area but not the number of schools, whereas their within-district value for *H* was calculated between schools within each district. Although fragmentation between school districts rather than within districts was their main focus, the study lacked a causal conjecture for the declines they found in within-district segregation. They suggest that "[f]indings for total and within-district segregation were *less consistent with expectations* [emphasis added]. In particular, regular district fragmentation was unrelated to change in within-district segregation across all three racial/ethnic comparisons" (Richards & Stroub, 2014, p. 22). Perhaps if they had taken into account the reduced number of schools within the districts, i.e.

decreasing fragmentation, in their sample they might have observed a similar relationship that this present study detected. For shrinking districts in this study, the mean change in *H* was -0.002, or about half the value of their observed decrease. The samples and methods in each study are different so a direct comparison must be undertaken with caution. However, the results of this study point to an explanatory variable—decreased within-district fragmentation—that may have led them to expectations more consistent with their results.

Jeremy Fiel (2013) measured racial imbalance across metro/county areas, across school districts, and then across schools using Theil's *H* as the metric. During the period from 1993 to 2010, Fiel found diminishing overall levels of racial imbalance, *H*, for African Americans and Hispanics and attributed this decrease to a lessening of the "distributive processes of segregation." He also vaguely asserts that "local distributive processes contribute so greatly to the racial composition of schools [suggesting] much more could be done to address school segregation" (p. 844). He causally proffers that social closure by whites are the "exclusionary segregation processes in the midst of group competition [that] lead to the uneven distribution of race/ethnic groups and resources across schools, generating racial imbalance.' (p. 843). While not discounting the importance of social closure by white elites, this current study suggests Fiel could have also considered more mundane factors, specifically the drawing of local boundaries in the face of numerical growth and declines, as part of the segregation processes that explain his results. Fiel acknowledges the role of district boundaries in helping create racial imbalances ["Researchers and policymakers should consider how school district boundaries are drawn and altered over time, and examine ways to weaken the link between residence and school assignment" (p.844)] but fails to expand that recommendation to local school zones.

While the present study focuses on racial/ethnic segregation, a recent analysis of income segregation between schools and districts (Owens et al., 2016) is relevant to the issue of whether fragmentation effects could explain some of the variance in their study's within-district results. The longitudinal study found that overall income segregation between schools, again measured by Theil's *H*, generally increased in the 1990s by about 13% and held steady from 2000 to 2012 within the 100 largest metropolitan areas. The authors then breakdown changes in *H* across the two decades according to district size, as measured by the number of schools, creating four categories: districts with 3 to 5 schools, 6 to 10 schools, 11 to 20 schools, and 21+ schools. They neglect to mention when these counts were determined, as if districts were basically stable in the number of schools during that period. Of the 329 districts in this study, only about one-third, during the seven-year span, were invariable in the number of elementary schools they contained, while 128 districts decreased by an average of 4.8 schools and 82 increased by about 2.1 schools. Bainbridge school district mentioned earlier had 19 elementary schools in 1990 and added its 35th elementary school in 2012. Also using *H* as the segregation index, the change in black-white-Hispanic segregation in Bainbridge during this time period due solely to increased fragmentation rose by about 12%. For growing districts in the present study, segregation gained about five percent due to fragmentation while in shrinking districts segregation dropped by two percent. The stability in *H* values over time reported by Owens et al. may obscure the dynamic nature of the districts they studied and add more contingency to their conclusions regarding between school economic segregation. Observing how segregation increased as the number of schools in a district increased, they concluded, "When there are more school options, more affluent parents can match their housing and enrollment preferences more closely, leading to more segregation" (p. 1178). This causal inference for school choice was not supported by any further evidence and other mechanisms were not considered. The present study has identified fragmentation as a possible contributor to be considered in studies, such as the one by Owens et al., that identify changes in intra-district segregation. When fragmentation effects in growing and shrinking districts are not factored in, then Tiebout sorting mechanisms may be given too much explanatory weight.

In a study of racial/ethnic segregation patterns in 217 metropolitan areas, Reardon, Yun, and Eitle (2000) measured levels of segregation using Theil's *H* between and among school districts categorized dichotomously into either central city or suburban districts. Finding that most of the segregation changes from 1989 to 1995 occurred between central city and suburban districts and between districts within these categories, they did report trends in within-district segregation that are consistent with this present study. Direct comparisons between the two studies are not possible due to differences in the districts sampled, the categorization of districts, racial/ethnic comparisons, and the time period examined, among others. However, in Reardon et al.'s study, the role of fragmentation is considered as a causal factor in increased segregation but only between districts and not within districts. First, their values of *H* for within-district segregation are slightly lower but comparable to this present study's mean values for growing, constant, and shrinking districts. Likewise, the changes in *H* within districts across the six years of their study are within the range of the changes this present study measured (see tables 4.2 and 4.3). They found within-district white/non-white *H* values dropped in central city districts by -0.0042 and rose in suburban districts by 0.0006. This present study did not classify districts by locale, but, in metropolitan areas that included central city districts, this study found every central city district to be a shrinking district and, for all shrinking districts, the mean drop in black/white *H* due to lower fragmentation levels to be -0.0022. This study found higher gains in black/white *H* in growing districts (0.0051) than Reardon et al. found in suburban districts (0.0006) but the direction of change for both were positive. In this current study, not all suburban districts added schools, which meant their change is *H* due to fragmentation was near zero (-0.00034). When positing explanations for low segregation within suburban districts, Reardon et al. note that “many suburban districts are very small; when a district contains only a handful of elementary schools and a single high school, as is the case in many suburban districts, there is little room for within-district segregation” (p. 358). An alternative interpretation from the perspective of fragmentation effects could be that when a district has low fragmentation, as is the case in districts with fewer schools, school zones contain more heterogeneous populations relative to the entire district’s population. Or more succinctly, little fragmentation yields little segregation. While Reardon et al. recognized fragmentation’s impact on segregation, i.e. “levels of segregation are related to levels of fragmentation among suburban school districts” (p. 362), they fail to consider its potential impact within districts. It is possible that decreasing fragmentation within central-city districts may have explained a good portion of the variance in their finding that white/non-white segregation declined by 9.4% within these district between 1989 and 1995 but the authors offered only the broad term “suburbanization” as an explanation.

The latter two decades of the Twentieth Century saw suburbs grow by 35%, with half of this growth coming from non-white populations (Reardon & Yun, 2001). Reardon and Yun asked how “minority suburbanization” was related to school segregation and identified two primary mechanisms at work: “When investigating whether minority-group suburbanization leads to increased integration or segregation among schools within the suburban ring, it is important to determine whether any observed relationship between suburbanization and segregation is due to the operation of the housing market or to within-district school-assignment policies” (p. 82). In their analysis of panel data they focused on *proportional* increases in non-white populations but did not consider how *absolute* increases in school enrollments would change the structure of district schools. When districts grow numerically, as they did during the 1980s and 1990s, they respond by adding more schools. From this basic fact it should be recognized that among the "within-district school-assignment policies" enacted by growing districts are the mutual issues of where to site new schools and how the new school attendance zones will be delineated. This study has shown that, during these joint operations, school segregation can rise due to increased fragmentation—a process that cannot be detected if the focus is solely on proportional changes rather than absolute gains in white and non-white populations. By adding growth in the number of schools per district as a predictor variable, Reardon and Yun's study may have been able to posit a causal interpretation to their within-district results. Noting that rapid growth in non-white populations accompanied rapid increases in segregation, as well as the inverse—districts with declining non-white enrollments had declining segregation levels—the authors hesitated to propose a reason for these results. "These patterns suggest," Reardon and Yun argue, "that suburban in-migration patterns are occurring in ways that tend to increase segregation, although the exact processes that occur are not discernible in these data" (p. 92). One of these "exact processes" (but not exclusive of other processes) that could have been considered is how increasing enrollments can lead to increasing fragmentation, which this present study has shown can result in more segregated schools. This process was illustrated by the example of the Bainbridge district and supported by this study's central finding that greater fragmentation raises levels of segregation in growing diverse school districts—for African Americans at least, but perhaps not for Hispanics. Reardon and Yun (2001) also found a similar difference in segregation levels for African American and Hispanic children. First noting that high growth in

Hispanic enrollments was not associated with higher between-district segregation, they remarked, "It does not, however, explain why the overall association between suburbanization and segregation is so much weaker for Hispanics than for blacks and Asians" (p. 93). They conjectured economic reasons for variable Hispanic sorting among districts. The results of this current study suggest examining districts where African Americans and Hispanics have divergent residential clustering patterns.

Richards and Stroub (2014) conducted one of only a few longitudinal studies of fragmentation. Examining districts in 366 metropolitan areas from 2002 to 2010, they found, somewhat contrary to general notions, that "school district fragmentation is unrelated to the overall level of segregation in a metropolitan area" (p. 1). Their methodology included assessing within- and between-district segregation using Theil's *H*. My purpose is not to evaluate their major conclusions but rather to point out once again how their within-district analysis would have benefitted from the inclusion of the effects of increased school zone fragmentation in their causal discussion. Their study measured changes in within-district segregation on the same order as this present study found in shrinking districts. White/non-white within-district segregation (*H*) decreased by -0.004 in the metro areas they studied and, in the shrinking districts examined in this study, multigroup segregation (*H*) due to consolidation decreased by -0.0022. Direct comparison of values should be interpreted with caution due to different samples, operational definitions, and time periods. However, the failure to consider the effects of changing boundary configurations, whether through fragmentation or consolidation, led the authors to an unsupported supposition:

> One potentially interesting moderator of the relationship between fragmentation and change in segregation over time is residential mobility. The Tiebout hypothesis contends

> that fragmentation facilitates between-district segregation through residential sorting. Thus, the effect of fragmentation on change in segregation over time is premised on the presence of residential mobility. *In a context of zero residential mobility, in which all residents stay in their existing homes and there is no net entry into or exit from an area, we would expect no effect of fragmentation on trends in segregation* [emphasis added]. (Richards & Stroub, 2014, pp. 25-26).

Expecting "no effect of fragmentation" if there is zero residential mobility makes sense if there are also zero boundary modifications. However, what if there was zero residential mobility but some boundary modifications? This is the precise question investigated by the present study. By attributing most of the change in segregation to Tiebout sorting mechanisms, the author's assume a stasis of existing boundaries. That would be a fair assumption for between-district segregation because district boundaries are relatively permanent compared to school attendance boundaries. However, within-district school attendance zones are some of the most dynamic of all political boundaries. A main argument of the present study is that the failure to consider this very mutable variable over-ascribes the causal role of residential mobility in between-school segregation.

Until the SABINS (2011) database was built and made publicly available, large-scale investigations of school attendance boundaries was not possible. Since that time, many studies have analyzed the nature and process of their construction and consequences (Monarrez, 2018; Richards, 2014, 2017; Richards & Stroub, 2015; Saporito, 2017a, 2017b; Saporito & Van Riper, 2016; Siegel-Hawley, 2013; Siegel-Hawley et al., 2017; Sohoni & Saporito, 2009).

One topic receiving much attention has been "gerrymandering", by which district planners and leaders construct school attendance boundaries with the intent to promote or reduce racial/ethnic diversity within district schools. Some researchers avoid the use of the term gerrymandering because it connotes intent, which is often difficult to ascertain (Saporito, 2017a). Moreover, gerrymandering usually carries the additional meaning that the shapes drawn are highly irregular, but it has been demonstrated that exclusion may be effectively enacted by employing compact zonal shapes (Saporito & Van Riper, 2016).

A missing component in all of the studies of attendance zone shape is a consideration of the entire *process* of drawing new attendance boundaries. New attendance lines are most often drawn when school-aged enrollments undergo substantial gains or losses, thereby precipitating the building of new schools or the closing of existing ones. Accompanying these actions are increases or decreases in the number of school attendance zones. When either of these actions occurs, the average size of catchment areas also increases or decreases. This consequence is just as pertinent to the question of between-school segregation as are the shapes of the zones themselves, as this study has demonstrated. Saporito (2017a) concluded that "great majority of school districts delineate reasonably compact attendance zones—and that these compact zones are either indifferent to residential segregation or do little to exacerbate it" (p. 312). Yet, he finds it "puzzling" that declines in residential segregation did not yield corresponding declines in racial segregation in public schools. "Given the nearly one-to-one correspondence between residential segregation and attendance zone segregation, one would expect that public school segregation would have declined at the same pace as residential segregation" (p. 312). The reasons for this lack of correspondence between residential and school-zone racial segregation may be numerous, but one factor that should be scrutinized, the present study argues, is the effect of changes in school zone boundaries over time—an element that Saporito also believes is worth contemplating. "Ideally, I would like to follow yearly alterations in school attendance zone irregularity and predict how much such changes are associated with changes in attendance zone racial segregation" (p. 311). If Saporito follows up with this inclination perhaps he will confirm how further segmentation of a school district by attendance zones can produce increases in the racial/ethnic balance between schools.

One of the few studies of changes in school segregation over time that included absolute growth in enrollments, in addition to the usual focus on proportional changes, was the Stroub and Richards (2017) study of urban, suburban, and exurban districts in 209 metropolitan areas from 2002 to 2012. Decomposing Theil's *H* into between- and within-district components, they asked whether segregation was shifting from urban areas to suburban and exurban locales.

Unlike other studies, Stroub and Richards reported aggregated changes in *total* enrollment for all three locales as well as average number of schools per district and students per district, thus giving an indication of absolute enrollment's association with segregation. Their results for within-district segregation are consistent with what one would predict from a fragmentation-effects perspective, but the comparison is limited because they did not distinguish which districts had growing enrollments and which had declining enrollments. Consequently, variation by district within locale categories on this particular variable went undetected.

As with other studies, Stroub and Richards (2017) use proportional changes in racial/ethnic group comparison as a predictor for segregation. Since growing districts face dissimilar issues with regard to segregation than districts with stable or declining enrollments (Diarrassouba & Johnson, 2014; Diem et al., 2016; Frankenberg & Kotok, 2013), including absolute enrollment changes as a predictor variable may have shed light on some of the mixed results they reported. Their regression on segregation of various racial/ethnic comparison groups did include total enrollment as a variable but not *changes* in enrollment. However, changes in enrollments are what districts respond to when making school assignment decisions, including the decision of when and where to add more schools and redraw new attendance areas. It is somewhat surprising that this dynamic was not more salient to the authors since both have conducted well-regarded research on school attendance boundaries (Richards & Stroub, 2015; Richards & Stroub, 2014).

As an example of a result that was reported but went unexplained, Stroub and Richards (2017) found that overall suburban black-white and Hispanic-white segregation remained relatively stable over the study period, yet this obscured wide variation within suburban districts. They reported that roughly twice as many districts saw meaningful decreases in Hispanic-white imbalance (i.e. absolute change in *H* greater than .05) than districts having meaningful increases. In contrast, about the same number of districts experienced meaningful black-white increases as decreases. These findings beg the question that went unaddressed in their study, namely, how were districts showing increasing racial/ethnic imbalance different than those showing decreases. From the perspective of the current study's results, I would conjecture that changes in absolute enrollments leading to within-district fragmentation or consolidation may have been a distinguishing factor between these districts.

Interpreting the results of Stroub and Richards (2017) study in light of the findings in this study, there is some consistency in those areas where more direct comparisons can be made. From the reported characteristics of the districts in their sample, suburban districts during the study period added about three percent more schools per district, urban schools eliminated almost 25% of their schools, and exurban districts added roughly five percent more schools. Comparing these numbers with changes in racial/ethnic imbalance (*H*), suburban within-district black-white segregation rose 7.4%, urban districts saw a reduction of 6.1%, and exurbs increased by 11.3%. These results are in the neighborhood of what one might expect given the changes in black-white *H* due to school zone fragmentation as reported in the present study. Likewise, the changes in Hispanic –white segregation reported by Stroub and Richards showed no clear trends (as was true in this study). They reported suburban Hispanic-white *H* remained relatively constant, urban *H* dropped 4.1%, and exurban *H* also dropped by 5.6%.

Tomas Monarrez's (2018) nationwide research on school attendance boundaries and segregation investigated the tradeoff between travel distance to the nearest school and tolerance for racial integration. He did this in part by devising a unique index to "quantitatively measure local governments' choice over the degree of racial equity in the school systems" (p. 7). Part of his methodology included linking residential racial compositions at the census block level to their corresponding school attendance zone, within which each block is contained. This was the same methodology the present study followed to impute projected school populations from the underlying residential layout, and both studies make the assumption that "residential racial sorting patterns are fixed with respect to school boundary change" (p. 29). Monarrez adds the caveat: "Holding residential patterns constant is a strong assumption, however. If residential sorting responds drastically and immediately after changes in school boundaries take place, this would potentially invalidate the results of this study" (p.29). He tests this assumption by conducting a "robustness check" using the school boundaries of the Charlotte-Mecklenburg, NC school system (CMS). It is this portion of Monarrez's study that I wish to critique on one point.

To test the assumption that residential sorting is relatively immutable in the short term with respect to school attendance boundary reassignments, Monarrez examines changes in block-level racial/ethnic compositions from 2000 to 2010, looking specifically at those blocks that were reassigned from one school zone to another during that decade.

> Suppose that a given block of homes is reassigned from a school boundary that is10% minority to one that is 40% minority. … I am interested in estimating whether the racial composition of this block of homes changes because of this reassignment. In other words, how many (if any) of the white inhabitants in this block would move away because they prefer schools that have a lower minority population? (p. 32).

In testing resident response to school attendance boundary realignments, Monarrez controls for many important confounding variables, e.g. gentrification of the central city. One variable that is unclear in the regression analysis that estimates white resident "compliance" with school boundary shifts is the set of values he uses for racial composition of school attendance zones. CMS added 24 new elementary schools between SY2000 and SY2010, representing a 36% increase. From the present study's results, it would be reasonable to assume an increase of this magnitude would affect the average size of school zones while altering the racial proportions of the residents contained within each zone. Monarrez does not indicate the time(s) that he determined the racial composition of each zone. The hypothetical block in his example, which was previously in a 10% minority zone, is reassigned to a zone that "is" 40% minority. It is unclear if that 40% was computed prior to the fragmenting of the district under the new boundary configuration. If it was then residents would respond, not to the previous school zone minority composition, but rather to the new racial makeup, which this study has demonstrated is likely to be a higher minority proportion than the former 40%. The high likelihood that demographic characteristics changed during the rezoning process that took the district from 68 to 91 schools can be inferred from the summary statistics reported in table 6 (see Monarrez, 2018, p. 59). To obtain these statistics, Monarrez apportioned populations from the block-level residential census geography into SY2000 CMS attendance boundary configuration (n = 67) and again into the

SY2010 attendance boundary configuration (n = 91). Since the census data was constant at year 2000, the average minority proportion for all school zones was 43% for both SY2000 and SY2010, by mathematical necessity. The statistic of interest that indicating that greater fragmentation led to higher racial imbalance was the change in the standard deviation across school zones between SY2000 and SY2010. The percentage minority standard deviation in SY2000 was 0.21 but rose to 0.31 in SY2010. Because these changes are due solely to changes in school attendance boundaries and not due to underlying shifts in resident populations, this increasing variance reported among school zones can only be attributed to greater segmentation of the entire district into smaller, more dissimilar units—the fragmentation effect the current study predicts.

Bartels and Donato (2009) presented a case study in Longmont, Colorado where the St. Vrain school district redrew its school attendance boundaries when a new middle school was built in a predominately white neighborhood. Race, ethnicity, class, geography, and politics combined for a contentious process of assigning children to the district's schools based upon residential location. In a district that was 22% Hispanic and having a poverty rate roughly the same, the older over-crowded Heritage middle school was two-thirds Hispanic. As growing districts usually do, the new sixth middle school, slated to be opened in 2005, was built in an expanding area of new housing. Three rezoning proposals were developed that the study's authors labeled the Integration scenario, the Status Quo scenario, and the Compromise scenario. Eventually, resisting white resident pressure, the Integration scenario was adopted by the school board sending some middle- and upper-class students to the older Heritage school, and drawing some Latino students from the city's core into the new Timberline school. This plan resulted in a Timberline student population that was 37% Latino—above the district average of 23.5% Latino.

Surprisingly to both the school board and the study's authors, in spite of their efforts to even out the ethnic distribution of students, Heritage's Latino population actually *increased* from 67% before Timberline had opened to 73% after the Integration plan was implemented. "We would have assumed that the number of low-income and Latino students at Heritage would have decreased after the re-zoning because of the number of Latino students who attended Trail Ridge. This was not the case, however" (Bartels & Donato, 2009, p. 244).

The authors speculated that "white flight" was the primary reason for this unexpected result. They supposed affluent white parents either sent their children to one of the two charter schools or used the open-enrollment option to get their children into another district middle school. The authors do not substantiate their reasoning through quantitative evidence. Rather, they assume "white flight" based upon the resistant attitudes expressed by affluent white parents prior to the board's boundary decision. If the authors had conducted a few calculations, they may have seen the near implausibility of these assumptions. I present the following analysis to justify this assertion.

Bartels and Donato (2009) stated that the district leaders built Timberline with the expressed intent of reducing both overcrowding and ethnic imbalance. After Timberline opened, Heritage had 615 students enrolled—down from 778—but was 71% Hispanic, which was *up* from 67% prior to the boundary changes. I will make the conservative assumption that the school board wanted to reduce Heritage's Latino proportion to at most 2.5 times the district average of 23% — still a relatively high 58% Latino proportion. If "white flight" was the cause of the high Latino proportion, the number of white children that otherwise would have attended Heritage but rather opted out to other schools would have been roughly 138.[14] Heritage would have had to add 138 white students to its stated enrollment of 615 students—yielding a total enrollment of 753—in order to obtain a student body that was still 58% Latino, but then this would not have satisfied the reduction in overcrowding that was also their expressed intent. Therefore, it is highly unlikely that 138 white students transferring to other schools would have gone undetected by the district or the authors because it would have increased the proportion of white students in the other middle schools. However, "the percentage of White students enrolled in other middle schools remained consistent for the 2005–2006 school year" (p. 245).

An alternative explanation, offered in the light of the findings of the present study, is that adding a new school, and a concomitant new attendance zone, increased the fragmentation level of the district, resulting in smaller, more ethnically homogeneous catchment areas, even though the intent of the district leaders was the precise opposite. I am not suggesting that white flight did not occur. I use this case study to make the argument that increasing the level of fragmentation by school attendance zones is a geometric mechanism that should be considered alongside other causal explanations, which mainly rely on volitional migration. Granted, other interpretations, such as Tiebout sorting or Exit-Voice-Loyalty, fit more easily into theoretical frameworks that may well take primacy over fragmentation effects as explanations for the ethnic segregation in the St. Vrain school district and other similarly growing and diverse school systems. Nevertheless, I contend that changing fragmentation should now be considered as a legitimate contributor to racial/ethnic imbalance alongside other, more commonly considered determinants of between-school segregation.

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[14] 29% of 615 total enrolled = 178 white students. To achieve 41% white proportion, solve the following for W: $\frac{178+W}{615+W} = 0.42$. Yielding W = 138 white students.

The implications of the findings of the present study may go beyond the academic assessments of segregation and into the practical arena of district planning. The consultants hired by the St. Vrain school board offered what appears to be thorough advice:

> They advised school officials to appoint a committee to acquire community support, create visual images of the district, collect past enrollment data, make projections into the future, recognize racial and ethnic information, crunch data with appropriate software and work through various scenarios to determine which plan would have the greatest potential for success. The ultimate key to success, they noted, was to have accurate information before making decisions. (p. 230).

I would add to this advice a recognition that partitioning a school district, whose residents are racially/ethnically clustered, will result in additional school zones that, by a simple geometric mechanism, create catchment areas that are more internally homogeneous. This process will to some extent be in opposition to efforts by planners to construct new and more equitable boundaries.

Fragmentation Effect for African Americans—not for Hispanics

The current study found that changes in attendance boundaries separated white children from African American children to a greater degree than white children from Hispanics children. In light of the fact that the residential data layer from which the school populations were extracted remained constant, the obvious explanation is that residential patterns for Hispanics are different from those of African Americans. This study measured the spatial variations using two global indices of spatial autocorrelation to gauge the level of clustering. Both of these indices compare the value of a single spatial attribute at one location with respect to that attribute's value in nearby locations, normalized by the average value for all locations within the study region. The limitation of these indices in a multi-racial/ethnic setting is their binary nature—they can only compare white to nonwhite proportions or black to white proportions or some other pair-wise proportional comparison. There currently exists no multigroup clustering index.

Assessing the white/non-white clustering for each district in this study was computationally intensive, requiring the comparison of every one of the study's roughly 1,500,000 census blocks with its closest 12 neighboring blocks. This was done twice—once for each index of spatial autocorrelation. But before these comparisons could be made, it was necessary to spatially identify each block's nearest 12 neighbors—a sub-task that required the most computational resources. Thus, the decision was made to assess racial/ethnic clustering using only one dimension.

There is scant information on the differences between white/black and white/Hispanic (and white/Asian) residential clustering. Most of the studies comparing segregation between these racial/ethnic groups use aspatial measures, such as the dissimilarity index (Logan, Oakley, & Stowell, 2008) or Theil's *H* (Farrell, 2008), which require no distance component in their calculations. However, "segregation is inherently geographical…but such richness in spatial variation is seldom captured by the dominant genre of empirical research" (Brown & Chung, 2006, p. 125). In Brown and Chung's study just cited, local Moran's Index was employed at the census tract level in the Columbus, OH metropolitan area. They found higher black/non-black clustering than either Hispanic/non-Hispanic or white/non-white clustering. The decision to analyze only one metropolitan area at the tract level (there are about 39 census blocks in each tract) is indicative of the extensive computational resources required for clustering measurements and other highly-spatial analyses. Even more recently, researchers have made methodological compromises when measuring clustering and other spatial patterns of segregation, and justifying these decisions using terms such as "computational expense" (Grubesic, Wei, & Murray, 2014; Saporito, 2017a), "computationally demanding" (Fossett, 2017), "minimize computational time" (Reardon et al., 2008), and "computational burden" (Rich, 2016). The one multi-location study I was able to find (Reardon et al., 2008) compared micro- and macro-scales of residential segregation using a spatial version of Theil's *H* developed by Reardon and O'Sullivan (2004). This study of 40 metropolitan areas found that block-level segregation between whites and Hispanics was lower than between whites and blacks. The findings are presented as preliminary, calling for "[f]urther multivariate analyses with a larger set of metropolitan areas are required for a more thorough investigation of the metropolitan factors that may shape the geographic scale of segregation" (Reardon et al., 2008, p. 502).

Given the present study's finding that African American populations are more susceptible to fragmentation than Hispanics, measuring black/white or black/nonblack clustering, as well as Hispanic/white or Hispanic/nonHispanic clustering, would be justified if resources permitted. It would also add to the micro-scale description of racial/ethnic residential cluster patterns—a description that is presently lacking at a nationwide level. Undertaking a task of this magnitude would be a major commitment of time and resources, which is perhaps the reason it remains unfulfilled.

On a smaller scale it would be feasible to compare the spatial arrangements of African Americans, whites, and Hispanics each with the other. The current study, by necessity, used two *global* measures of clustering for each school district. An investigation of a single metropolitan area could reasonably use finer-grained *local* indices of clustering, such as Anselin Local Moran's I or Getis-Ord Gi* (see figure B1 in appendix B for an example of Getis-Ord Gi* being applied to the Bainbridge school district.) If the Baltimore/DC metropolitan area was investigated using local clustering measures of all three racial/ethnic dyads, then more sense could be made out of the maps in figure 4.6 by uncovering the hidden differences in the residential patterns for whites, African Americans, and Hispanics in relation to each other.

It may seem contradictory to advocate for a finer description of racial/ethnic clustering given that the clustering variables in this study failed to add more predictive power than did changing fragmentation alone (see table B7 in appendix B). I explain this outcome by looking first at the overall non-white clustering levels across districts. The fact that values for both Getis-Ord G and Moran's I were significant for over 90 percent of all districts in this study, including the districts undergoing no net gain or loss in the number of schools, indicates that almost all districts exhibited residential clustering above some threshold level that was needed to sort children into schools differentially—at least between whites and African Americans. What this threshold level is could not be determined from this study due to the small number of districts having low nonwhite clustering. To be clear, because almost all districts in this study were significantly clustered (substantially as well as statistically), changing fragmentation alone was sufficient to increase the separation of African American children from white children in growing districts.

Supporting the clustering-segregation nexus are the results found in table 4.6 showing a strong relationship between nonwhite residential clustering and segregation within district schools. The comparison here is between clustering and absolute levels of imputed school segregation in SY2015-16 and not *changes* in school segregation due to *changes* in fragmentation. When school populations are apportioned from the residential layer into the 2015-16 school attendance zones, their racial/ethnic compositions are calculated for each zone. When segregation (*H*) between schools was calculated for the district, it was then regressed on residential nonwhite clustering. In growing districts, elevated clustering values correspond to higher attendance zone segregation for both white-black and white-Hispanic comparison groups. However, much more of the variation in black-white segregation is explained by clustering (adj. R^2 = .443) than the segregation between whites and Hispanics (adj. R^2 = .139). Shrinking districts show a similar yet stronger pattern. Residential nonwhite clustering in shrinking districts explains roughly 63% of black-white between-school segregation and 49% of Hispanic-white segregation.

Another finding from this study points to the important role that spatial patterns, such as clustering, play in segregation by attendance zones. Segregation between school zones was not meaningfully related to the percentage of nonwhite children residing in each district. Districts with higher proportions of African American children had slightly more segregation between schools and the proportion of Hispanic children in a district showed no relationship with school segregation (see table 4.7).

Taken together, these findings show that in all categories, districts that are highly clustered residentially have correspondingly high levels of racial/ethnic unevenness between schools. This holds true for all racial/ethnic group comparisons but especially between whites and African Americans. These results say a bit more than merely reconfirming that school segregation reflects residential segregation. If we look at only growing districts in table 4.6 (the focal districts in this study) nonwhite residential clustering is a much stronger predictor of school imbalance between whites and African Americans than between whites and Hispanics. The large differences in the explained variance due to clustering for white-black segregation and for white-Hispanic segregation is strong evidence that small-scale residential patterns for African Americans is qualitatively different than for Hispanics—at least in the manner in which attendance zones differentially sort children into schools along racial/ethnic lines. The conclusion that school-attendance zone fragmentation affects African Americans more than Hispanics is not surprising given the large body of residential segregation research showing African Americans to be the most segregated group from whites (e.g. Iceland & Steinmetz, 2003; Johnston, Poulsen, & Forrest, 2007; J. R. Logan, 2013).

The difference in segregation patterns for African Americans as compared to Hispanics was one of the main points in the seminal work of Massey and Denton (1993) who found persistent levels of white-black segregation more than white-Hispanic segregation. Even when African Americans improved their economic standing, there was little progress from their "near-apartheid" situation, whereas Asian and Hispanic separation from whites saw greater differentiation by class status. Logan, Stults, and Farley (2004) found no shift to living in less segregated areas for African Americans in the 1990s. However, there was net movement of Hispanics and Asians to areas of lower segregation, but in these areas, as Hispanics and Asians moved in, segregation of these groups from whites increased. Alba and Logan (1993) examined the greater New York City metropolitan area, finding the spatial separation of blacks from whites to be greater than whites from either Hispanics or Asians. This pattern was confirmed on a wider scale by Frey and Myers (2005), who found dissimilarity between whites-Hispanics (D = 44.2) and between whites-Asians (D = 42.9) to be much lower than between whites-blacks (D = 58.7) in 318 metropolitan areas. In one of the few nationwide studies evaluating *clustering* of both African Americans and Hispanics, Iceland and Weinberg (2002), using the spatial proximity index, found African Americans to be more clustered than Hispanics nationwide in the 330 metropolitan areas examined, as well as in each region of the country.

While there needs to be more large studies of micro-level spatial variations for the different racial/ethnic groups, it may be reasonably inferred from this review that the general spatial patterns of Hispanics exhibit more dispersion and African Americans more concentration in relation to white residents. If this is indeed the case, then attendance zone fragmentation would have a greater propensity to cut African Americans off from whites than it would for Hispanics. Additional nationwide research would be needed to confirm whether there is a qualitative and/or quantitative difference in clustering between the two groups and other racial/ethnic groups on this particular dimension of segregation at the smallest scales, i.e. census block level.

Investigation of Consolidation Needed

Growing districts garner most of the attention from researcher examining racial/ethnic segregation (Frankenberg & Orfield, 2012). Consistent with this emphasis, the research on within-district segregation that has considered *spatial* variables has also focused on districts with expanding enrollments (Bischoff, 2008; Monarrez, 2018; Richards, 2014; Saporito, 2017; Saporito & Van Riper, 2016; Stroub & Richards, 2013). While the present study maintains that attention on growing districts, it also measured the effect on segregation of the consolidation process, i.e. reducing in the number of attendance zones in a district. The results of consolidation was consistent with the findings of fragmentation's effect on segregation in growing districts. In the shrinking districts, black-white segregation due to school zone consolidation dropped significantly. However, the average magnitude of these changes did not reach those of growing districts.[15] (Also, as was true for fragmentation in growing districts, consolidation in shrinking districts was not associated with changes in white-Hispanic segregation.) Finding an explanation for why black-white segregation decreases were not of the same magnitude as were the increases under fragmentation would require greater understanding

[15] See model 4 in both table 4.4 and table 4.5. Adj. $R^2 = .054$ in shrinking districts and adj. $R^2 = .378$ in growing districts.

of the processes, politics, and implementation plans of school districts that are facing declining enrollments. Scant research incorporating spatial variables has been conducted on districts losing students to surrounding areas. To my knowledge, there exists no study examining how districts make internal boundary decisions when they are forced to close schools and redraw the attendance zones. In this study, shrinking districts outnumbered growing districts (n = 128 and n = 82 respectively). Since so many districts are facing issues of how to aggregate students into fewer schools, the various policy responses of districts to this spatial challenge bears some attention.

Gerrymandering or Increased Fragmentation

There has been concern expressed in the still-nascent school gerrymandering literature, as well as in other segregation research, that attendance boundaries are manipulated with the intent to segregate (Diem et al., 2015; M. Orfield, Luce, & Finn, 2010; Richards & Stroub, 2015; Siegel-Hawley, 2011, 2013). This concern is particularly focused on growing suburban and exurban districts that have experienced marked growth and rapid increases in racial/ethnic diversity over the last few decades. Orfield and Luce (2013) point to gerrymandering as a contemporary response by suburban districts wishing to maintain racially homogeneous schools. Richards and Stroub (2014) directly examine whether educational boundaries are drawn in a manner to exclude certain groups of students from others. Their study compared segregation levels from two sets of boundaries: actual attendance zones and Voronoi polygons, which are idealized zones constructed using a minimal-distance algorithm centered on existing school buildings. Through this comparison they concluded that "gerrymandering has a small but significant effect" (p. 25) on between-school segregation.

In their study, Richards and Stroub (2014) examined a national sample drawn from the same SABINS database and block-level 2010 census data that this study employed and measured differences between actual attendance zones and Voronoi attendance zones using Theil's *H*. Both the present study and Stroub and Richards' study compared two sets of attendance zones to determine if the difference between the two sets of boundaries affected segregation. Stroub and Richards compared ideal attendance zones to the *same number* of actual zones. Their study assessed whether segregation changes were a result of the manner in which the boundaries were drawn. The present study compared previous attendance zone configurations to subsequent zone configurations after a period of a few years and assessed whether segregation changes were a result of more and smaller zones, i.e. increased fragmentation.

Adding more schools has a greater effect on black-white segregation than the way in which those zones are constructed. Whereas Stroub and Richards reported that differences between actual and ideal zones resulted in gains in black-white segregation of $\Delta H = 0.002$, the current study, using nearly identical data and apportionment methodology, found a 2.5 times higher increase in black-white segregation due to adding attendance zones ($\Delta H = 0.005$). The contrast in results between the two studies underscores the primary argument of the present study, namely that overall growth in school districts has as much or more of an effect (through increased fragmentation) on within-district segregation than does the actual shapes of the zones themselves. The simple process of adding more attendance zones is a hidden mechanism that raises segregation, an unmentioned factor in the school segregation literature up to this point.

Further Fragmentation Research using Voronoi Zones

Richards and Stroub's (2014) methodology of using idealized Voronoi zones could be illuminating as a follow up to this study's examination of actual attendance zones. The increase in black-white segregation due to increased fragmentation of actual attendance zones, which the present study found could perhaps be attributed to the peculiarities of a school district's boundary drawing procedures. Because policies and processes of boundary change can be highly variable district by district, one could test the effect of increased fragmentation using a single standardized method of constructing hypothetical school attendance zones across all the school districts under investigation. Using Richards and Stroub (2014) methodology from computational geometry, each school district could be subdivided into a set of Voronoi polygons generated from the point locations of each elementary school in every school district. Together, these polygons tessellate to form a Voronoi map and are constructed using a nearest-neighbor algorithm, which places all points in the study area (i.e. school district) into one of several polygons in such a way that every location within a given polygon is closer to the focal point (a particular elementary school in this case) than it is to any other focal point in the study area (Aurenhammer, 1991). Each polygon forms what Aurenhammer termed a "natural neighborhood" but which I refer to as a *standardized attendance zone*. Every school-aged child within a standardized attendance zone is closer to the focal school for that attendance zone than to any other school in the district. Figure 5.1 provides an example using Voronoi polygons to generate standardized attendance zones for the Bainbridge school district in SY2009-10.

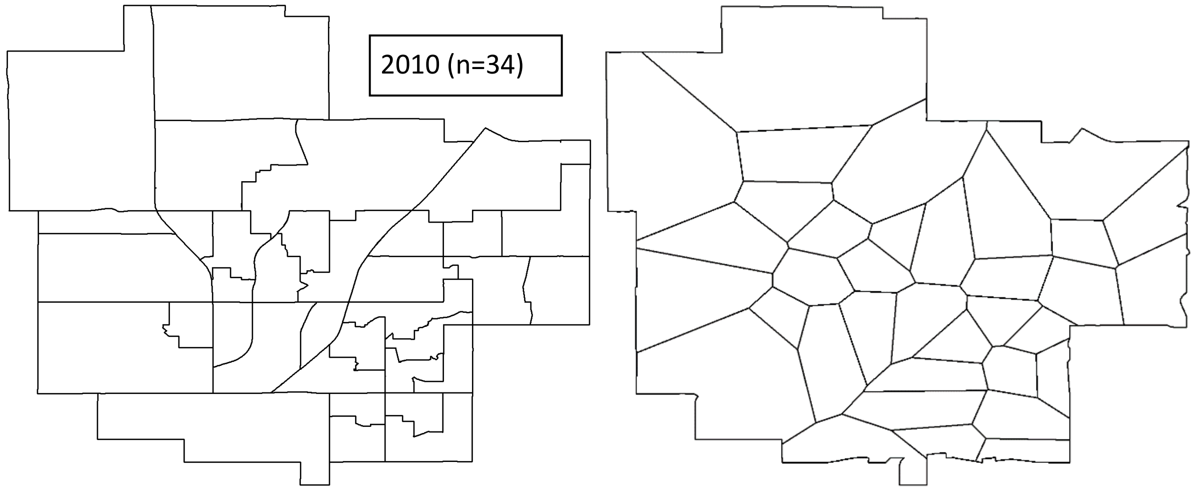

Figure 5.1. Bainbridge elementary school attendance zones. Left panel shows actual 2010 attendance boundaries. The right panel shows Voronoi boundaries constructed using school building locations as the focal point of each zone.

This approach of generating standardized attendance zones is an adaptation of the methods of Richards and Stroub (2014) and follows their reasoning up to a point. One feature of Voronoi polygons in their favor is that all polygons are drawn using the same algorithm, thus avoiding the vagaries of actual boundary changes enacted by each school district. "As such, they provide a counterfactual attendance zoning scheme" (p. 10). While Richards and Stroub compared extant attendance zones to Voronoi maps of each school district in order to ascertain the extent of gerrymandering in each district, follow-up research would compare like maps: between actual attendance zones for each school district at two points in time and another comparison made between Voronoi maps generated at those same two times.

The rationale for using Voronoi maps in a follow-up study would be to assess the persistent effects of increased fragmentation on between-school segregation absent any idiosyncrasies in boundary-drawing processes. Therefore, the comparison of most interest would be between Voronoi maps at two different times exhibiting varying amounts of fragmentation. With "gerrymandering" influences removed, any increase in measured segregation can be attributed solely to the influence of a more fragmented school district. However, by making two separate comparisons, one between actual attendance configurations at two different times and the other between standardized attendance zones contained in the Voronoi maps at those same times, one could also examine the relative differences in the changes to *H* from one time to the next for both the actual and the theoretical zones. Comparing these relative differences would allow an estimation of whether the actual boundary changes are either exacerbating segregation, as social closure would predict, or are helping to reduce it as Saporito and Van Riper (2016) maintain.

Conclusion

To some it may seem improbable that the process of fragmentation by school attendance boundary has not been previously considered as a possible contributor to within-district segregation. To the author's knowledge, fragmentation processes at this level have never been mentioned, even if to discard them as insignificant. Fragmentation has long been recognized as a component of spatial segregation (Clotfelter, 1999; Morgan & Mareschal, 1999; Schneider, 1986; Weiher, 1991) enabling volitional mechanisms to operate, i.e. Tiebout sorting, opportunity hoarding, exit/recruitment. Implicit in these spatial mechanisms is a degree of choice: a community could join the central city or another municipality or it could self-incorporate, it could annex another community or allow to be annexed, etc. However, school districts are forced into a choice when faced with rising enrollments. If they reach or surpass their current capacity, they must expand that capacity. A district's first response is often to expand classroom space at current building sites. Eventually, constructing more schools is a forced inevitability. For districts implementing a neighborhood-schools policy, this also entails the equally inevitable redrawing of attendance boundaries. This further partitioning of a school district into smaller attendance areas appears benign on the surface, and previous investigators of school attendance boundaries have never considered how the mere act of adding new school zones might have a social effect. Instead, recent interest has focused on the manner in which new zones were drawn—whether irregular or compact—and on the intentional shaping of zones for the purpose of including or excluding certain groups.

There has been no suggestion, however, that the segmenting process itself would have a significant independent effect on the average segregation level within a school district. This study concludes that there is an extreme likelihood that it does—at least for African American children who are residentially clustered, as most are. This conclusion does not exclude other factors contributing to between-school segregation nor does it preclude any subsequent residential movement post-redistricting. Those other possible determinants of segregation are independent and unnecessary for fragmentation effects to operate. The mechanism of racial/ethnic segregation identified by this study is the result of a fairly simple geometric process. Namely, when an area containing an uneven distribution of some feature is repeatedly subdivided, the average imbalance of that feature among the subunits increases as the internal homogeneity with respect to that feature ineluctably increases within the subunits.

Perhaps the previous lack of attention to this process was due to the inaccessibility of the data needed to examine the question. Until as recently as 2009, there were no nationally available data on school attendance boundaries. Furthermore, investigating *changes* to school attendance boundaries employing a large sample would require a subsequent comparable dataset of those same school districts at a later time. Small scale investigations, such as the Bainbridge analysis in this study, were possible but would lack generalizability.

Certainly a major reason for inattention to this possible mechanism is that other, highly visible, factors contribute more to school segregation than does increasing fragmentation. It is not the contention of this author to suggest that fragmentation processes should stand alongside these other principal impediments to integration. The goals of this study were to (1) determine if fragmentation processes alone could affect racial/ethnic segregation and, if so, (2) to identify which groups were the most affected and to estimate by how much. By accomplishing these goals, it is hoped that, when appropriate, fragmentation processes are taken into consideration in future investigations of between-school segregation.

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Appendix A: Various Methods Used to Measure Clustering

Feitosa et al. (2004; 2007) make clustering central to their analysis of segregation in urban Brazil where they advocate for using a combination of global and local indices, noting that large cities may have local variabilities that global indices are unable to capture. While defining residential segregation as "the degree of spatial proximity between families belonging to some social group" (Feitosa et al., 2004, p. 59) they reject the SPI, instead developing spatial versions of aspatial segregation indices, such as the spatialized dissimilarity index. These measures require a decision as to what bandwidth value to use. "Bandwidth" is a term used in spatial statistical analyses that refers to the distance within which the analysis will be performed. Clustering analysis assesses the similarity or difference of some attribute of the target feature to all the other features that lie within the chosen bandwidth. Bandwidth is usually defined by Euclidean distance or time. Determining bandwidth is similar to determining what radius to use when defining who one's neighbors are and, as such, will affect the value of the index and the chosen bandwidth value will depend on the scale of segregation that is of interest to the investigators. The use of bandwidth stems from other proximity measures originating in the field of econometrics: kernel density functions (KDF) (O'Sullivan & Wong, 2007), which have their own limitations when used to identify clusters. KDFs are smoothing devices that, if a large enough bandwidth is used, can lead to over-smoothing, and thus obscuring local patterns (Logan & Martinez, 2018). However, if the bandwidth is too small then no smoothing would occur, KDFs then would merely duplicate the original population array (Páez et al., 2012). Feitosa et al. (2007) used various bandwidths to develop a nuanced view of class segregation in *São José* dos Campos, Brazil and, in drawing their major conclusions, relied on visual inspection of choropleth maps in order to identify individual clusters and their relationships to each other.

Logan and Martinez (2018) contend that “unfortunately the effect of including a kernel-density function has not been demonstrated empirically, and little attention has been given to the selection of the particular function to be used” (p. 14).

The impracticality of a bandwidth approach for this study stems from the differences in geographic scale from one school district to another and even within school districts. A distance considered “nearby” varies with geographic and social contexts rendering a single distance band inadequate for identifying clusters in large scale investigations without knowing the spatial scale of segregation within each school district. As a remedy to this problem, Reardon et al. (2008) and Lee et al. (2008) would suggest constructing a “segregation profile” for each school district that graphs the value of unevenness at varying scales and notes changes between micro- and macro-segregation. While the researchers suggest that the slope of a region’s segregation profile provides valuable information on the scale dependence of racial segregation, the interpretation of slope values is still in its nascent stage and will not be relied upon in this study.

Saporito (2017a) proposes “proximity-based population thresholds” to address the problem of the varying scales of segregation among disparate districts. Rather than define a “neighborhood” areally, proximity-based population thresholds each contain the same number of children—a number specified by the researcher. Thresholds are calculated for each child by finding “the distance between the approximate residential location of each focal child and the approximate residential location of every other child” and is analogous to “building (extremely compact) school attendance zones around every focal child and then calculating racial segregation across those zones” (p. 305). Saporito uses block centroids to represent the location of each child within that block rather than street address of individual children. This approach is computationally impractical in this study that examines over two million blocks within 484 school districts. Even without this limitation, there remains the question of fixing the threshold population number. Saporito uses a threshold of 2000 children, maintaining that this is the approximate average population of school-aged children within school attendance zones without offering any reference for this figure. Perhaps 2000 is an accurate estimate of the average number of children in an attendance zone, however, using a fixed number without addressing variability in attendance zone populations adds a source of error that is comparable to using a fixed bandwidth distance to define all neighborhoods across dissimilar regions. Using proximity-based population thresholds to define neighborhoods holds promise if variability between contexts is addressed. However, like segregation profiles, this method has only recently been introduced and it is still unclear how this method could be employed reliably to identify clusters of racial/ethnic groups.

Spatial Autocorrelation

A broad spectrum of approaches intended to assess clustering and other spatial patterns involve measures of spatial autocorrelation. Spatial autocorrelation looks at the degree to which one feature is similar of other nearby features, following Waldo Tobler's "first law of geography" that "everything is related to everything else but nearby things are more related than distant things" (Tobler, 1970, p. 236). If nearby features are more alike than distant features then spatial autocorrelation is positive. Otherwise, if nearby features are less like each other compared to distant features then spatial autocorrelation is negative. Unlike many of the segregation measures stemming from the social sciences, such as the SPI, measures of spatial autocorrelation have their origins in geography and were devised mainly by spatial econometrics scholars (Getis, 2008). Spatial autocorrelation is often used to assess the segregation dimension of evenness/clustering but positive spatial autocorrelation is not synonymous with the presence of clusters. Close proximity of like features is a necessary condition for cluster presence but not sufficient. Wong (2011) has shown how a gradient surface with no clusters produces the highest levels of spatial autocorrelation, similar to the gradient problem of the SPI. Two widely used measures of spatial autocorrelation are Moran's Index ("Moran's I" or just "I") and the Getis-Ord General ("Getis-Ord G" or just "G"). They both capture spatial autocorrelation slightly differently and will be used concurrently in this study to characterize the manner of racial/ethnic spatial clustering in the population distributions of each school district.

The segregation dimension of *clustering* can also be evaluated using distance-based approaches, like the often-used SPI mentioned previously. However, Wong (2014) finds two main drawbacks with using SPI unrelated to the gradient problem. First, SPI is a "deterministic index" that compares measured index values to the value of 1.0. As such, it cannot detect a difference between a chance array, where all groups are scattered about the region randomly, and a dispersed array, where members of groups are evenly spaced throughout the region. Second, the more uneven the groups' population sizes are, the higher the average distance between members of the minority group tends to be. Hypothetically, if the population of a minority group were cut in half but still resided in the same locations, SPI would increase, causing it to fail the principle of compositional invariance, a desired property of segregation indices. The implications of using this measure across multiple contexts, which in this study would be between school districts, would be to distort comparisons between regions having greatly different minority proportions. Mainly for this reason, this study will forgo the use of SPI, despite being the most common method of cluster analysis in segregation research, in favor of spatial autocorrelation measures. Wong (2011) addressed these limitations by developing a weighted SPI, but his index has not been fully tested, nor generally accepted, making its interpretation within the context of this study uncertain.

Appendix B: Supplemental Tables and Maps

Table B1

Association between changes in segregation and changes in fragmentation—All shrinking districts

df (1, 171)	Change in segregation (ΔH)						Change in *proportional* segregation ($\Delta H/H_0$)					
	Racial/ethnic comparison group	R	adj. R^2	*F*	*p*	b	Racial/ethnic comparison group	R	adj. R^2	*F*	*p*	b
Change in fragmentation	White-Black	.164	.021	4.699	.032	.000	White-Black	.059	-.002	.600	.440	.020
	White-Hispanic	.048	-.004	.393	.532	.000	White-Hispanic	.009	-.006	.013	.908	.000
	White-Black-Hispanic	.115	.007	2.257	.135	.000	White-Black-Hispanic	.020	-.005	.070	.791	.001
Change in *proportional* fragmentation	White-Black	.305	.088	17.349	.000*	.043	White-Black	.191	.031	6.424	.012*	.395
	White-Hispanic	.146	.016	3.684	.057	.018	White-Hispanic	.021	-.005	.098	.754	.059
	White-Black-Hispanic	.207	.037	7.577	.007*	.023	White-Black-Hispanic	.086	.001	1.255	.264	.175

Table B2

Association between changes in segregation and changes in fragmentation—All growing districts

df (1, 109)	Change in segregation (ΔH)						Change in *proportional* segregation ($\Delta H/H_0$)					
	Racial/ethnic comparison group	R	adj. R^2	*F*	*p*	b	Racial/ethnic comparison group	R	adj. R^2	*F*	*p*	b
Change in fragmentation	White-Black	.019	-.009	.040	.842	.000	White-Black	.003	-.009	.001	.973	.001
	White-Hispanic	.094	.000	.970	.327	.000	White-Hispanic	.045	-.007	.221	.693	.003
	White-Black-Hispanic	.045	-.007	.216	.643	.000	White-Black-Hispanic	.008	-.009	.007	.933	.001
Change in *proportional* fragmentation	White-Black	.289	.075	9.866	.002*	.053	White-Black	.531	.275	42.423	.000*	1.518
	White-Hispanic	.083	-.002	.753	.387	-.004	White-Hispanic	.034	-.008	.129	.721	.037
	White-Black-Hispanic	.303	.083	10.894	.001*	.027	White-Black-Hispanic	.535	.280	43.338	.000*	1.407

Table B3

Pearson correlations between clustering (Getis-Ord G and Moran's I) and proportional change in segregation (ΔH and ΔH/H0) in growing & diverse school districts.

Segregation measure	Racial/ethnic comparison	r	*p*	Cluster index
ΔH	White Black	-.109	.331	*z*(*G*)
		-.083	.456	*z*(*I*)
	White-Hispanic	.012	.912	*z*(*G*)
		.007	.954	*z*(*I*)
	White-Black-Hispanic	-.073	.515	*z*(*G*)
		-.044	.694	*z*(*I*)
$\Delta H/H_0$	White Black	-.187	.093	*z*(*G*)
		-.169	.130	*z*(*I*)
	White-Hispanic	-.092	.413	*z*(*G*)
		-.086	.442	*z*(*I*)
	White-Black-Hispanic	-.167	.133	*z*(*G*)
		-.152	.171	*z*(*I*)

Note. There was no significant correlation between change in segregation and either clustering variable for all racial/ethnic comparisons.

Table B4

Pearson correlations between clustering (Getis-Ord G and Moran's I) and proportional change in segregation (ΔH and ΔH/H0) in shrinking & diverse school districts.

Segregation measure	Racial/ethnic comparison	r	*p*	Cluster index
ΔH	White Black	.023	.798	*z*(*G*)
		.023	.801	*z*(*I*)
	White-Hispanic	-.018	.839	*z*(*G*)
		-.036	.684	*z*(*I*)
	White-Black-Hispanic	-.009	.916	*z*(*G*)
		-.020	.822	*z*(*I*)
$\Delta H/H_0$	White Black	.031	.725	*z*(*G*)
		.041	.649	*z*(*I*)
	White-Hispanic	-.073	.411	*z*(*G*)
		-.061	.492	*z*(*I*)
	White-Black-Hispanic	-.070	.434	*z*(*G*)
		-.049	.581	*z*(*I*)

Note. There was no significant correlation between change in segregation and either clustering variable for all racial/ethnic comparisons.

Table B5

Association between changes in segregation and changes in fragmentation plus ***clusterin****g—Growing districts (middle 70%)*

df (1, 80)	Change in segregation (ΔH)					Change in *proportional* segregation ($\Delta H/H_0$)				
	Racial/ethnic comparison group	R	adj. R^2	*F*	*p*	Racial/ethnic comparison group	R	adj. R^2	*F*	*p*
Change in fragmentation	White-Black	.128	.016	.435	.729	White-Black	.190	.036	.971	.411
	White-Hispanic	.083	.007	.179	.911	White-Hispanic	.125	.016	.414	.744
	White-Black-Hispanic	.113	.013	.334	.801	White-Black-Hispanic	.169	.029	.763	.518
Change in *proportional* fragmentation	White-Black	.313	.098	2.814	.045	White-Black	.628	.394	16.892	.000
	White-Hispanic	.087	.008	.198	.898	White-Hispanic	.104	.011	.286	.835
	White-Black-Hispanic	.346	.119	3.582	.019	White-Black-Hispanic	.623	.388	16.453	.000

Table B6

Association between changes in segregation and changes in fragmentation plus ***clustering****—Shrinking districts (middle 70%)*

df (1, 126)	Change in segregation (ΔH)					Change in *proportional* segregation ($\Delta H/H_0$)				
	Racial/ethnic comparison group	R	adj. R^2	*F*	*p*	Racial/ethnic comparison group	R	adj. R^2	*F*	*p*
Change in fragmentation	White-Black	.276	.054	3.409	.020	White-Black	.189	.012	1.532	.210
	White-Hispanic	.108	-.012	.492	.688	White-Hispanic	.084	.007	.291	.832
	White-Black-Hispanic	.198	.016	1.683	.174	White-Black-Hispanic	.117	.014	.571	.635
Change in *proportional* fragmentation	White-Black	.362	.131	6.245	.001	White-Black	.265	.070	3.124	.028
	White-Hispanic	.152	.023	.978	.405	White-Hispanic	.099	.010	.412	.745
	White-Black-Hispanic	.223	.027	2.170	.095	White-Black-Hispanic	.111	.012	.512	.675

Table B7

Comparison of models with and without clustering: Change in segregation vs. change in fragmentation--both absolute change and proportional change.

df(1, 80)

		ΔH with clustering		ΔH without clustering		ΔH% with clustering		ΔH% without clustering	
		adj. R^2	*p*	adj. R^2	*p*	adj. R^2	*p*	adj. R^2	*p*
ΔFrag.	W-B	0.016	*0.729*	-0.012	*0.929*	0.036	*0.411*	-0.012	*0.906*
	W-H	0.007	*0.911*	-0.007	*0.500*	0.016	*0.744*	-0.007	*0.528*
	W-B-H	0.013	*0.801*	-0.984	*0.984*	0.029	*0.518*	-0.012	*0.867*
ΔFrag.%	W-B	0.098	*0.045*	0.085	*0.005*	0.394	*0.000*	0.378	*0.000*
	W-H	0.008	*0.898*	-0.006	*0.458*	0.011	*0.835*	-0.005	*0.455*
	W-B-H	0.119	*0.019*	0.101	*0.002*	0.388	*0.000*	0.368	*0.000*

Note. "ΔFrag." is absolute change in fragmentation. "ΔFrag.%" is proportional change in fragmentation. "ΔH" is absolute change in segregation. "ΔH%" is proportional change in segregation.

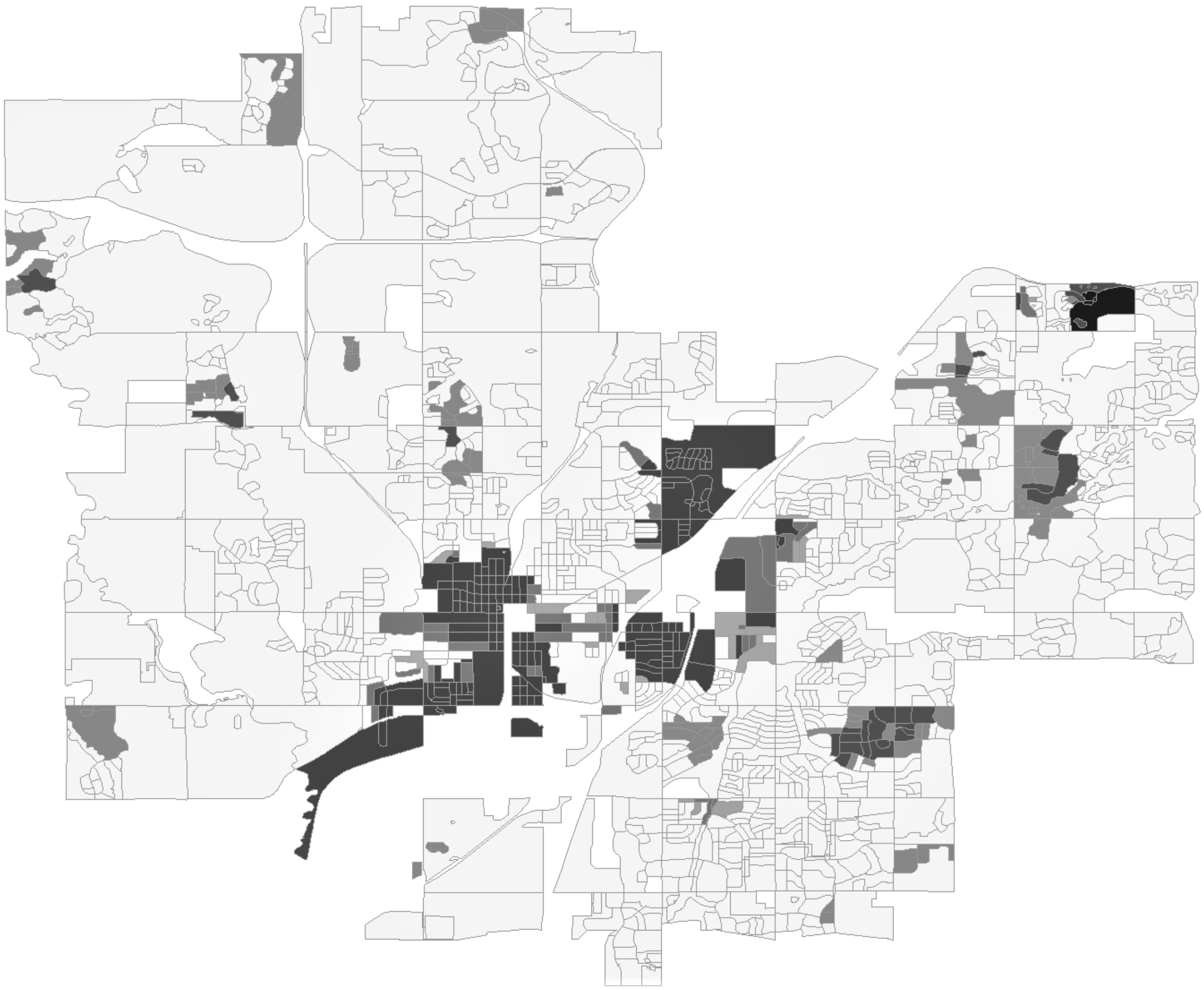

Figure B1. Census blocks in Bainbridge school district showing local clusters of white and nonwhite residents as measured by Getis-Ord Gi*.