Explaining Recent Trends in US School Segregation: 1988-2014

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Abstract

We document trends in public school segregation throughout the United States from 1988 to 2014. While predominantly minority schools have increased in prevalence, discrimination cannot be the only explanation as predominantly White schools have decreased in prevalence even faster. Overall, the majority of commuting zones in the US have experienced decreasing levels of school segregation measured in a variety of ways, and regional patterns in these trends point to changing demographics across commuting zones as an important cause. We develop an empirical framework to analyze segregation in a non-stationary environment, e.g., one that is undergoing demographic change, and conclude that this demographics are over ten times more important than discrimination in explaining the observed pace of desegregation of White schools and two times more important to explain the pace of segregation of minority schools. In recent decades, the gradual endogenous process of segregation due to discrimination has been dwarfed by a systematic and continuing inflow of minorities in most areas of the country.

1 Introduction

School segregation has occupied a prominent role in the public sphere ever since the landmark *Brown v. Board of Education* (1954) ruling and the Elementary and Secondary Education Act (1966), which identified the reduction of school segregation as a primary goal of federal policy. Recent well-publicized studies[1] have advanced the idea that schools have been growing more segregated in recent years with an increasing proportion of minority students enrolling in segregated minority schools.[2] This has led many observers in the popular press to conclude that we have en-

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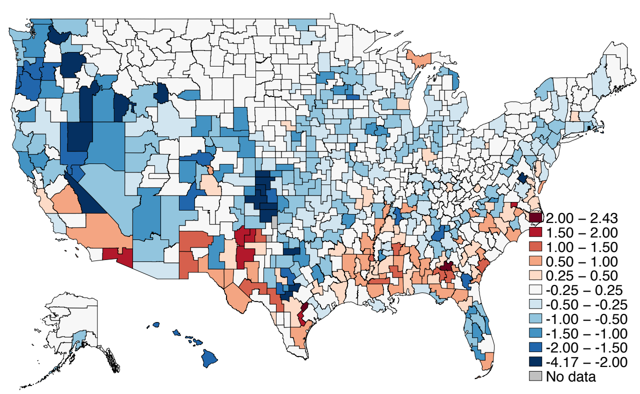
[1]See, for example, GAO-16-345 ("Better Use of Information Could Help Agencies Identify Disparities and Address Racial Discrimination," April 2016, Government Accounting Office) and Orfield et al. (2014).

[2]Throughout this paper, we will follow GAO nomenclature and use the term "minority" to refer only to Black and Hispanic students (including white Hispanics), and "White" to refer to all other students. Our results are essentially

tered into a new era of discrimination.[3] To better understand the determinants of these important trends, we argue that these findings should be viewed in the context of a broader trend: In 1988, 9% of schools were minority-segregated (over 75% minority); by 2014, 23% of schools were. At the same time, in 1988, 68% of schools were White-segregated (over 75% White), but by 2014, only 47% were. Hence, segregated White schools have been disappearing faster than segregated minority schools have been appearing.

Regional trends cast even more doubt on the view that heightened discrimination is solely to blame for the increase in segregated minority schools. In Figure 1, we present a map of the average annual change in the proportion of segregated public schools in each commuting zone of the US over a 27 year period. Blue zones, comprising most of the country, correspond to areas in which segregated schools have become rarer, while red zones, primarily distributed across parts of the sunbelt, correspond to areas in which segregated schools have become more common. As we show below, the recent desegregation of schools across the country reflects a rapid reduction in predominantly White schools. Discriminatory preferences for peers are unlikely to generate such a pattern by themselves, as theory predicts that such preferences would lead to a concentration of White students into segregated schools following, for example, White flight.

Figure 1: Average Annual Change in Proportion of Segregated Schools, 1988-2014



Note: A segregated school is defined as one in which the enrollment of minority or White students exceeds 75% of the total enrollment. Blue (Red) commuting zones have experienced declining (increasing) segregation during this period. Annual changes shown in percentage points.

unchanged if we consider all non-Whites to be minorities or if we omit all students who are not White, Black or Hispanic.

[3]See, for example, Strauss, Valerie, "School segregation sharply increasing, studies show," *The Washington Post*, 9/22/12; Bouie, Jamelle, "Still Separate and Unequal," *Slate,* 5/15/14; Toppo, Greg, "GAO Study: Segregation worsening in U.S. schools," *USA Today*, 5/17/16. In contrast, Clotfelter et al. (2006) document that segregation levels in Southern schools have remained roughly constant from 1994-2004.

In this paper, we study the determinants of recent trends in school segregation. We find that the effects of steady inflows of minority students into commuting zones have been experienced by schools of all racial compositions within those areas. This has led to the concomitant increase in the number of segregated minority schools and reduction in the number of segregated White schools. In order to identify the effects of this demographic change, we extend a recently developed empirical framework to study school segregation (Caetano and Maheshri (2017)) in two directions: (1) We analyze segregation across the entire country, which allows us to explore the role of aggregate demographic effects, and (2) We analyze how these effects unfold over the short-run and the long-run.

Aggregate demographic changes can continue to affect the racial composition of school enrollments over many periods because of dynamic social multiplier effects first described in the seminal Schelling model of segregation.[4] If, for example, parents prefer their children to attend schools with more peers of the same race, then inflows of minorities may lead to a positive feedback loop in which successively more (fewer) minority (White) students enroll in some schools, while the opposite may occur in other schools, ultimately leading to highly segregated schools. This process, colloquially known as "tipping," is further complicated by general equilibrium effects, as a school in the process of tipping may affect the attractiveness of close substitutes, potentially setting the racial compositions of other schools off on different trajectories. Identifying both the short-run and long-run effects of demographic change is thus difficult because of the well known obstacles inherent in identifying social effects (Manski (1993)) and the necessity to account for these effects in all schools simultaneously. We circumvent the first of these difficulties with the use of instrumental variables based on plausibly exogenous variation in the enrollments of adjacent cohorts of students as developed in (Caetano and Maheshri (2017)). This allows us to determine how White and minority parents differentially respond to the minority shares of schools, which in turn can be used to identify the extent to which demographic trends and discriminatory sorting have impacted segregation *independently* of other changes to the local schooling environment (e.g., due to local policies or changes in school-specific amenities). We circumvent the second of these difficulties with a novel simulation procedure that allows us to estimate the co-evolution of the racial compositions

[4] We use the phrase "Schelling model" to refer to the seminal model of segregation put forth in Schelling (1969), Schelling (1971) and Schelling (2006).

of all schools simultaneously under different counterfactuals.

The demand responses that we estimate are consistent with discriminatory preferences: all else constant, White parents tend to leave schools that are increasing in minority share, whereas minority parents tend to enroll in those schools.[5] While White parents respond to changes in the racial composition of a school roughly twice as strongly as minority parents, these responses are moderate and have not changed systematically over time.[6] Our findings of moderate discriminatory demand responses may not necessarily reflect parents' moderate discriminatory *preferences*, but rather it may reflect a moderate ability to exercise their (potentially strong) discriminatory preferences. All else constant, even these moderate discriminatory responses would be enough to increase the number of White and minority segregated schools in the long-run. However, all else has not been constant in the US over the past quarter century. In a non-stationary environment with systematic inflows of minorities in the commuting zones, the relative importance of discrimination to explain the observed trends in segregation diminishes, as the gradual increases in segregation that are due to discriminatory sorting take time to accumulate. For predominantly White schools, the short-run effect of these aggregated demographic trends is fourteen times more important than the short run effect of discrimination in explaining the observed trends in segregation. For predominantly minority schools, the demographic explanation is two times more important than the discrimination explanation.

Policymakers that aim to improve student achievement, graduation rates, and long-run outcomes in the labor market (and, importantly, reduce racial gaps in these outcomes) have good reason to target school segregation. A high concentration of minority students has been repeatedly found to adversely effect minority achievement (Guryan (2004); Card and Rothstein (2007); Hanushek et al. (2009); Fryer Jr (2010)). More broadly, segregated schools have been linked to long-run adverse effects on the occupational aspirations, expectations, and attainment of minority students (Wells and Crain (1994)) at least in part through social network effects (Granovetter (1986); Julius (1987)). We find that changing demographic trends will heavily shape the effectiveness of any particular policy. But in a broader sense, our analysis shows that any higher level

[5] These findings of homophilic racial responses complement the extensive literature in economics that has estimated revealed racial preferences in housing markets (Bajari and Kahn (2005)), dating and marriage markets (Fisman et al. (2008)), and friendships (Currarini et al. (2010)).

[6] Our finding that White and minority parents exhibit no more or less discrimination towards minority peers in 2005 than in 2014 is consistent with surveys of stated racial attitudes (Bobo et al. (2012)).

intervention, whether explicit as in the case of federal and regional policy or implicit as in the case of demographic shift, has the potential to affect the racial composition of a single school when parents are free to choose where to enroll their children. Importantly, different schools are susceptible to such policies to differing degrees, so much so that in equilibrium, a policy that decreases the minority share in some minority-segregated schools may even increase it in other minority-segregated schools in the long run. An important implication of this is that there may be substantial scope for highly localized policies (e.g., at the school or neighborhood level) and place-based investments to mitigate increases in segregation. To that end, we view our findings as complementary to the large literature on Tiebout (1956) sorting and school choice.[7]

The remainder of the paper is organized as follows. In Section 2, we describe our data set and document how the levels of school segregation have evolved from 1988 to 2014. We also document geographic trends in the racial composition of students enrolled in public schools. In Section 3, we present a theoretical model of segregation that highlights the role of demographics and endogenous social effects in determining the racial composition of schools, and we show how this model can be taken to the data. In Section 4, we develop a strategy to identify endogenous social effects in school choice, and we present our estimates of these responses. Using these estimates, we leverage our model to assess the extent to which demographic shifts have contributed to short-run and long-run trends in segregation in Section 5. We conclude in Section 6.

2 National and Regional Trends in School Segregation

Our sample consists of all students enrolled in all public schools in the United States from 1988-2014.[8] We obtain enrollment data from the Common Core of Data maintained by the National Center for Education Statistics at the US Department of Education. For each public school in the country, we observe the numbers of White, Black, Hispanic, Asian and Native American students enrolled in each year, and we use the term minority to refer to any Black or Hispanic student (including White Hispanics) and the term White to refer to any other student.[9]

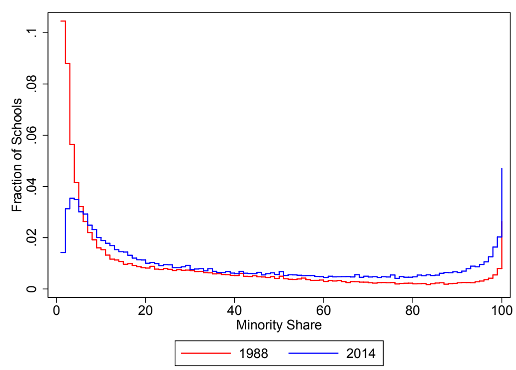
[7] See, for example, Epple and Sieg (1999), Bayer et al. (2004), Urquiola (2005), Bayer et al. (2007), Billings et al. (2013) and Caetano and Macartney (2013).

[8] We use 2000 to refer to the 2000-01 academic year and follow this convention throughout the paper. We restrict our sample to the 50 states and the District of Columbia and ignore schools in US territories. Enrollment data from a small number of states in some early years of the sample are missing. We provide detailed documentation of our sample in Appendix A.

[9] This definition of White and minority follows the US Government Accountability Office study GAO-16-345. If we instead define minorities as all non-white students or omit all Asian and Native-American students from our sample,

We begin by documenting changes in the racial composition of schools at the national level. In Figure 2, we present empirical distributions (PDFs) of the minority share of enrollment in all US schools in 1988 and 2014, from which we draw two important implications. First, each distribution is bi-modal, so the cross-sectional variation in the racial composition of schools is consistent with the Schelling model of segregation in which discriminatory, homophilic responses by parents lead to the proliferation of predominantly White and predominantly minority schools. Second, the distribution in 2014 is shifted to the right relative to 1988 (in fact it stochastically dominates it). This longitudinal variation in the racial composition of schools is unlikely to be generated by discriminatory responses, which would lead to increases in the density at *both* extremes. Instead, it is more suggestive of a demographic shift towards a more highly minority student body.

Figure 2: Empirical Distribution of Minority Share of US Schools, 1988 and 2014



The national trend in Figure 2 is supported by regional patterns in school segregation. In Figure 3, we present the change in the proportion of schools that have over 75%[10] White and minority enrollments disaggregated to the commuting zone level (as defined in the 2000 Census).[11] These maps correspond to the data presented in Figure 1 broken down by race. From panel 3a, it is evident that the prevalence of White segregated schools has diminished throughout the country, often at annual rates of 1-4%. The national trend revealed in the left tails of Figure 2 has unfolded in both highly populated metropolitan areas and relatively less diverse rural areas. In panel 3b, we see that minority segregated schools have become more prevalent over the sample period throughout the

our results are essentially unchanged.

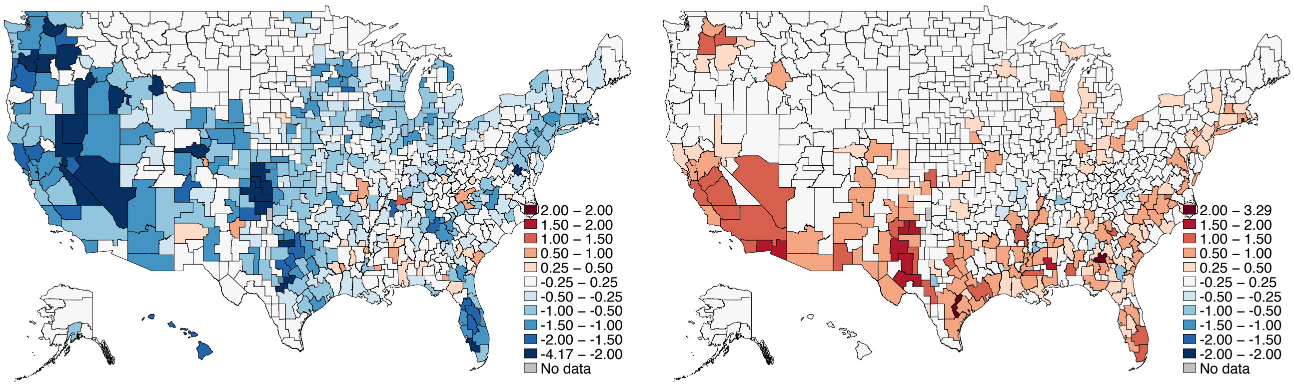
[10]We find highly similar patterns when we adopt any alternative threshold between 66% and 90% to define a school as segregated.

[11]This choice of aggregation is consistent with other recent work on local "socioeconomic" markets such as Chetty et al. (2014).

sunbelt (especially along the Mexican border) at an annual rate of 0.5-2%, and to a lesser extent, in urban areas of the Northeast and rust belt at an annual rate of 0.25-1%. This is consistent with the national trend revealed in the right tails of of Figure 2. The larger magnitudes and broader geographic scope of the desegregation of White schools relative to the segregation of minority schools has resulted in a public school system that is becoming less segregated over time.

Figure 3: Average Annual Change in Proportion of Segregated Schools, 1988-2014

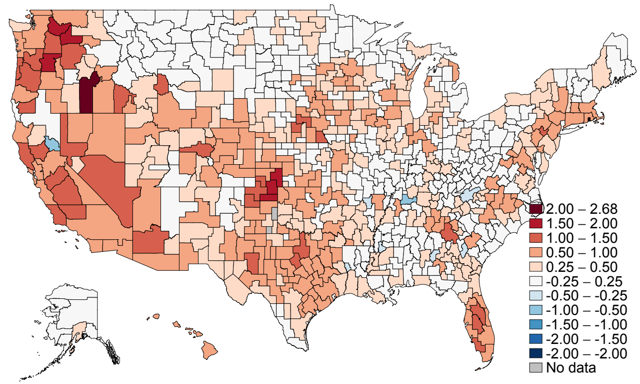
(a) Change in Proportion of Segregated White Schools (b) Change in Proportion of Segregated Minority Schools



Note: A segregated school is defined as one in which the enrollment of White (or, respectively, minority) students exceeds 75% of the total enrollment. Blue (Red) commuting zones have experienced declining (increasing) segregation during this period. Annual changes shown in percentage points.

The shift in distributions in Figure 2 that are consistent with broad demographic change suggests we should explore whether the clear regional patterns in Figure 3 accompanied a similar regional pattern in demographics. In Figure 4, we present the average annual change in the minority share of enrollments at the commuting zone level. Demographic changes over this period have been widespread, leading to a greater fraction of minority students in all regions of the US. The regional pattern matches Panel 3a closely, suggesting that changing demographics may play an important role in explaining the recent trends in school segregation.

Figure 4: Change in Minority Share of Students in Commuting Zone, 1988-2014



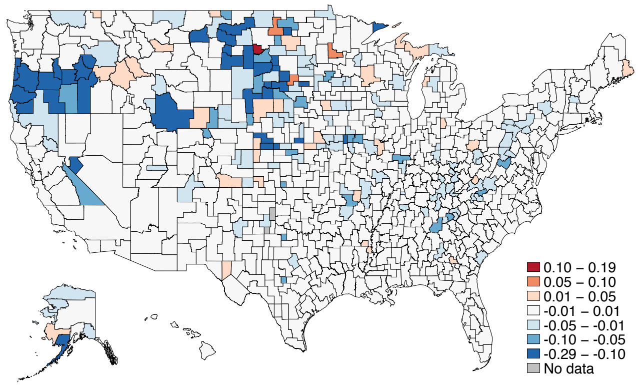
Note: Map shows average annual change in the minority share of all students in each commuting zone in percentage points. Red (blue) areas have become more (less) heavily minority.

To further our understanding of national and regional trends in school segregation, we turn to a variety of alternative measures of segregation to see how they have changed since 1988. A large literature in the social sciences has assessed the advantages and disadvantages of different measures of segregation (see, e.g. Massey and Denton (1988)), and while no single measure can fully capture all aspects of segregation – similarity in the racial composition of schools, concentration of racial groups, isolation, entropy – certain measures are well suited to capture particular aspects of segregation. Taken together, they are complementary and reveal a fuller view of how segregation has evolved.

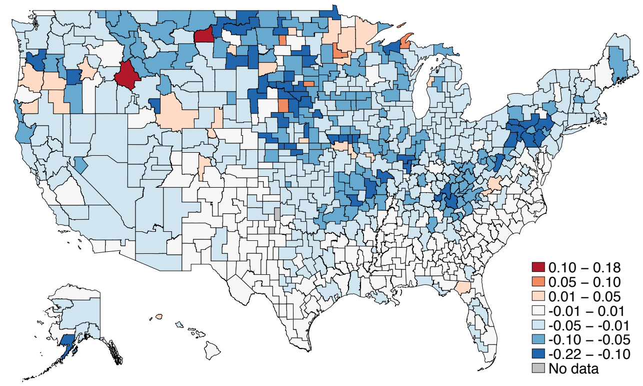
In Figure 5, we present the average annual change in five different standard measures of segregation (details on the construction of each measure can be found in Appendix B). In order to facilitate meaningful comparisons, we standardize each measure, so, for example, "0.01" corresponds to an average annual increase of 0.01 standard deviations of the corresponding measure. All maps are colored such that red areas have become more segregated while blue areas have become less segregated. We present the change in the simplest measure of the concentration of minorities, the Herfindahl Index, in panel 5a. This index measures the extent to which minorities in a commuting zone are evenly distributed across schools. We find no change in this index in the vast majority of the country over the sample period. Because this measure is quite insensitive to the aggregate racial composition of the student body at the commuting zone level, this is consistent with demographics driving the changes in Figure 3. In panel 5b, we present the change in the Theil Index, which is a commonly used index of segregation (e.g. Chetty et al. (2014)) that measures the difference between the observed allocation of minority students and a hypothetical random allocation of minority students across all schools in a commuting zone; it is also fairly insensitive to changing demographic trends. As measured by the Theil Index, segregation has slightly decreased in most of the country (larger decreases are visible in more sparsely populated regions). In panel 5c, we present the change in the Dissimilarity Index, which corresponds to the minimal fraction of minority (or White) students in a commuting zone that would have to switch schools in order to obtain a perfectly even allocation of students across all schools. According to this measure, segregation has increased slightly in the sunbelt while decreasing in other parts of the country. This pattern is consistent with a demographic shift characterized by an influx of minorities in the sunbelt, but it is inconsistent with purely discriminatory sorting. Finally, in panels 5d and 5e, we present the changes in the Isolation Indices of White and minority students respectively. These indices measures the extent to which students of a given race interact with students of that race. Not surprisingly, White students have become less isolated in most populated regions outside the South, and all minority students have become more isolated in parts of the sunbelt and Midwest that have seen the greatest relative inflows of minority students. The trend for minority students is consistent with both demographic change and discriminatory sorting, but the trend for White students is only broadly consistent with demographic change.

Figure 5: Change in Various Measures of Segregation, 1988-2014

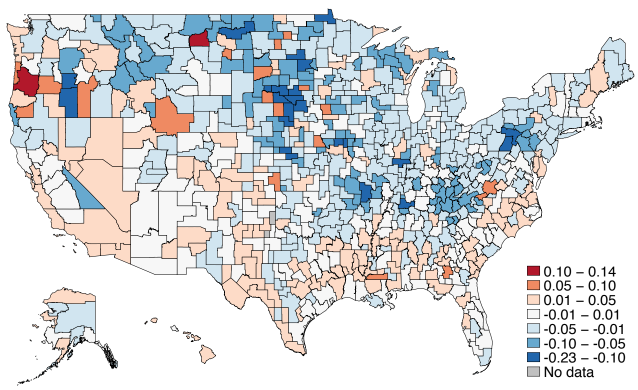
(a) Herfindahl Index



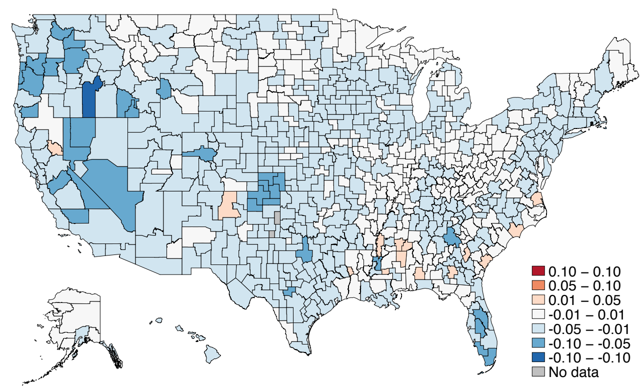
(b) Theil Index



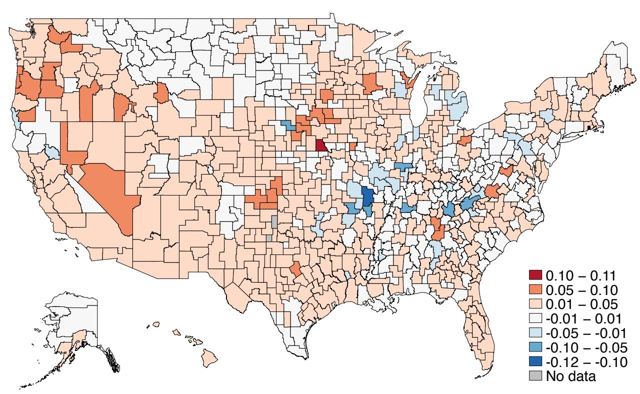
(c) Dissimilarity Index



(d) Isolation Index (Whites)



(e) Isolation Index (Minorities)



Note: Each map shows the average annual change in a particular measure of segregation. Each measure has been standardized, so "0.01" corresponds to an average annual increase of 0.01 standard deviations. Red (blue) areas have become more (less) segregated. Details on the construction of each measure can be found in Appendix B.

Taken altogether, a quarter century of enrollment data reveals broad decreases in segregation throughout the country measured in a variety of ways. Although highly segregated minority schools have become more prevalent, segregated White schools have become less prevalent at a higher rate. Hence, schools in the country tend to be less segregated in 2014 than in 1988, and all race-blind measures of segregation (Herfindahl, Theil and Dissimilarity Indices) have tended to decrease. This evidence leads us to conjecture that recent trends in segregation are predominantly driven by demographic shifts as opposed to increases in or a persistence of discriminatory preferences for peers.

3 Determinants of Segregation: Theory and Empirics

3.1 A Theoretical Model of Segregation

We begin with a simple, standard model of segregation in the spirit of Schelling (1969) and Becker and Murphy (2000) whereby households in observe the amenities of local schools and then choose where to enroll their children. Formally, let N_{rt} denote the total number of school-aged White ($r = W$) and minority ($r = M$) children living in a commuting zone with J public schools in year t. For each school j, we define n_{rjt} to be the number of race r students enrolled in year t. The school's racial composition, defined as

$$s_{jt} = \frac{n_{Mjt}}{n_{Wjt} + n_{Mjt}} \tag{1}$$

corresponds to the minority share of the school. Before the start of each school year, parents observe the amenities of all public schools in the area (including their historical racial composition) and then decide where to enroll their child. Given this set up, the race r demand for school j can be written as

$$n_{rjt} = N_{rt} \cdot \pi_{rj} \left(\boldsymbol{s_{t-1}}, \boldsymbol{X_t}\right) \tag{2}$$

where the general, school-specific function π_{rj} is the probability that a parent of a given race enrolls their child in a particular school, $\boldsymbol{s_{t-1}}$ is a vector whose jth element is s_{jt-1}, and $\boldsymbol{X_t}$ is a matrix of other school-specific amenities, whose jth element is vector $\boldsymbol{X_{jt}}$.[12] Together, equations (1) and (2) define how the race-specific enrollments (and hence the racial composition) of a school evolve from $t-1$ to t. The three arguments in equation (2), N_{rt}, $\boldsymbol{s_{t-1}}$, and $\boldsymbol{X_t}$ correspond to three distinct

[12] Hereafter, vectors and matrices are displayed in bold typeface.

mechanisms behind this process.

First, variation in the racial composition of the overall enrollment of the commuting zone over time due to migration or fertility differences across races (i.e., $\boldsymbol{N_{rt}} \neq \boldsymbol{N_{rt-1}}$ where $\boldsymbol{N_{rt}} = \{N_{Wt}, N_{Mt}\}$) can cause the racial compositions of individual schools to change simply because these new students must enroll somewhere. For example, a regional influx of minority households with children would increase the minority share of at least some schools.[13] We denote this mechanism as *demographic*.

Second, parents of different races may respond systematically differently to the racial composition of a school (i.e., $\frac{\partial \pi_{Wj}}{\partial s_{kt-1}} \neq \frac{\partial \pi_{Mj}}{\partial s_{kt-1}}$). As a result, equations (1) and (2) together characterize a dynamic system (note that the arguments on the left and right hand sides of equation (2) are in different time periods). As a result, this mechanism can reinforce the effects of demographic changes through dynamic social multiplier effects, and it can also result in a positive feedback loop commonly associated with segregation – "tipping". Because these dynamics will propagate even in the absence of any other changes to the schooling environment, we denote this mechanism as *endogenous*.

Finally, the racial composition of a school can be affected by local variation in school-specific amenities besides $\boldsymbol{s_{t-1}}$. This could happen because these amenities may be valued differently by Whites and minorities (i.e., $\frac{\partial \pi_{Wj}}{\partial x} \neq \frac{\partial \pi_{Mj}}{\partial x}$ where x is a specific amenity in $\boldsymbol{X_{kt}}$). For instance, if White parents value football more than minority parents, then increases to the football budget of a particular school would be expected to decrease the minority share of enrollment in that school. In contrast to the endogenous mechanism, changes to these amenities do not generate dynamic multiplier effects by themselves; accordingly, we denote this mechanism as *exogenous*.

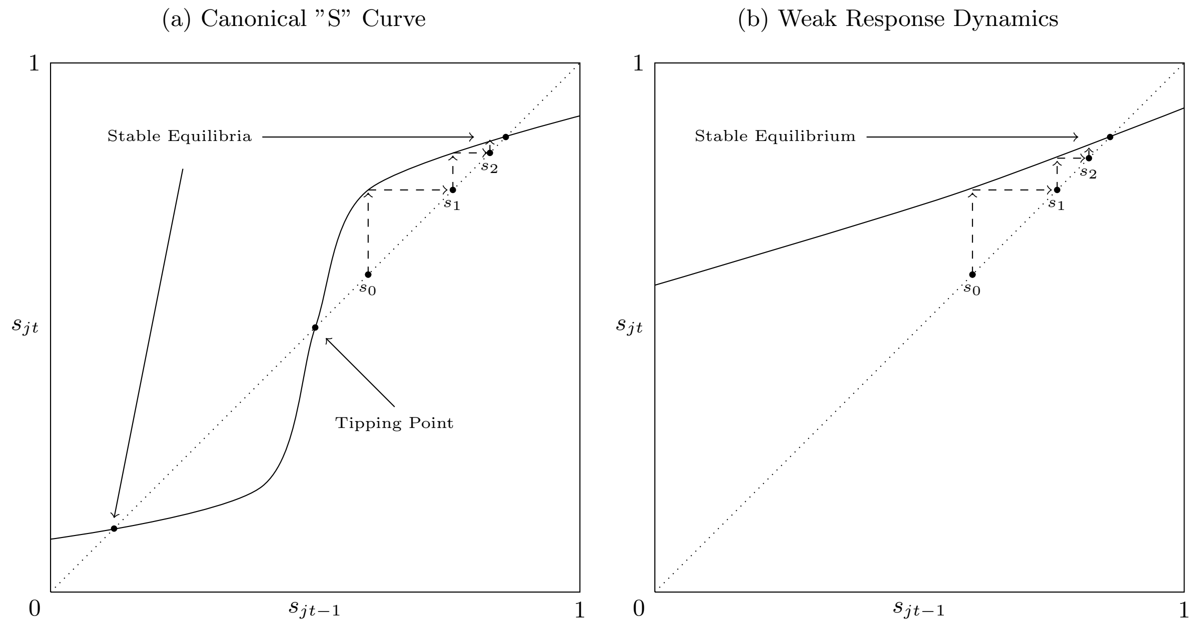
We can combine equations (1) and (2) to obtain the dynamics of the racial composition of school j, which we present graphically in Figure 6.[14] In panel 6a, we plot a *ceteris paribus* curve of s_{jt} on s_{jt-1} holding $\boldsymbol{N_{rt}}$, $\boldsymbol{s_{-jt-1}}$ and $\boldsymbol{X_t}$ fixed[15], which summarizes the endogenous evolution

[13] A relative change in the propensity of students of one race to enroll in private schools could also affect $\boldsymbol{N_{rt}}$. Nationally, the racial composition of private schools has changed very little from 2001-2013 from 18.3% minority to 19.5% minority (source: *Private School Universe Survey,* 2001-2002 and 2013-2014, National Center for Education Statistics).

[14] To simplify exposition, we assume that White and minority parents have homophilic preferences for peers, i.e., $\frac{\partial \pi_W}{\partial s_{jt-1}} < 0$ and $\frac{\partial \pi_M}{\partial s_{jt-1}} > 0$ when drawing Figure 7. We do not make this assumption in our empirical analysis but instead obtain it as a result of estimation.

[15] $\boldsymbol{s_{-jt-1}}$ denotes the subvector of $\boldsymbol{s_{t-1}}$ without the element s_{jt-1}.

Figure 6: Dynamics of s_{jt}



of s_{jt} in a canonical "S" curve. Points at which the curve intersects the 45 degree line represent equilibria; stable equilibria correspond to points where the curve crosses from above, while the equilibrium in between corresponds to a tipping point. In panel 6b, we plot an alternative *ceteris paribus* curve of s_{jt} on s_{jt-1} assuming dynamic responses are weak (i.e., $\frac{\partial \pi_{Wj}}{\partial s_{kt-1}}$ and $\frac{\partial \pi_{Mj}}{\partial s_{kt-1}}$ are small). Such weak responses may cause the "S" curve to collapse and only intersect the 45 degree line at a single, stable equilibrium. Deducing the dynamics of the racial composition of j from the figure is straightforward; for a hypothetical school with a racial composition of s_0, the endogenous mechanism will result in a racial composition of s_1 one period ahead, s_2 two periods ahead, and so on. The locations of equilibria and the speeds of convergence depend upon $\boldsymbol{N_{rt}}$, $\boldsymbol{s_{-jt-1}}$ and $\boldsymbol{X_t}$ since different values of these would result in shifts and deformations of the "S" curve. This implies that these curves are school-specific (and year-specific). Following the literature (e.g., Schelling (1971); Bayer and Timmins (2005)), we utilize the canonical "S" curve for the remainder of the explanation of our model.

In order to assess the extent to which demographic shifts have contributed to recent trends in the racial compositions of schools, we consider the effect of an inflow of minorities to the commuting zone (i.e., an increase in N_{Mt}). In panel7a, we consider a school that was in equilibrium in $t-1$

(i.e., either at point $A^{\star}$ or $B^{\star}$). The inflow of minorities results in an upward shift of the "S" curve to the dotted curve, resulting in new equilibria. For the school at point $A^{\star}$, the demographic shift from $t-1$ to t generates the short-run effect shown as the red arrow. Other things equal, the school is no longer in equilibrium in period t and will move along a trajectory to the new equilibrium $A^{\star\star}$. The endogenous mechanism acts as a dynamic social multiplier, generating an additional social effect from t onward shown as the blue arrow. The long-run demographic effect will be equal to the instantaneous effect plus the social effect, which is the vertical distance from $A^{\star}$ to $A^{\star\star}$. Similar logic holds for the school at point $B^{\star}$. Note that the magnitudes of these effects depend not only on the demographic shift but also on the locations of the stable equilibria and the shapes of the "S" curves, both of which also depend on $\boldsymbol{s_{-jt-1}}$, $\boldsymbol{X_t}$ and the shape of π_{rj} for all r.[16]

This analysis is more complicated when schools are out of equilibrium in $t-1$. Such schools would be subject to an endogenous social effect even in the absence of a demographic shift, hence this must be accounted for when calculating the long run effects of changing demographics. In panel 7b, we consider two schools with the same curve that are out of equilibrium in $t-1$. The school at point C would have moved along the solid curve to $C^{\star}$ through the "old" social effect shown as the green arrow. The inflow of minorities instead generates a short-run effect shown as the red arrow. Because the new equilibrium is at $C^{\star\star}$, the endogenous mechanism generates a "new" long-run social effect shown as the blue arrow. The total long-run effect, which is the vertical distance from the old equilibrium, $C^{\star}$, to the new equilibrium, $C^{\star\star}$, is thus equal to

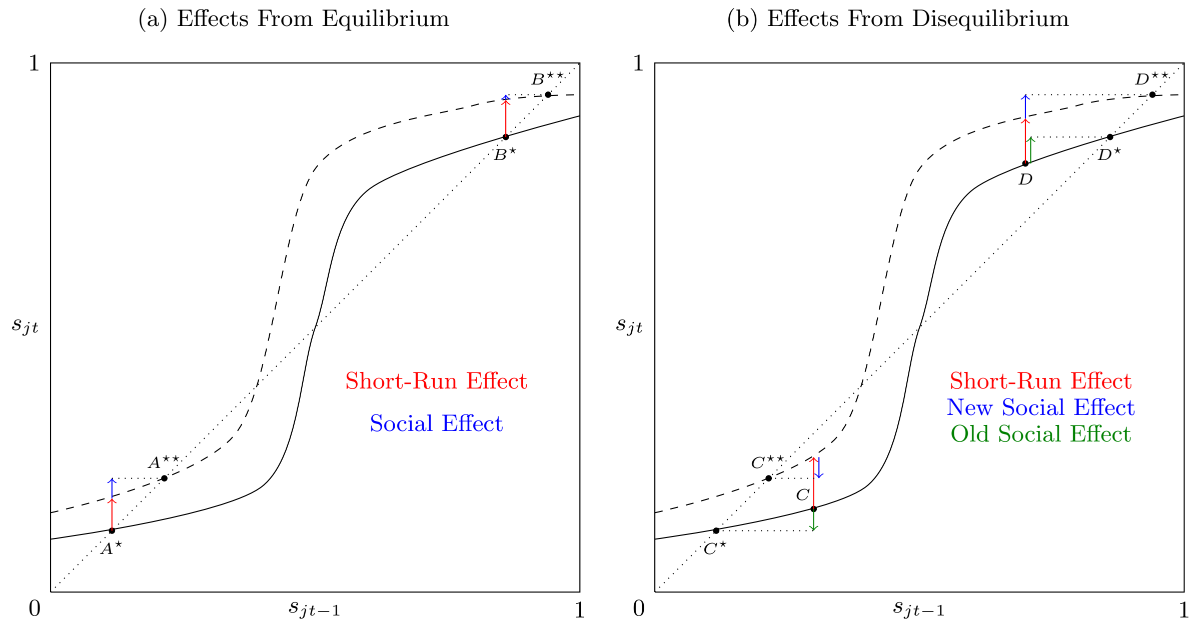
$$\text{LR Effect} = \text{Short-Run Effect} + \text{New Social Effect} - \text{Old Social Effect} \tag{3}$$

Similar logic holds for the school at point D. Note that these three effects might not all have the same signs. Not only are they dependent on the demographic shift, locations of stable equilibria and shapes of the "S" curves as before, they also depend on the extent to which schools are out of equilibrium in $t-1$. (We discuss the practical implications of this in greater detail with our results in Section 5.) For the special case when schools are in equilibrium in $t-1$ (as in Figure 7), the old social effect is equal to zero.

The diagrams shown in Figures 6 and 7 present the dynamics of the racial composition of a

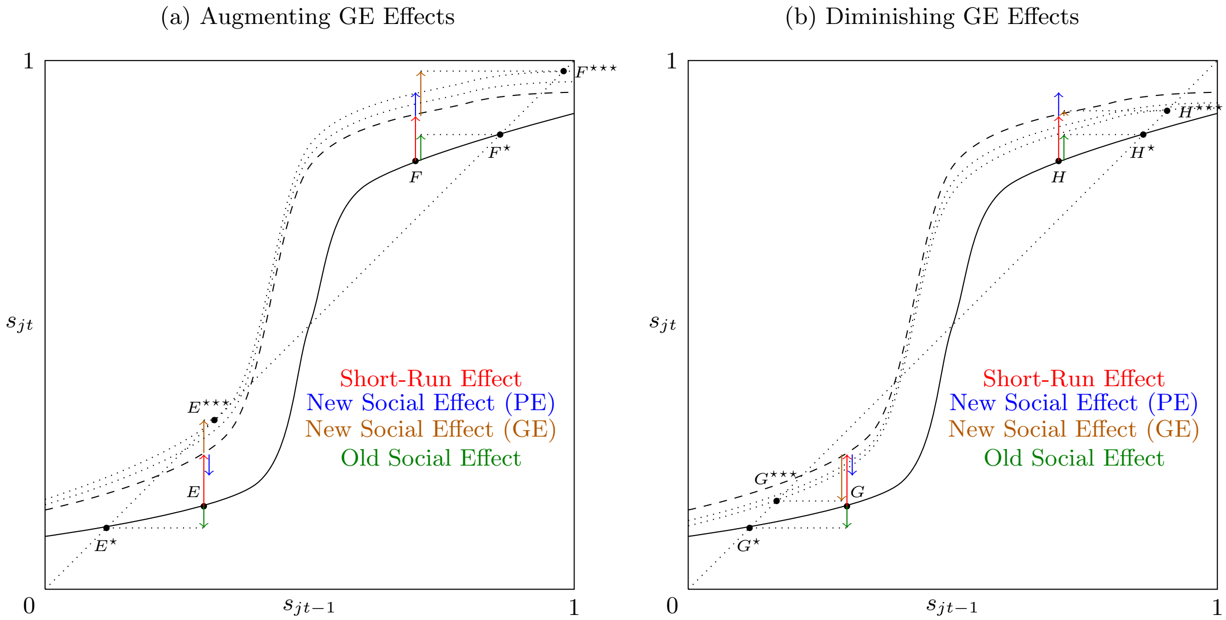
[16]The function π_{rj} captures the degree of substitution between school j and the other schools $k \neq j$, and the degrees of complementarity/substitution between the amenities of a given school.

Figure 7: Demographic Effects on s_{jt}



single school, hence the equilibria as drawn represent only partial equilibria. However, equation (2) implies that enrollment demand for a single school j is potentially a function of the prior racial compositions of *all* schools in the commuting zones ($\boldsymbol{s_{t-1}}$) depending on substitution patterns across schools. As a result, changes in the racial composition of one school may have complex general equilibrium effects on the dynamics of other schools (and these effects may feed back on each other as well). General equilibrium effects can be represented as additional shifts of the "S" curve, which we draw in Figure 8. In the first panel, we show general equilibrium effects that augment the short-run demographic effect, pushing the "S" curve further up. For clarity, we show only two iterations of these effects. The short-run and old social effects are unchanged by general equilibrium considerations, but the new social effect is now augmented in the direction of increasing minority share. A comparison of the blue and the brown arrows indicates that this can flip the direction of the new social effect. In the second panel, we show general equilibrium effects that diminish the short-run demographic effect, pushing the "S" curve further down. Once again, only the new social effect is changed. In principle, these effects could be so powerful that the stable general equilibrium (shown with three stars) lies to the other side of the initial point than the original equilibrium (shown with one star). In such cases, the total long run effect of a demographic

Figure 8: General Equilibrium Demographic Effects on s_{jt}



change would move in the opposite direction of the short-run effect. If this happened in enough schools, then an influx of minorities might actually lead to *fewer* minority segregated schools in a commuting zone. For instance, if this demographic shift made a previously 85% minority school relatively more attractive than a previously 75% minority school, then the minority share of the latter school could in principle decrease in spite of the aggregate change. It follows that the true long-run effect in equation (3) should be calculated with new social effects that incorporate general equilibrium considerations.

3.2 An Empirical Model of Segregation

Our simple model of segregation has a straightforward empirical analog that can be easily taken to data. Because we observe enrollments across many commuting zones, we first index all variables with c. Following a standard discrete choice framework (McFadden (1973), Berry (1994), Berry et al. (1995)),[17] we specify the demand equation as:

$$\log n_{rjct} = \beta_{rc} \cdot s_{jct-1} + \gamma_{rct} + \epsilon_{rjct} \tag{4}$$

[17] As discussed in Caetano and Maheshri (2017), this demand equation can be understood in a discrete choice framework with no mathematical modification.

The parameter β_{rc} represents the enrollment response by parents of each race to the minority share of the school, and is allowed to vary by commuting zone. The race-commuting zone-year fixed effect γ_{rct} subsumes N_{rct} and encapsulates any demographic changes in the overall commuting zone level enrollment of each race (due to fertility, migration, shifts to private schools, etc). Finally, the residual ϵ_{rjct} subsumes $\boldsymbol{X_t}$ and includes all school-specific amenities other than its minority share to the extent that they affect the choices of households who already have decided to enroll in c. It follows that the first term in the right-hand-side of equation (9) corresponds to the endogenous mechanism, the second term corresponds to the demographic mechanism and the third term corresponds to the exogenous mechanism. Because each of these three terms varies at the commuting zone level, we explicitly allow for the importance of each of the three channels to vary by location and time.[18]

With causal estimates of the social effects, $\hat{\beta}_{rc}$, we can compute the short-run and the long-run effects of observed demographic changes on the racial composition of each school in c and the overall level of segregation in c. This requires us to simulate the evolution of the racial compositions of all schools many periods into the future.

For a given counterfactual number of total students of each race in the commuting zone, $\boldsymbol{\tilde{N}_c} = (\tilde{N}_{Wc}, \tilde{N}_{Mc})$, we can simulate the counterfactual minority share of each school and number of total students in future periods $t+\tau$, $\tau = 0, 1, 2, \ldots$ using the recursive equation

$$n_{rjct}\left(\tilde{N}_{rc}, \boldsymbol{\tilde{s}_{ct+\tau-1}}\right) = \tilde{N}_{rc} \cdot \pi_{rjct}\left(\boldsymbol{\tilde{s}_{ct+\tau-1}}, \boldsymbol{X_{ct}}\right)$$
$$\tilde{s}_{jct+\tau} := s_{jct}\left(\boldsymbol{\tilde{N}_c}, \boldsymbol{\tilde{s}_{ct+\tau-1}}\right) = \frac{n_{Mjct}\left(\tilde{N}_{Mc}, \boldsymbol{\tilde{s}_{ct+\tau-1}}\right)}{n_{Mjct}\left(\tilde{N}_{Mc}, \boldsymbol{\tilde{s}_{ct+\tau-1}}\right) + n_{Wjct}\left(\tilde{N}_{Wc}, \boldsymbol{\tilde{s}_{ct+\tau-1}}\right)}$$

where $\boldsymbol{\tilde{s}_{ct+\tau-1}} = \boldsymbol{s_{ct-1}}$ and $\pi_{rjct}\left(\boldsymbol{\tilde{s}_{ct+\tau-1}}, \boldsymbol{X_{ct}}\right) = \frac{n_{rjct}}{\sum_{k\in c} n_{rkct}}$ for $\tau = 0$, and $\pi_{rjct}\left(\boldsymbol{\tilde{s}_{ct+\tau-1}}, \boldsymbol{X_{ct}}\right) = \frac{\tilde{n}_{rjct}\left(\tilde{N}_{rc}, \boldsymbol{\tilde{s}_{ct+\tau}}\right)}{\sum_{k\in c} \tilde{n}_{rkct}\left(\tilde{N}_{rc}, \boldsymbol{\tilde{s}_{ct+\tau}}\right)}$ with $\log \tilde{n}_{rjct}\left(\tilde{N}_{rc}, \boldsymbol{\tilde{s}_{ct+\tau}}\right) = \log n_{rjct}\left(\tilde{N}_{rc}, \boldsymbol{\tilde{s}_{ct+\tau-1}}\right) + \hat{\beta}_{rc}(\tilde{s}_{jct+\tau} - \tilde{s}_{jct+\tau-1})$ for $\tau = 1, 2, \ldots$.

In order to estimate the effects of demographic changes, we perform this simulation under two counterfactuals. In the first counterfactual, we assume $\boldsymbol{\tilde{N}_c} = \boldsymbol{N_{ct-1}}$, and in the second counterfactual, we assume $\boldsymbol{\tilde{N}_c} = \boldsymbol{N_{ct}}$. These respectively correspond to a baseline that assumes no

[18]In practice, we also allow it to vary by type of school (e.g., K-5, 6-8, 9-12, etc).

demographic change from $t-1$ to t, and to a counterfactual that assumes that the commuting zone level demographics only evolved from $t-1$ to t as observed in the data. In both counterfactuals, we set $\tilde{\boldsymbol{s}}_{\boldsymbol{ct-1}}$ equal to the observed minority shares of all schools in period $t-1$, $\boldsymbol{s}_{\boldsymbol{ct-1}}$. This allows us to estimate the short- and long-run effects of this demographic change in school j as follows:

$$\begin{aligned}\text{SR Effect} &= s_{jct}\left(\boldsymbol{N_{ct}}, \boldsymbol{s_{ct-1}}\right) - s_{jct}\left(\boldsymbol{N_{ct-1}}, \boldsymbol{s_{ct-1}}\right) && (5)\\ \text{LR Effect} &= \lim_{\tau\to\infty} s_{jct+\tau}\left(\boldsymbol{N_{ct}}, \tilde{\boldsymbol{s}}_{\boldsymbol{ct+\tau-1}}\right) - \lim_{\tau\to\infty} s_{jct+\tau}\left(\boldsymbol{N_{ct-1}}, \tilde{\boldsymbol{s}}_{\boldsymbol{ct+\tau-1}}\right), \quad \tilde{\boldsymbol{s}}_{\boldsymbol{ct-1}} = \boldsymbol{s_{ct-1}} && (6)\end{aligned}$$

Finally, to match the relevant arrows in Figure 8, we can decompose these effects as

$$\begin{aligned}\text{New Social Effect (GE)} &= \lim_{\tau\to\infty} s_{jct+\tau}\left(\boldsymbol{N_{ct}}, \tilde{\boldsymbol{s}}_{\boldsymbol{ct+\tau-1}}\right) - s_{jct-1} && (7)\\ \text{Old Social Effect (GE)} &= \lim_{\tau\to\infty} s_{jct+\tau}\left(\boldsymbol{N_{ct-1}}, \tilde{\boldsymbol{s}}_{\boldsymbol{ct+\tau-1}}\right) - s_{jct-1} && (8)\end{aligned}$$

4 Estimating Social Effects

Empirically implementing our model requires causal estimates of β_{rc}, the social effect that generates the endogenous mechanism behind segregation. Before delving into our identification strategy, we should comment on the appropriate interpretation of β_{rc}. As a parameter of a demand response, it represents how individuals' enrollment *choices* at a given school are affected by its past racial compositions of schools. This should not be understood to be equivalent to individuals' *preferences* for the past racial composition of a school or any simple transformation thereof. While it is true that β_{rc} is influenced by parents' preferences for the racial composition of schools, it is also comprised of all other environmental considerations that affect the ability of parents to exercise those preferences such as the availability of local schools with the desired levels of amenities. Hence, the finding of a small positive value of β_{Mc} or a small negative value of β_{Wc} should not be interpreted as evidence of weak racial discriminatory preferences. Instead, it should be interpreted as weak discriminatory demand responses that may be due to either weak discriminatory preferences or weak ability of parents to exercise their strong discriminatory preferences.

Identifying social effects is well known to be a difficult problem, but following the suggestion of Manski (1993), we leverage dynamic variation in enrollments – both over time and across grades – using the identification strategy developed in Caetano and Maheshri (2017). Briefly, this approach involves estimating race-specific demands separately at the grade level, with identification achieved by instrumental variables based on the enrollments of adjacent cohorts. To do so, we first enrich the model by allowing demands for schooling to vary by grade. Let n_{rgjct} be the number of race r students enrolled in grade g in school j in commuting zone c in year t, and let $\underline{g}_j$ and $\overline{g}_j$ be the lowest and highest grades of instruction that are offered at j. Then we can replace estimating equation (4) with the following:

$$\log n_{rgjct} = \beta_{rgc} \cdot s_{jct-1} + \gamma_{rgct} + \epsilon_{rgjct} \tag{9}$$

The parameter β_{rgc} now represents the enrollment response of each race to the minority share of the school, and is allowed to vary additionally by grade.[19] The race-grade-area-year fixed effect γ_{rgct} encapsulates a more disaggregated demographic effect at the race-grade-commuting zone-year level. Finally, the residual ϵ_{rgjct} incorporates all school-specific and grade-specific amenities besides its minority share.

4.1 Identification of β_{rgc}

Causal identification of parents' enrollment responses to the racial compositions of schools, β_{rgc}, requires variation in s_{jct-1} that is orthogonal to other race- and school-specific determinants of demand in t. Such variation is difficult to observe directly because many school amenities are serially correlated and hence persist from t to $t+1$. Moreover, because the β_{rgc} parameters should reflect parents' varied reactions across a broad set of contexts corresponding to the entire country, we must specify them so that they can vary across commuting zones. This requires us to observe distinct orthogonal variation in s_{jct-1} for each commuting zone in the country. Given these considerable requirements we develop an identification strategy that exploits the panel structure of our data and uses instrumental variables that can be constructed from only observed enrollments by grade (i.e., it does not impose any further data requirements.)

Our approach relies on the fact that students enrolled in the second highest grade of a school in year $t-2$ no longer attend the school in t. Hence, the racial composition of this cohort of students (the IV cohort) affects s_{jct-1} but does not directly affect $\log n_{rgjct}$ for any g. Of course, some

[19] In practice, we also allow β_{rgc} to vary over time, as we estimate it separately over a 2005-2009 subsample and a 2010-2014 subsample. To simplify notation, we omit the t subscript.

school amenities that influenced the IV cohort's enrollment decision in $t-2$ will likely persist and influence the enrollment decisions of future cohorts of students in t, hence invalidating our IV. We circumvent this issue by controlling for the enrollments of future cohorts of students in $t-1$. In doing so, we control for school amenities that persisted from $t-2$ to $t-1$. Thus, our identification assumption is that all school amenities persisting from $t-2$ to t will also persist from $t-2$ to $t-1$.[20]

More formally, define $s_{gjct} = \frac{n_{gMjct}}{n_{gMjct}+n_{gWjct}}$ as the minority share of students enrolled in grade g in school j in area c in year t. Let $\underline{g}_j$ and $\bar{g}_j$ be the lowest and highest grades of instruction, respectively, that are offered at school j. We add to equation (9) the control term $C_{rgjct-1}$:

$$\log n_{rgjct} = \gamma_{rgct} + \beta_{rgc} s_{jct-1} + \underbrace{\sum_{i=\underline{g}_j}^{\bar{g}_j-1} \left(\alpha^i_{rgcW} \log n_{Wijct-1} + \alpha^i_{rgcM} \log n_{Mijct-1}\right)}_{C_{rgjct-1}} + u_{rgjct}, \qquad (10)$$

and use $s^{\bar{g}_j-1}_{jct-2}$ as an IV for s_{jct-1}. Our IV estimator is consistent under the following identifying assumption:

Assumption 1. *Identifying Assumption.* $Cov\left[s^{\bar{g}_j-1}_{jt-2}, u_{rgjct} | C_{rgjct-1}, \gamma_{rgct}\right] = 0$.[21]

That is, if we control for the enrollments of all students in all grades except for the last grade in year $t-1$ ($C_{rgjct-1}$), then the racial composition of the IV cohort, as observed in $t-2$, is a valid IV for the overall racial composition of the school in $t-1$.[22]

Relevance: What is the Identifying Variation?

In the context of equation (10), changes in the levels of school amenities that generate variation in s_{jct-1} must affect the past enrollment of the IV cohort without affecting any of the enrollments of cohorts in the immediate future (otherwise, the variation generated would be absorbed by the control variables in $C_{rgjct-1}$). Such changes in school amenities would likely have disappeared after

[20] In Caetano and Maheshri (2017), we provided several robustness checks designed to falsify this identifying assumption, and we have implemented them all here as well. We found no evidence against this identifying assumption.

[21] This assumption contains an abuse of notation in order to simplify the exposition. We condition on the variables in $\left\{\log n^{gr}_{jt-1}; g = \underline{g}_j, \ldots, \bar{g}_j - 1, r = W, M\right\}$, not on C^{gr}_{jt-1} as written above. In practice, we find that a linear projection of these variables and a more flexible specification of these variables generate the same results.

[22] An IV that follows this property is often called a "Conditional IV". See Angrist and Pischke (2009), pp. 175.

$t-2$, (otherwise they would have affected the enrollment decisions of future cohorts in $t-1$). Nevertheless, students in the IV cohort might be compelled to remain in the same school from $t-2$ to $t-1$ for inertial reasons, even if the reasons that originally led them to enroll in that school no longer remain.

As a concrete example, consider a popular, and well known football coach in a 9-12 high school who retired just before year $t-3$. If football was differentially valued by White and minority parents, then this coach would have affected the enrollments of ninth graders in $t-4$ (who are members of the IV cohort) without affecting the enrollments of any subsequent cohorts of students. Still, this coach would have influenced the minority share in $t-1$ (because of the inertia of the IV cohort). Because the IV cohort ages out of the school in t, the only way this coach could affect the enrollment decisions of students in t would be through their response to the minority share in $t-1$, which is the effect we want to identify. Of course, this is just a specific example. In practice, a wide variety of circumstances could lead to a cohort of students remaining enrolled in a school despite the fact that the initial attraction is no longer present. Moreover, broader transitory shocks that operate through the demographic channel may also contribute to the power of our IVs. For instance, if the demographic channel played a role in determining the racial composition of schools in 1990, then a transitory fertility shock in that year that differentially affected Whites and minorities would generate exogenous variation in the racial composition of the IV cohort of students attending 12th grade in $t-1=2007$, those attending 8th grade in $t-1=2003$, and so on. This variation is a candidate IV for a 9-12 high school (or a K-12 school) in $t=2008$, a 6-8 middle school (or a K-8 school) in $t=2004$, and so on.

Because we use only enrollment data to isolate this plausibly exogenous variation, our approach is agnostic to the nature of the specific transitory shock in the past that led students to the school. Thus, we are not required to obtain data on any specific shocks (such as the quality of football coaches or fertility changes, per the examples above). This crucially allows us to perform our analysis nationally and over a relatively long sample period. Moreover, it increases the power of our IV by aggregating all such transitory shocks, including those of which we as researchers are unable to conceive.

Validity: Threats to Identification

A change in a school amenity that leads to a violation of Assumption 1 would have to satisfy three properties: (1) it leads to a change in enrollment decisions in t (i.e., it is included in u_{rgjct}), (2) it is correlated to changes in the minority share of students in grade $\bar{g}_j - 1$ in year $t-2$ (i.e., it is correlated to the IV), and (3) it is uncorrelated to changes in the enrollment decisions of students of different races in all other grades in year $t-1$ (i.e., it is not absorbed by $C_{rgjct-1}$). The existence of such variation in amenities is implausible, because it must lie dormant from year $t-2$ to $t-1$ before becoming relevant again in t, and this return to relevance must be unanticipated by students who enroll in year $t-1$.

To further this logic, consider an unobservable that satisfies properties 1 and 2 above. By construction, this unobservable is an amenity that is either *not* unique to grade $\bar{g}_j$ in $t-1$, or it is an amenity that is unique to grade $\bar{g}_j$ in $t-1$. We will now argue that such unobservable likely does not satisfy property 3 in both cases.

First, any unobservable amenity that is *not* unique to grade $\bar{g}_j$ in $t-1$ (e.g., a neighborhood unobservable) is valued by at least some students enrolled in some grade $g < \bar{g}_j$ in $t-1$. As a result, it will fail to satisfy the third property. For instance, imagine that a 9-12 high school features a good library in t (property 1), and that the library is valued in $t-2$ by 11th grade students (property 2). As long as the library is valued by any students outside of the IV cohort (i.e., students of any race in grades 9, 10 or 11 in $t-1$), property 3 will fail to hold.

Conversely, any school unobservable that is unique to grade $\bar{g}_j$ in $t-1$ will fail to satisfy property 3 if students in some grade $g < \bar{g}_j$ in $t-1$ *anticipate* the amenity will be present in t. This anticipation is likely because the amenity must be present in t (property 1), and must have been considered by students of different races in grade $\bar{g}_j - 1$ in $t-2$ (property 2). For instance, in the case of a football coach, property 3 would hold only if the coach was reinstated in grade $\bar{g}_j$ in t *after* the enrollment decisions in $t-1$ (so that the control cohorts did not anticipate the return of the coach). (Moreover, because this amenity is unique to grade $\bar{g}_j$, this would lead to a bias only in β_{gct} for $g = \bar{g}_j$, allowing us to test for the presence of such bias.)

Robustness Checks

Although our IV approach exploits plausibly exogenous variation in the racial composition of schools in principle, there are some practical issues with its implementation. For instance, a log-linear specification such as $C_{rgjct-1}$ may not fully absorb all confounding determinants of enrollments of non-IV cohort students. Moreover, students in the IV cohort might systematically repeat the last grade of the school. Further, students of the IV cohort may have younger siblings who enter the same school in t in a way that systematically affects the racial composition of the school.

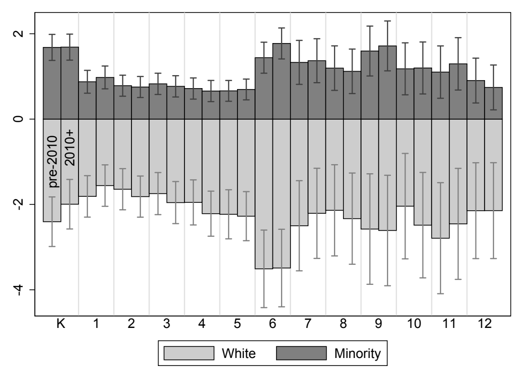
We are sensitive to these concerns, and have conduct robustness checks that allay these and other concerns. For instance, we exploit the fact that we observe the IV cohort's enrollments at multiple points in time: when they are in grade $\bar{g}_j - 1$ in $t-2$, in grade $\bar{g}_j - 2$ in $t-3$, and so on. Because of this, we have multiple IVs at our disposal: $s^{\bar{g}_j-1}_{jct-2}$, $s^{\bar{g}_j-2}_{jct-3}$, etc, each with a slightly different identifying assumption (for $s^{\bar{g}_j-1}_{jct-2}$, the assumption is that variation from $t-2$ that is dormant in $t-1$ does not suddenly show up in t; for $s^{\bar{g}_j-2}_{jct-3}$, the assumption is that variation from $t-3$ that is dormant in $t-1$ does not suddenly show up in t; and so on.). Under the logic of Assumption 1, our claim is that all such assumptions in this family should be valid. Thus, the multiplicity of IVs allows us to test for potentially confounding variation that is specific to different grades ($\bar{g}_j - 1$, $\bar{g}_j - 2$, etc.), and it also allows for formal over-identification tests (Hansen (1982)) of Assumption 1.

4.2 Estimates of β_{rgc}

In order to allow for spatial heterogeneity in β_{rgc}, we subdivide our sample into three quantiles by total commuting zone enrollment as of 2002 $(N_{Mc2002} + N_{Wc2002})$. In order to allow for β_{rgc} to vary over time, we also estimate it separately from 2005-2009 and from 2010-2014. For each of the two races and 13 grades, this yields six distinct effects that capture heterogeneity in enrollment responses between urban and rural areas and heterogeneity in enrollment responses between highly minority regions and highly White regions. Given the large number (156) of parameters of interest, we aggregate these effects along two dimensions in order present results in a more easily digestible, graphical format.

We first focus on the heterogeneity in parents' responses by sample period, race, and grade of enrollment. For each sample period, we construct race- and grade-specific estimates of β by taking averages of β_{rgc} across all commuting zones, weighted by commuting zone level enrollments of each race, which we present graphically in Figure 9. There is very little change in β_{rgc} over the sample period for all parents of both races with children in all grades. White (minority) parents have negative (positive) enrollment responses to more heavily minority schools, which can potentially lead to endogenous segregation. In magnitude, White parents react roughly twice as strongly as minority parents. This does not necessarily imply that White parents have more discriminatory preferences than minority parents; it might only reflect the fact that White parents can more easily make the choices that they prefer as they face fewer frictions, e.g., capital constraints. Finally, parents' responses are of roughly similar magnitude across grades, though they are largest in kindergarten, sixth- and ninth-grade, which makes sense given that these are the most salient enrollment decisions for K-5, 6-8 and 9-12 schools.

Figure 9: Average Estimates of β by Race and Grade, 2005-2014

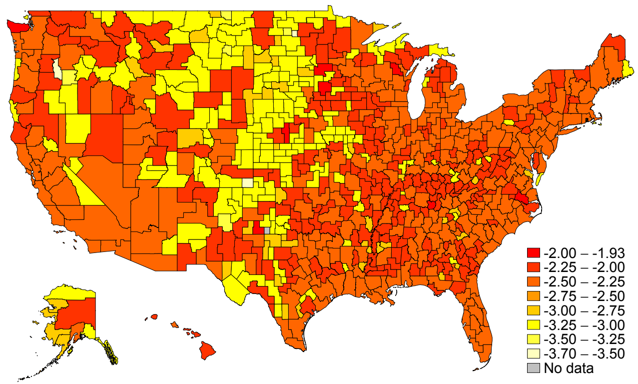


Note: Each bar corresponds to the average of $\hat{\beta}_{rgc}$ weighted across all commuting zones by total enrollment of students of each race. The first bar for each grade is estimated on a 2005-2009 subsample, and the second bar for each grade is estimated on a 2010-2014 subsample.

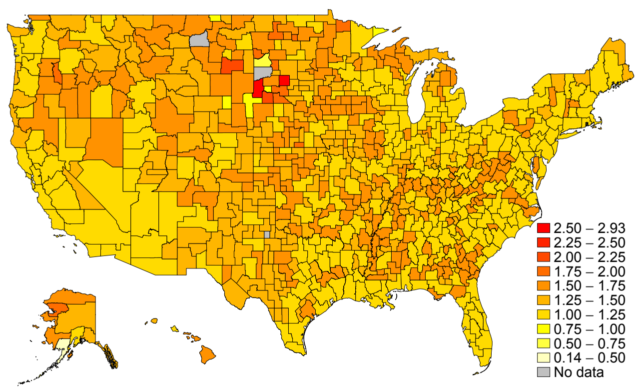
We next focus on geographic heterogeneity in parents' responses by constructing race- and commuting zone-specific estimates of β, this time averaging β_{rgc} across all grades, weighted by enrollments of each race and grade. We map these responses in Figure 10. White parents in the sparsely populated plains states react slightly more negatively to more heavily minority schools than the rest of the country, but there is relatively little variation in responses across more populated regions. Minority parents display a similar geographic pattern, with stronger (positive) responses to more heavily minority schools is less populated areas, though there is relatively less variation.

Figure 10: Average Estimates of β by Race and Commuting Zone, 2005-2014

(a) White Responses to Increases in s_{jt-1}



(b) Minority Responses to Increases in s_{jt-1}



Note: Each map shows commuting zone level averages of $\hat{\beta}_{rgc}$ weighted across all grades by total local enrollments of students in each grade.

5 Demographic Effects on Segregation

Computing the short- and long-run effects of demographic shifts on segregation with grade-specific estimates of $\hat{\beta}_{rgc}$ requires a simple modification to equation (11):

$$s^i_{jct}\left(\tilde{\boldsymbol{s}}^{\boldsymbol{i-1}}_{\boldsymbol{c}}, \tilde{\boldsymbol{N}}^{\boldsymbol{i}}_{\boldsymbol{gc}}\right) = \frac{\sum_g n_{Mgjct}\left(\tilde{\boldsymbol{s}}^{\boldsymbol{i-1}}_{\boldsymbol{c}}, \tilde{\boldsymbol{N}}^{\boldsymbol{i}}_{\boldsymbol{gc}}\right)}{\sum_g n_{Wgjct}\left(\tilde{\boldsymbol{s}}^{\boldsymbol{i-1}}_{\boldsymbol{c}}, \tilde{\boldsymbol{N}}^{\boldsymbol{i}}_{\boldsymbol{gc}}\right) + n_{Mgjct}\left(\tilde{\boldsymbol{s}}^{\boldsymbol{i-1}}_{\boldsymbol{c}}, \tilde{\boldsymbol{N}}^{\boldsymbol{i}}_{\boldsymbol{gc}}\right)}, \tag{11}$$

where $\tilde{\boldsymbol{N}}_{\boldsymbol{gc}}$ consists of $\tilde{N}_{rgc}$ for all r and g. The remainder of the simulation follows straightforwardly.

We present four sets of results, each of which shows how demographic shifts have affected the proportion of segregated White schools and segregated Minority schools respectively. For each measure, we present (1) the average annual instantaneous effect of demographics (induced by the red arrows in Figure 7), (2) the average annual short-run effect of demographics defined in equation (**??**), (3) the average annual long-run effect of demographics defined in equation (3), and (4) the average annual "old" social effect (induced by the green arrows in Figure 7), corresponding to what segregation would have been in a counterfactual world without demographic change. Because our data allows us to estimate the β_{rgc} only from 2005 onward, these annualized averages are computed over that sample period.[23]

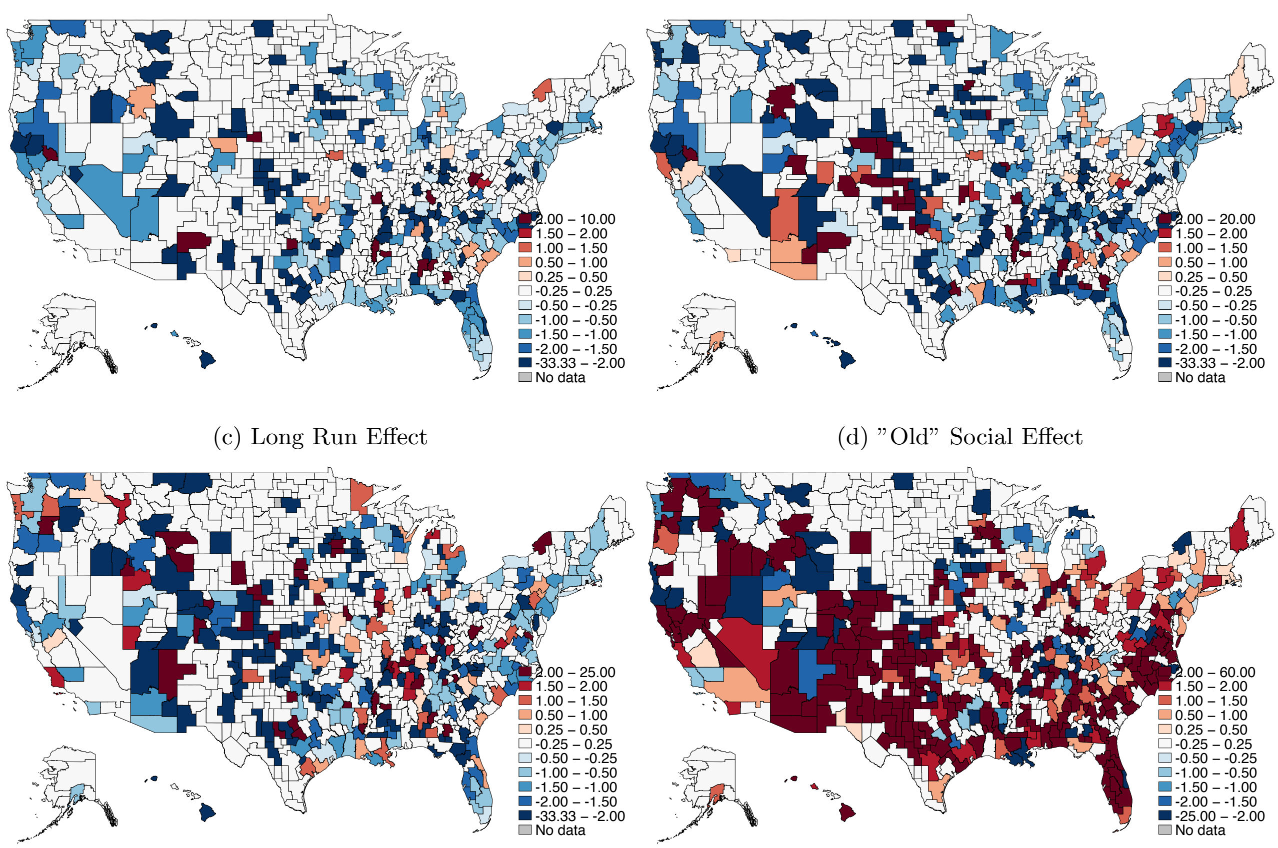
In Figure 11, we present the effects of demographic change on the prevalence of segregated White schools. Panel 11a shows the average instantaneous effect of a one-year demographic change. In most of the country, this has reduced the prevalence of segregated White schools by 0.5-2%. These are schools at points like A and C in Figure 7 that lie just to the left of the 25% threshold. When we compute the short-run demographic effect in panel 11b, the results are similar. In areas where the effects are slightly larger than in panel 11a, the endogenous effect reflects a social multiplier that accentuates the demographic effect. In some areas, the effects are smaller, or even result in an increase in the prevalence of segregated White schools. Such areas have many schools that were originally so far out of equilibrium to the right of C' that they were also to the right of $C^{\star}$; here, the endogenous effect acts against the demographic effect, resulting in a movement downward across the 25% threshold.

In panel 11c, we present long-run effects, which are broadly similar to the short-run effects in panel 11b, but of slightly higher magnitude. For a handful of commuting zones, the long-run effects of demographic change lead to increasing segregation. There are two explanations for this. First, schools in these areas could experience "new" social effects that are sufficiently larger than their "old" social effects. A second, more subtle explanation is that in the long-run, relative inflows of minorities may actually shift the "S" curve *downward* for some schools due to general equilibrium effects, as described in Figure 8. Recall that the choice probability π_{rj} is a function of $\boldsymbol{s_{t-1}}$, the racial compositions of *all* schools in the commuting zone. A minority inflow may make some schools so much more attractive to minorities (or unattractive to Whites) that over time it draws minority students out of relatively whiter schools or induces "White flight" into these schools. If this secondary general equilibrium effect is sufficiently large, it may offset the

[23] For most states, enrollment data at the grade level is only available starting in 2002, and our IV approach requires data from $t-3$ and $t-2$.

short-run demographic effect. Finally, in panel 11d, we present a map of a long-run counterfactual in which no demographic changes occurred. In most parts of the country, there would have been dramatically more segregation of White students. In some sparsely populated regions, there would have been fewer segregated White schools, likely because the enrollments of schools in these regions were originally mismatched with school amenities, and many of them were at points to the *left* of $C^{\star}$ in Figure 7.

Figure 11: Average Annual Effects of Demographic Change on Proportion of Segregated White Schools, 2005-2014



(a) Instantaneous Effect

(b) Short-Run Effect

(c) Long Run Effect

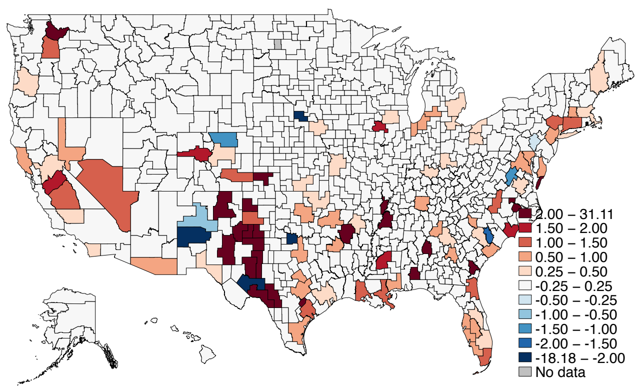
(d) "Old" Social Effect

Note: A segregated school is defined as one in which the enrollment of White students exceeds 75% of the total enrollment. Blue (Red) commuting zones have experienced declining (increasing) segregation during this period. Annual changes shown in percentage points.

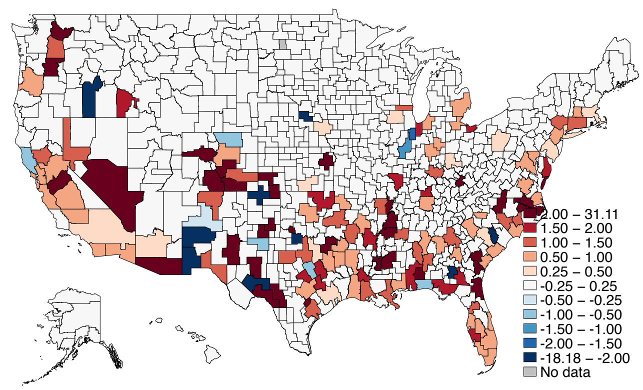
In Figure 12, we present the analogous effects of a one-year demographic change on the prevalence of segregated minority Schools. Panels 12a and 12b show that the immediate effects of demographics have been to increased the prevalence of segregated minority schools in the sunbelt and some northern cities by 0.25-2%. In other areas, the effects have been negligible, likely because there are so few schools near the 75% minority threshold. In the long-run (panel 11c), demographic change has a broader impact of moderately increasing segregation in more parts of the country. However, in some commuting zones, accumulated social effects actually lead to decreases in segregation. This can be attributable to the general equilibrium effects similar to those described above. The relative attractiveness to minorities (or unattractiveness to Whites) of highly segregated minority schools (e.g., 85% or more minority) has, in general equilibrium, drawn enough minority students out of less highly segregated minority schools (e.g., 75% minority) that these schools have actually experienced, in the long-run, *downward* shifts in their "S" curves. Finally, in panel 11d, we present a map of a long-run counterfactual in which no demographic changes occurred. Without such changes, most of the sunbelt would have experienced sharp increases of over 2% in the prevalence of segregated minority schools, and many cities in the Northeast would have experienced increases of 0.5-2%.

Figure 12: Average Annual Effects of Demographic Change on Proportion of Segregated Minority Schools, 2005-2014

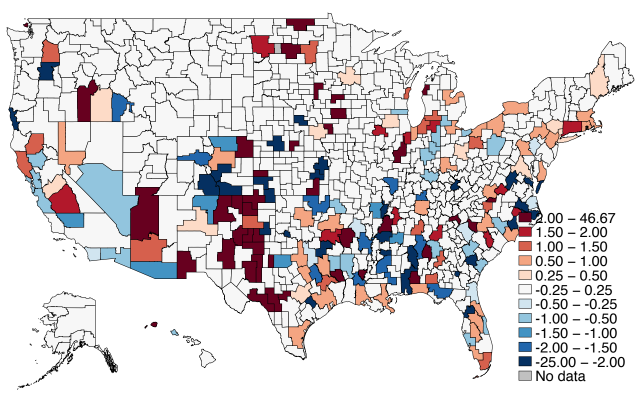
(a) Instantaneous Effect



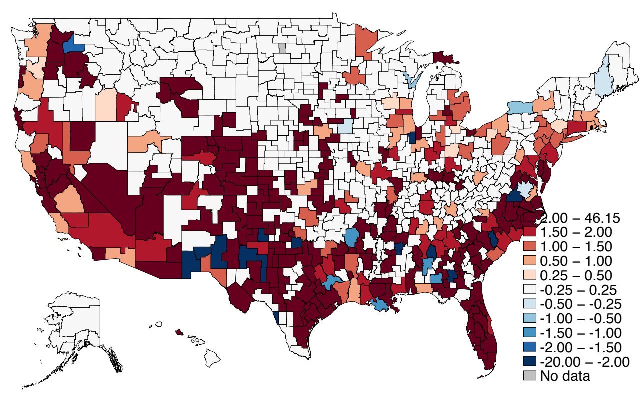
(b) Short-Run Effect



(c) Long Run Effect



(d) "Old" Social Effect



Note: A segregated school is defined as one in which the enrollment of minority students exceeds 75% of the total enrollment. Blue (Red) commuting zones have experienced declining (increasing) segregation during this period. Annual changes shown in percentage points.

6 Conclusion

A growing body of research has found adverse short-run and long-run effects of school segregation, particularly for minority students. It is understandable then to be concerned about the increase in the proportion of predominantly minority public schools in the United States. However, policymakers seeking to address segregation would be wise to understand the mechanisms underlying this trend. Those who insist that low minority-share schools are the only acceptable outcome will be disappointed for purely arithmetic reasons; for instance, in 2014, the four most populous commuting zones had majority minority enrollments.[24] Meanwhile, models of segregation predict

[24]The minority share of 2014 enrollment of the four largest commuting zones was, in order of size: Los Angeles (70%), Chicago (53%), New York City (57%) and Houston (68%).

that even when holding all else constant, even mild discriminatory responses will endogenously lead to concentrations of White and minority students over time. This could hamstring the ability of policy interventions to have lasting effects – as long as parents can choose freely where to enroll their children, whether explicitly through school choice programs or implicitly through residential choices, even mild discrimination will lead to segregation in all types of schools.

Our findings reveal that all else is not constant. We should be slower to conclude that persistent, pervasive discrimination is the sole driver of recent trends in segregation when the proportion of segregated White schools in the country has declined precipitously by over 20 percentage points in the past quarter century. Aggregate demographic trends have been an important force in reducing the segregation of White students and increasing the segregation of minority students. These trends will push more and more schools out of equilibrium, leading to mismatch between their racial compositions and the amenities that they provide. Policymakers may be able to exploit this mismatch by targeting investments wisely. Investments in amenities that make predominantly white schools more attractive to minorities (and vice-versa) will reduce segregation. If schools are appropriately out of equilibrium (e.g., a school that is reasonably attractive to parents of both races has a predominantly White enrollment for historical reasons), then such investments will be even more effective at reducing segregation by taking advantage of dynamic social multiplier effects.

More broadly, our findings suggest that an understanding of sorting at the local level could be enriched by a greater understanding of sorting at regional levels. Synthesizing a model of migration with a model of segregation might reveal complementarities between broad regional policies regarding immigration or relocation incentives with narrow place-based policies at the school or neighborhood levels. As more precise data on individuals' settlement and enrollment patterns become available, we believe this will become a promising avenue for further inquiry.

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A Data Appendix

Our data comes from the Common Core of Data maintained by the National Center for Education Statistics at the US Department of Education. Common Core data is available from 1987 to 2014, but we drop the 1987-88 school year because of incomplete data coverage. Data from some states is missing, mostly in the early years of the sample and in 1998-1999 school year, but this represents a very small proportion of our sample. In Table 1 below, we present the state-years that are missing, and hence omitted from our analysis. Because of these data issues, we report all summaries of the data as annualized averages.

Table 1: Missing Data

State	Years Missing	Fraction of Sample Period Missing
Arizona	1998	4%
Colorado	1998	4%
Georgia	1988-1992	19%
Idaho	1988-2001	44%
Louisiana	1988	4%
Maine	1988-1992	19%
Massachusetts	2000	4%
Minnesota	1998	4%
Missouri	1988-1990	7%
Montana	1988-1989	7%
New Hampshire	1988	4%
New Jersey	1998	4%
New Mexico	1988	4%
New York	1998	4%
Nevada	2004	4%
North Dakota	1998	4%
Oregon	2000	4%
Pennsylvania	1998, 2000-2001	11%
South Dakota	1988-1991	11%
Tennessee	1998-2004	26%
Vermont	1998	4%
Virginia	1988-1991	11%
Washington	1998-2000	11%
West Virginia	1998	4%
Wyoming	1988-1989	7%

We have recalculated all results presented omitting all states with data missing in any years and omitting all commuting zones that contain schools from any state with missing data. Our findings are qualitatively unchanged. Note that only Nevada and Tennessee have any data missing from

2002-2015, which corresponds to the sample period of our estimation (and simulation) subsample.

B Measures of Segregation

Consider a commuting zone with J schools, each of which enrolls n_j^W white students and n_j^M minority students. Let $n_j = n_j^W + n_j^M$ and $s_j = \frac{n_j^M}{n_j}$. Similarly, define N^W, N^M and N, as the total numbers of white, minority and all students in the commuting zone respectively, and let $S = \frac{N^M}{N}$. From these primitives, we define the following measures (see Massey and Denton (1988)):

1. The Herfindahl index $H = \sum_{j=1}^{J} s_j^2$ captures the extent to which minority students are concentrated in schools.
2. The Theil index $A = \frac{1}{J}\sum_{j=1}^{J} \frac{s_j}{\bar{s}} \log \frac{s_j}{\bar{s}}$ where $\bar{s}$ is the simple mean of s varies from 0 to $\log J$ and measures the amount of entropy in the distribution of minority students across schools. Increasing values correspond to greater segregation.
3. The Dissimilarity index $D = \frac{1}{2}\sum_{j=1}^{J} \left| \frac{n_j^W}{N^W} - \frac{n_j^M}{N^M} \right|$ varies from 0 to 1 and represents the proportion of minority students in the commuting zone that would have to switch schools to achieve an even distribution of minorities across schools.
4. The Isolation index $I_r = \sum_{j=1}^{J} \frac{n_j^r}{N^r} \frac{n_j^r}{N}$ captures the extent to which students of race r are exposed to other students of that race in schools.