Population Density and Educational Inequality: The Role Of Public School Choice and Accountability[1]

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Abstract

This paper examines the differences in performance in test scores across different areas of the United States and relates them to levels of population agglomeration. Commuting zones with denser population levels have higher average outcomes and also greater inequality in the National Assessment Education Progress (NAEP), a large national standardized exam. Using detailed individual level-data, I establish that being in a denser area is associated with an increase in the socioeconomic gap of about 1 percent for each 10 percent increase in density levels. This relation is robust to the use of a geographic regression discontinuity design that leverages changes in density across neighboring commuting zones and to the use instrumental variables that exploit the relation of contemporary density levels with the fertility of the terrain and with historic density levels. These findings are consistent with a theory where, in denser areas, there is greater school segregation by socioeconomic status and poorer families do not succeed in holding the schools they go to accountable. Using census data, I find that there is in fact more school segregation in denser areas, and using a proprietary survey I show that the gap in involvement in schools between richer and poorer parents is not smaller in denser areas. These findings underscore that the fragmentation of geographic areas into multiple districts can be beneficial for many but increases inequality between groups and that the conventional democratic accountability mechanisms are insufficient to overcome the inequality driven by residential segregation. As populations throughout the world urbanize, this raises questions for jurisdictional design and the need to create effective accountability and choice mechanisms for disadvantaged populations.

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Introduction

We know a great deal about the effect of socioeconomic characteristics in explaining variations in student performance in K-12 education. In addition, a wide literature in educational policy analyzes the role of school inputs such as teacher quality, class size, or the mode of delivery of instruction. In addition, schooling interacts with the social context, such as the socioeconomic characteristics of students and their families. We know less about the systematic differences across regions and between areas within regions. However, in the United States, if two students attend school in areas of the country, this location alone can explain up to 50% of the difference between their educational outcomes in addition to all their differences explained by their individual socioeconomic characteristics.[3] The effect of being educated in the best areas is more than twice as large as the effect of having a highly effective teacher compared to an average teacher.[4] Panel A of Figure 1 maps the geographic distribution of the commuting zones by average performance. The first of two puzzles this paper seeks to answer is: what explains persistent differences in average levels of performance across different areas of the country not fully explained by differences student characteristics? Given the increased importance of a knowledge economy in the United States, the growing role of the Federal Government in education and the relatively high mobility across areas of graduates but also teachers and information on education "best practices", we may expect convergence on high levels of educational quality throughout the country. After all, plenty of initiatives have been rolled out to ensure all students receive high quality education to compete in the national and international economy is the impetus for initiatives such as the federal "Every Student Succeeds Act" or others such as the national Common Core Standards, whose goal is to bridge these differences.

The second puzzle this paper seeks to explain is the variation within an even smaller geographic area (the commuting zone), which typically shares institutions, labor markets

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[3] These standard results are summarized in our dataset are shown by the difference in the explanatory power of models with geographic fixed effects and those with individual fixed effects in Table 1.

[4] Teacher ability is an example of an educational variable widely agreed to be important. Indeed, in a large city in the United States, Chetty et al. (2014) found that the average effect of 1 standard deviation higher performance of the teachers on the test scores is .080 standard deviations in English and .116 in Math. Table 2 shows that an area in the top quartile by performance in the United States differs from one in the bottom quartile by 0.26 standard deviations in standardized test scores.

and importantly people: why are there great differences in the inequality between in student performances throughout the country, and why is it that denser or more urban areas see more variation among students? Figure 1 (panel B) maps this within-commuting zone variation in student performance.

To answer both puzzles, I explore the hypothesis that part of the variation in student performance between and within areas of the country is related to the concentration of the population in space. It is known that cities and higher density areas have been shown to have agglomeration advantages. Focusing on variation related to population density is also justified by rapid changes in urbanization levels: 85% of the population in the United States will be urban by 2050, compared to 50% in 1950 (United Nations, 2014).

For schools and potentially other locally provided services, I argue there are two main theoretical mechanisms whereby agglomeration affects outcomes. The first is through the increased opportunities for public school choice through residential sorting. This has positive implications for average levels of performance but also brings with it increased inequality as a result of segregation across groups through sorting on economic grounds. The second mechanism is that density in the form of urbanization facilitates interaction, information and ultimately political participation. As a result, one may expect a greater level of accountability exercised on school system, contributing to higher average levels. However, the result of the segregation from sorting is that those who need this accountability the most (poorer families) are unable to benefit from the greater opportunities for accountability that denser areas afford to them. These mechanisms are well exemplified by the contrasts in outcomes that we expect between two education markets in Arizona, with radically different student density levels. In the Phoenix commuting zone (which I will take to match its education market), with one of the highest density levels in the country at 19 students per square kilometer, there are 58 districts and 1,250 schools that families can choose from. Down the road in the neigbouring commuting zone centered in Safford, AZ (density: 1 student per square km), there are 13 districts in the entire commuting zone and 39 schools. The contrast between the two commuting zones' level of fragmentation can be seen in Figure 2. Crude measures of political participation also show significant contrasts between the two areas: whereas 69 percent of Safford electors voted in the 2016 Presidential election, 75 percent voted in Phoenix. There are 17 paper and online Phoenix-based newspaper, while there are only 2 publications in Safford. The claim of this paper is that the differences between Phoenix and Safford that their respective level of agglomeration induces have important consequences for the schools in each education market.

To establish the relation between density and outcomes, I exploit cross-sectional national test score data from the National Assessment of Educational Progress microdata, geo-located to education markets, which I operationalize as census-defined commuting zones. I find that denser areas have higher levels of student outcomes on average, but also greater levels of inequality. The gap is driven by both a lower performance of poorer students and a higher performance of richer ones, compared to less dense areas, across a number of indicators of socioeconomic status (SES), such as being a free or reduced lunch recipient, having parents with no college education, being black or Hispanic) Establishing this descriptive relation is a novel result. In addition, I use a geographic discontinuity design and establish a plausible causal link, by looking at the effect of discontinuities in commuting zone density across neighboring commuting zone boundaries, for test-takers that are close to those boundaries. I find the same results when I use popular instrumental variables in studies of agglomeration economies which instrument contemporary area density levels using historic density levels and the ruggedness of the terrain, as well as inter-generational predictors of school density.

Building on the classic framework of exit and voice of Hirschmann (1970), I explore the role of both mechanisms and their interaction in explaining these results. I expect both to be theoretically more available in denser areas and, so this is a most likely case for the view that both mechanisms can act as substitutes. I use census district-level data on levels of segregation in areas with different density levels and a nationally representative survey on opinions about educational issues and policies. I find support for the hypothesis that there is more school district economic segregation in denser areas. I also find that there is no effective countervailing force through political participation that may compensate those who are harmed by greater segregation: there is no more school board participation, attention paid to schools or knowledge about schools.

These arguments and findings highlight an underemphasized type of inequality in educational outcomes that stands in between individual drivers, neighborhood effects and cross-country differences. While we increasingly know that there are differences in inequality levels across areas, this research begins to explain the drivers of such differences and finds that the geographical agglomeration of the population is an important part of the story. It also nuances our knowledge of the effects of agglomeration by emphasizing tradeoffs between different groups, in the context of a literature that has found largely positive effects of agglomeration on desirable outcomes such as economic prosperity, health and even happiness (Glaeser and Gottlieb, 2009), as well as expects levels of political participation (Deutsch 1961, Dahl 1967) and redistributive ("left") politics (Rodden, forthcoming).

The detrimental effects of increased exit for certain groups through residential sorting we find warrant policy interventions by governments to provide similar opportunities for choice for poorer families in urban areas such as through charters or school voucher programs, or access to broader opportunities leveraging technology. Similarly, local systems of school accountability have been unable to ensure high quality schooling for populations with greatest needs and a greater understanding for the reasons of those failures and the opportunity for using better information dissemination tools or participatory budgets.

The rest of the paper is divided as follows. First, I review the literatures that this paper seeks to contribute to and the gaps it fills. Second, I lay out the theory and hypotheses I seek to test. Third, I describe the setting, data and empirical strategies I use. Fourth, I show the results of the relation in reduced form between performance levels, inequality and density, both descriptively, using a geographic regression discontinuity design and an instrumental variable approach. Fifth, I explore how the mechanisms of exit and voice may explain the relation I find and test directly for the relevance of those mechanisms. Sixth, I provide some tentative policy implications, discuss limitations and directions for future work and I conclude.

Connections with the literature

This work speaks to four literatures most directly. The first of these studies denser places to establish the effect of agglomeration economies. It has found that agglomeration and spatial distribution can have a positive effect on levels of economic growth, subjective well-being, entrepreneurship levels or the quality of hospital care (Glaeser and Gottlieb, 2009 and Glaeser, 2010). The reduction of transportation and information costs (agglomeration economies) that these studies document has a positive impact on the broader economy. However its effect on the delivery of government services and, in particular, education has not been studied. The inequality that such agglomeration may bring is also not typically studied. [5]

The second literature is about the geographic variation in performance and inequality levels in education. This has begun to be documented by Reardon et al. (2016). They leverage the data available from state test scores to measure intra-district and inter-district racial achievement gaps. Their findings suggest that a large portion of the variation in racial achievement gaps between districts and metropolitan areas is correlated with levels of inter-district racial and economic segregation as well as differences in the size of the income gap between races in different areas. Gingrich and Ansell (2014) characterize more unequal areas in the UK and document the presence of greater variation in individual outcomes in more affluent districts. In their analysis of educational outcome data, they show that these areas with more affluent districts have greater disparities in educational performance through sorting into schools within the district. They conclude that even in a context such as the UK where there are no differences in funding across districts and schools (unlike in the United States), there are still be dramatic differences in outcome levels. The findings from this emerging literature lead themselves to a more systematic exploration of the determinants of this inequality across geographical areas I provide here and should ultimately be tied to studies of geographic variation in labor market inequalities and of social mobility, such as of Chetty et al. (2014).

The framework of Hirschman's (1970) insight on the role of consumer exit (in switching the organizations they receive products or services from) and voice (by expressing their

[5] A related literature studies the optimal size of jurisdictions. First, on endogenous jurisidiction formation, Alesina and Spolaore (2003) and Alesina et al. (2004) look at school districts in particular, who face a tradeoff in determining their optimal size with two opposing forces: economies of scale (leading to larger jurisdictions) and racial or class heterogeneity (pressing for smaller, more homogeneous). The consequences this may have for the quality of services such as education are not explored. Lassen and Serritzlew (2011) find a stark negative relation between size of jurisdictions and individual citizens' beliefs that they are competent to understand and take part in politics in an experimental setup in Denmark. In later work, (Lassen et al. 2016) they find that consolidations do not lead to additional savings for the public purse either.

demands to them) has had extensive repercussion in the social sciences. Despite this, in the paradigmatic example of education that Hirschman uses, the relation between the exit of more involved families, the overall levels of voice and the resulting quality levels for different groups has not been widely studied empirically. I study it in a context where both mechanisms are potentially available, such as school districts in the United Status. Providing a link between literatures that consider versions of exit and voice in schooling separately is a goal of this paper. The third literature this study relates to is thus on the effect of exit opportunities in the form of school choice. The extensive literature is reviewed in Urquiola (2016). The present study, in so far as it posits a mechanism about residential public school choice, relates to Tiebout competition (see for instance, (Oates 1972 and Tiebout 1956) as a way for citizens to increase their welfare through moving their residence to districts that better match their preferences for schooling. The most important study that uses quasi-experimental variation in order to assess the effects of variations in the degree of public school choice throughout the nation continues to be Hoxby (2000). Using terrain characteristics as a source of variation in the levels of public school choice, Hoxby finds positive effects of having greater public school choice in metropolitan areas on student achievement and on the productivity of the education system, although she finds little evidence of effects on the socioeconomic gradient.

A key part of the present study is that the effect of choice is importantly determined by income segregation. Increases in income inequality have been shown by Reardon and Bischoff (2011) to relate to increased segregation of families by income in their residential location, which in the United States is bound to be closely linked to school segregation – although this has not been studied systematically. These (expected) increases in income segregation across schools would affect performance most directly if peer effects are strong, which would be consistent with current research (Lavy et al. (2012) reviews the literature of peer effects).

The fourth literature is on the importance of voice. The evidence on the effect of any form of voice on schooling outcomes is very limited. Berry and Howell (2007) and Barrows (2015) provide indirect evidence of voice in the form of voting being related to education performance. They both show that re-election in school board elections is linked to the performance of schools prior to the election. This suggests the importance of voice accountability as a way of influencing education policy. The relation with performance in public services should be strongest for education in the United States, given the preponderance of local single issue jurisdictions. A sizeable literature connects density and forms of voice empirically and even more broadly, how density in space may shape attitudes. Recent evidence such as Hopkins and Williamson (2012) finds that denser areas have greater levels of political participation. Analytically, a classic view explains this through conceiving urban politics as unusually rich, as it has more reasons to attract citizen's attention including more disputes over common resources and space across disparate groups (Dahl 1967, Deutsch, 1961). Versions of this view abound. For instance, some emphasize thicker media markets in cities that stimulate political interest (Milbrath and Goel 1982, Campante and Do, 2014) and other attribute the difference to a legacy of more activist left politics as a historic legacy of industrialization (Rodden forthcoming).[6]

In summary, there are four open debates along each of these literatures that I will speak to. The first is whether the largely positive effects of agglomeration enabled by the reduction of costs extend to the delivery of local public services and, in particular, education. To that debate, the key question in this paper is whether education benefits from positive consequences of agglomeration and whether all groups benefit homogeneously. Second, whether some of the variation in educational outcomes and in inequality that has begun to be documented across different areas of the country can be explained in any systematic way –and whether geographic density may be part of that explanation. Third, there is a need to continue to explore the effects of public school choice for different groups which has not sufficiently focused on inequality patterns and where some of the key studies date back to the early 2000s and much has changed in education in the United States, not least two major federal laws, an emphasis on transparency and accountability and a more diverse student population. Fourth, we need to know more about the effects of voice in the quality of public services and in particular schooling and we have to understand the relative importance of the exit and voice mechanisms that Hirschman (1970) posits as well as their

[6] This view is not unanimous. See Oliver (2001) for a different argument. In it, localities grow cities become less connected and urban issues become more complex and professionalized, leading to withdrawal from participation. Note that these arguments applies most obviously to local politics in which citizens may not have a specific stake.

joint effects, we need richer frameworks where the interaction of choice is and voice and their effect on outcomes of interest is modeled empirically. Ultimately, only a better understanding of these processes can result in the identification of the greatest policy gaps and a sense of how they may be filled.

Theory and predictions

Quality levels and differences across schools and districts are linked to the extent to which families are able to exercise pressure on them to be of high quality. Families are able to keep schools and districts close to their full potential through the "exit" and "voice" mechanisms described by Albert Hirschman (1970). His contention is that these two are the main ways users have of communicating the failings in performance of an organization and so, of exercising accountability. In a general context of firms providing a product of service to its customers, dissatisfied customers can either shift their patronage to a different firm or, alternatively, they can express their unfavorable views of the firm and, certainly in the context of schools or school districts work directly to change it through the management (principals, in the analogous case of schools) and front-line workers (teachers).

The core of the theoretical argument relating density and test outcomes is that the availability of both of these mechanisms is greater in denser areas. First, in terms of exit opportunities, take a given geographic education market. For a greater concentration of the population, there will be more schools and school districts. After all, the largest driver of the number of schools is having a sufficient critical mass in the catchment area. Since many districts are historically created in relation with supporting a school, particularly a high school, more people in a given area will also lead to more school districts (Fischel 2009). Second, in terms of the voice mechanism, denser areas are also more likely, other things being equal, to have more politically active citizens and more organized political groups: it is easier to organize interest groups and to find critical masses of people to advocate for any given interest, such as quality schools. This resonates with classic observations about the greater intensity of urban politics (Dahl 1967, Deutsch 1961). It is also more likely that families in denser areas will have more access to information through thicker media markets (Campante and Do 2014) and differential attitudes that would lead individuals to invest more in education (Sng 2017).

The relation between density and the greater number of schools and districts and its consequences is the most complex, so I turn to exploring it in greater detail. The main reason that such a relation exists is that families will be able to more easily or more cheaply "vote with their feet" and move to the district or near the school of their choice, as an abundance of schools and school districts facilitates greater levels of residential sorting (Tiebout, 1956, Oates, 1999).

The question is then about what the downstream consequences of this sorting for average performance and performance by the different socioeconomic groups. For average performance in denser areas, the effect of this residential sorting is arguably one of competition that benefits everyone. As Hoxby (2000) puts it, "the incentives that schools have to be productive are generally increased by Tiebout choice because it gives households more information and leverage in the principal-agent problem that exists between them and the people who run their local schools". Schools will exercise more effort and dedicate their resources to producing the social good that is education for fear that families will move elsewhere if they are not. This straightforward positive effect of competition needs to be nuanced, as sorting is mediated by differences in socioeconomic status through house prices. But a positive average effect is still consistent with that mediated relation. Take a simple model that stipulates two different groups, rich and poor and assumes the population and house price distribution is constant and unrelated to the quality of schools (i.e., areas in the relevant horizon contain constant numbers of rich and poor). Then denser areas will have an average positive effect if, for all or most house price levels, denser areas have more opportunities for people to move to a different district within the same house price band.

The house price mediation will also mean that there are greater economic differences between the residents of districts and schools in denser areas. In the extreme, in an education market with a single school and school district, rich and poor families all attend the same school. As more districts are available, house price-quality bundles will be available, with some high price-high quality that only the rich attend. Within each house price band, greater numbers of districts may raise quality (due to competition), but the difference between bands may be large for several reasons: first, lower performance students (which on average will coincide with poorer ones) will not be pooled with higher performance ones and thus will not benefit from positive peer effects. Second, poorer students will not benefit from the exercise of voice from richer ones. Richer families, like they do for all kinds of political participation (Brady et al. 1995) will be better at advocating for better schools and at ensuring quality education where their children attend. And so, if poorer and richer students are less likely to be pooled in the same schools, poorer students will not benefit from others exercising voice *on their behalf*. Lastly, as there is less pooling, each family will be spending on their own in-group in line with their means. The gap between spending on poor and rich will be greater since families of poorer students are able to contribute less through property taxes (while their education may be costlier). Richer families will have greater property taxes per pupil to spend and will be willing to spend more of this money, as their expenditure does not subsidize poorer students.[7]

In other words, the consequences of increased exit opportunities follows Hirschman's contention that "those customers who care the most about the quality of the product and who, therefore, are those who would be the most active, reliable, and creative agents of voice are for that very reason also those who […] exit first in case of deterioration". Those who have the means will benefit more from exit to the detriment of those left behind who are unable to exercise it and do not exercise voice either. In addition, in the case of education, the poor may moreover be harmed by the absence of peer effects and cross-subsidies.

Thus, the consequence of the greater numbers of districts and schools in denser areas are positive average effects but greater differences across groups. The downstream effect of the voice mechanism on different groups is less clear theoretically: density should enable the exchange of information and political organization for all groups. One can conceive certain circumstances where density will directly benefit the exercise of voice differentially for poorer families, for instance, there may be ceiling effects for richer families if they are involved in school politics no matter how favorable the circumstances are and in that case the benefits of density would accrue more to poor families and enable them to compensate

[7] There is considerable dispute in the economics literature about the effect of additional spending on education, although the most credible evidence suggests that certain forms of it can have a significant effect (Kirabo Jackson et al. 2016). In my own work I focus on the relation between density and local spending share in Lastra-Anadón (2018).

for the greater exit levels of rich ones. While I will explore this empirically, I expect that the fundamental barriers that impede this political activity of the poor are more important than the circumstantial forces in denser areas that may enable them to be more politically active and so that this countervailing mechanism to the detrimental effect of exit on poor families will have little purchase.

Taking stock, I argue that in more populous areas, exit is a theoretical possibility for everyone but in practice one richer parents exercise, since they can find and change schools and school districts with little disruption to their work or community life. By contrast, parents in less populous areas have no option but to push for improvements in the only schools that their children are able to attend, since there are no alternatives, and they become more involved in school life and are more "vociferous". In less dense areas, poorer parents are more likely to benefit from having people around them who push for the improvement of their schools. In denser ones, these families attend other schools. In short, in *less dense-low exit* areas, poor students are more likely to be pooled with richer families. However, in *denser-high exit areas*, lower socioeconomic status families are no longer able to benefit as much from the presence in their schools and districts of more vociferous families.

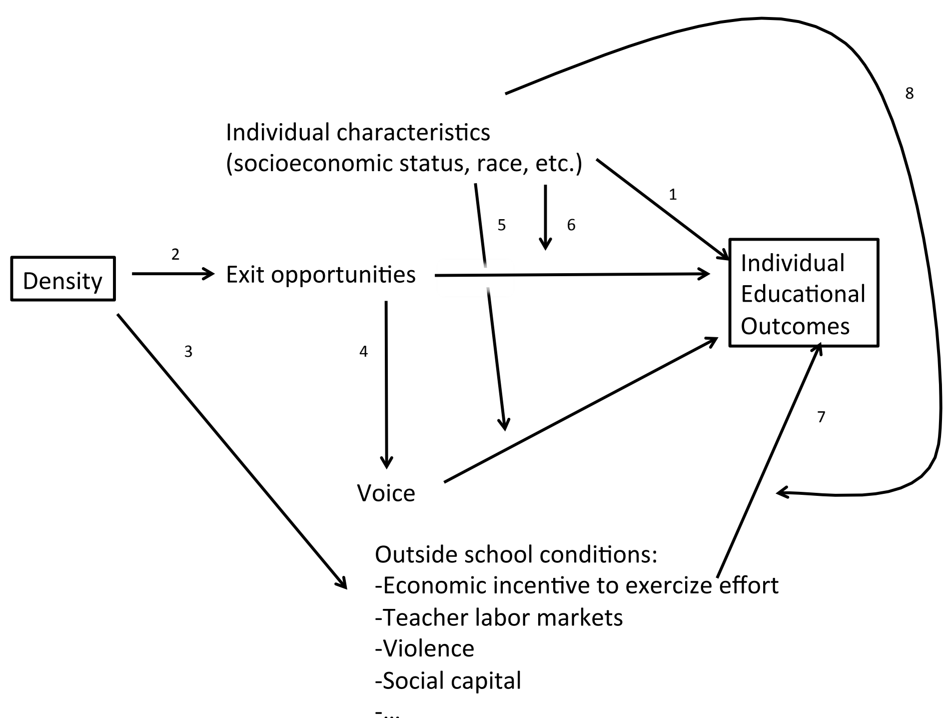
I argue that these dynamics of exit and voice are the dominant forces in explaining differences in educational gradients across schools at different levels of density and that their net result depends on the relative magnitudes of the two effects of density:

-The effect of density on the exit of richer families

-A possible countervailing effect of density on the exercise of voice of poorer families

Exit and voice are the over-arching mechanisms affecting the quality of schools but they will have to express themselves through tangible differences in what average schools and schools that the different groups attend look like. Resources, teachers, buildings, the relation between teachers and parents, management of the school, etc. may be different in dense urban areas. For instance, we know teacher labor markets are thicker in denser areas. Additionally, within each of these areas, there may be inequality in their distribution across dense and less denser areas: if the best teachers are attracted to metropolitan areas but then teach in schools in the suburbs of cities, this may affect the variation across districts in metropolitan areas. At the individual level, the people living in denser areas may also be different. Denser areas may attract more immigrants and possibly more ambitious people in search for opportunities. But also in knowledge-intensive local economies, the incentives for students and family to raise achievement may be different at different points in the distribution of income, which may affect inequality levels. While these mechanisms will be part of any relation between density and outcomes, to establish a causal relation I will want to abstract from the individual differences in composition in dense and less dense areas to focus only on differences in schools.

The following diagram and subsequent explanation synthesize a comprehensive model of how density may relate to individual outcomes, through exit and voice as well as other channels that may interact with them:



A primary direct driver (arrow labeled 1) of individual outcomes and inequality are individual and family characteristics, such as the socioeconomic status itself. Density has two primary channels that affect educational outcomes. First, and our focus its relation with exit opportunities, the number of public schools and school districts that a family can send their children to without altering other aspects of their lives (2). Second, under "outside school conditions" a bundle of economic and social differences that agglomeration leads to (3). These have an effect on educational outcomes since they may alter, e.g. the availability of teachers, the economic incentives at different positions in the distribution to exercise effort in school and possibly others. Examples include greater differences in more urban areas in neighborhood and home environments between socioeconomic groups, including nutrition, family composition and dynamics, (e.g. substance abuse).

Focusing on the effect of exit opportunities, Hirschman contends in the passage above that higher exit levels would result in lower voice, since those who exit are the same as those who would exercise pressure or voice for improvements (4). The presence of the relations 5 and 6, where exit and voice are moderated by socioeconomic status are the principal reason why we would expect density to affect the degree of inequality levels in outcomes across dense and less dense areas: while density affects the *availability* of exit and of voice, the *practice* of exit and voice is highly conditional on socioeconomic status. Lastly, 7 indicates the direct effect that outside school characteristics have on educational outcomes, which in turn is most likely moderated by socioeconomic characteristics of the individual (8), impacting inequality levels.[8] Notice that there is no direct arrow between density and voice since I shall argue that despite differences in political norms, media, etc., if this exists this is a relation of much less significance compared with the other ones. This is ultimately an empirical question and I will show what the magnitude of this relation is in the results below.

Predictions and hypotheses to test

If density relates to educational outcomes substantially through the framework of exit and voice and is moderated by subgroup characteristics, a number of predictions follow.

Reduced form effects: the key empirical predictions are that:

[8] An additional moderating factor on the magnitude of the effect of exit opportunities on outcomes stems from what Hirschmann calls "loyalty". It is likely related to the degree of social capital or integration across different socioeconomic communities present in one place. This factor is harder to measure in a static context and, in order to simplify the theory tested and its presentation, I did not include it in the diagram.

1) Higher area density levels are associated with higher average outcomes
2) There is a positive relation between density and outcome inequality between rich and poor students

Mechanisms: First, in terms of the **exit** mechanism, the theory predicts:

3) There are more schools and more school districts in denser areas (providing greater exit opportunities)
4) There is greater inequality in correlates of educational outcomes such as income and race, as well as in school inputs, across school districts in denser areas. Meanwhile, within-school district demographics are more homogeneous in denser areas, as there is less pooling of groups inside districts.

In terms of the **voice** mechanism:

5) Low SES families exercise less voice on average, and exercise no more voice in denser areas, so there is no countervailing force for the negative effect from the exit mechanism on this group.

Empirical setting, data and strategies

Locally provided services and K-12 education in the United States constitute an ideal setting in which to test the relation between density and agency in voice and exit since there is a direct link between neighborhood selection and the quality of schools and schools have well-established channels for the exercise of voice through school districts, PTAs and other bodies and offices at the state level, often directly elected.

I will compare areas that are education markets. They are the context where the choice of school or district, through change of residence, is most salient and less costly: it must be feasible to change districts or schools within an education market without having to change jobs, break from regular contacts with existing networks or otherwise have one's livelihood severely disrupted. We know that most of the relevant forces of residential sorting that are important for inequality of income occur within metropolitan areas and not through migration of different types of people between metropolitan areas, particularly across school districts (Cutler and Glaeser, 1997 and Owens, 2016). As the closest approximation to these elusive education markets, I use the census-defined commuting zones (CZs) introduced by Tolbert and Sizer (1996). They partition the entire US mainland into 741 clusters of counties, and are defined in accordance with self-reported commuting patterns from the 1990 census. They are characterized by intense commuting patterns within CZs and weak commuting patterns across CZs. The size of these commuting zones means that I contrast relatively large areas by their level of density. My comparisons are thus between areas that include large metropolis, their suburbs and exurbs; smaller cities and towns and their surrounding areas; and rural area with no clear focus. Any such large areas include substantial population and several school districts and schools and the difference will be in how numerous they are.

Data sources

For educational outcome data, I use a cross-section of the bi-annual federal National Assessment of Educational Progress studies in reading and math (NAEP). Their restricted micro-data contains some 150,000 observations per subject (each of reading and math), which are meant to be representative at the state level. This relatively little used data is representative nationally and at the state level for public schools. It has been exploited for the study of state level distributions of achievement between districts within commuter zones, for instance by Lafortune et al. (forthcoming) and Jackson et al. (2018). In this paper I present results for Reading and Math in the 2007 testing cycle for 8^{th} grade, the last cross-section with micro-data available at the time of writing. In the Appendix, I complement these results with those obtained by using average outcomes at the school district level (in state exams), as related to the average district income and its interaction with density levels, using data that is standardized to a common scale by Reardon et al. (2016), based on state exams.

Individual demographic variables will be used as controls and to elicit differences in the effect of density by demographic groups are obtained from the school and student survey that is a companion to the NAEP micro-data, complemented with aggregate area data from the National Center for Education Statistics Common Core of Data. The individual data on socioeconomic status used in most analyses includes race and ethnicity, free and reduced lunch status, individual learning programs (as a marker for disability), English learner status, and whether parents graduated from college, as well as an SES index constructed by these variables. From the same source, we also have some information about the educational behavior of students and access to books, newspapers and the characteristics of the teachers they have.

I use a simple measure of density: the area level density of enrollment within commuting zones, i.e the enrolled K-12 students per square kilometer. This data comes from the National Center for Education Statistics matched with the US Census' TIGER mapping data, geographically matched by the zipcode of residence of the student. At the level of commuting zone, this measure is unlikely to be affected by the problems that an analogous measure would have when looking at smaller units: measurement error due to the recorded density between residential and industrial areas or areas with large open spaces, for example is less relevant if they are all subsumed within larger economic areas.

In analyzing the socioeconomic segregation in denser and less denser areas, I use aggregate data on income and racial mixes and its distribution at the district level is obtained from the American Community Survey (compiled by Reardon et al. 2016).[9] Additional aggregate data for commuter zones on income and racial segregation, crime data and levels of social capital comes from Chetty et al. (2014) and data on the commuter zone economy, such as the share in routine jobs comes from Autor and Dorn (2013).

To establish measures of "voice", I use the EdNext survey, a nationally representative survey on issues of education, with oversamples for teachers and parents and done via computer, with data for each year in 2007-2015. It contains an average of 100 observations by commuter zone-year. While the majority of the questions change year to year, there are a few recurring questions that I exploit to form samples of up to 34,459 observations in the period on the involvement in school system politics. They are the perception of school quality, attention paid to education, voting in school board elections and policy preferences for education reform.

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[9] This is complemented with county level data obtained from Chetty et al. (2014), who compile it from individual tax returns (and I use in the Appendix) that should reflect the entire population of taxpayers, rather than a sample.

Empirical strategy

The descriptive empirics of the paper proceeds as follows. I first document descriptively the average relation between density and student outcomes and how this varies along the distribution of test scores. For this task, I use quantile regression, which allows me to estimate the effect of commuter zone density for observations at different deciles of the distribution of scores. In essence, the quantile regression estimator weighs the observations centered around the specified quantile in a regression framework and linearly decreasing away from the center (it was introduced by Koenker and Bassett (1978)).

In regression form, the link between student density in enrollment and outcomes is established by running a series of regressions of the form:

$$(1)\ Y_{\theta ics} = \alpha \log d_c + \boldsymbol{\beta} X_{ics} + State_s + \varepsilon_{ics}$$

For a subject *i* in commuter zone *c* in state *s*, d_{ics} is the enrollment density variable and indicates enrollment in K-12 education per square kilometer in the commuter zone, X_i are student level controls (not included in the main model), which include indicators for exact age in months, gender, race, disability status, English learner status and free and reduced lunch status and whether the student received extra time in the exam. $State_s$ are state fixed effects. I run these individual-level regressions for the cross-section of student outcomes as well as survey results (the Y_i), with regressions weighted by the sample weights to achieve state representative samples. Standard errors ε are clustered at the commuter zone level. θ is the quantile level of performance, and for the average effect, the θ parameter should be ignored.

In order to test the relationship of density with an inequality gradient more systematically I look at disadvantaged students by running a series of mean (non-quantile) regressions which interact indicators of socioeconomic status (SES) with density, of the form:

$$(2)\ Y_{ics} = \alpha \log d_c + \gamma \log d_c \times SES_i + \delta\ SES_i + \boldsymbol{\beta} X_{ics} + State_s + \varepsilon_{ics}$$

γ is here the coefficient of interest that indicates differences in the effect of inequality for different socioeconomic groups.

Causality: geographic discontinuity design and instrumental variable specifications

In order to test the theoretical predictions, the ideal experiment would be to have students with exactly the same individual characteristics randomly assigned to areas that differ in terms of their density levels alone. This ideal setting is not available and individuals in denser places may differ in many economic, social, demographic and other ways outside schools, in ways that are unobservable.[10] Reverse causality is also a concern since the educational success of certain areas may attract people to those areas and drive their density up. If places that have more successful economies tend to have or attract families at extreme ends of the socioeconomic distribution, such as workers in finance or recent immigrants we may expect that, given correlations between socioeconomic status and educational outcomes, the density-inequality gradient would be greater without any need for differences in schools they attend.

To deal with such concerns, I undertake a geographic regression discontinuity design that exploits boundaries between commuting zones and three instrumental variable strategies, described below.

Geographic discontinuity design

The contrasts in density levels in neighboring commuting zones allow us to consider a specification that exploits potential discontinuities in the boundary through a geographic regression discontinuity design. Intuitively, the rationale for using such a design is that for people living close to the commuting zone boundaries, their living on one side of the boundary or the other is as good as randomly assigned, since both sides are close in many other characteristics but may influence the education market they belong the respondents are in discontinuously.

Regression discontinuities (RD) have been increasingly used in the social sciences in recent times. A particularly popular strategy has been to exploit election cutoffs, by looking at candidates who either get elected or fail to by looking at either side of the required vote share, 50% in two-way races (see Cattaneo et al. 2015). Candidates who get just above

[10] Unobserved individual characteristics correlated with the socioeconomic status markers will in general bias average level regressions more so than the ones trying to capture inequalities. Density-inequality gradients (γ in the specification above) will only be biased if density is related to socioeconomic groups in different ways: if the effect of density is biased in the same direction for poor and rich subgroups, the relation between density and inequality across groups will not be biased.

50% of the vote get elected while those who get just under 50% do not, but otherwise those candidates and elections are essentially similar. The same idea of cutoffs in a continuous variable with different treatments on either side of the cutoff can be applied to geographic boundaries. Dell (2010), for instance has done this by looking at historic and no longer applicable colonial administrative boundaries in South America and Keele and Titiunik (2015) exploit seemingly arbitrary media market boundaries. At its basic, the idea is to find a boundary that divides areas in an "as-if random" fashion, i.e. one that is only related to the outcomes through a change in the mechanism postulated. In the example, historical processes of segregation or the media that citizens are exposed to change abruptly at the boundary, while other variables from economic conditions to education levels does not. I implement a RD design where I exploit test-takers who live close boundaries between commuting zones of different densities. I select the subset of boundaries where there is a substantial drop in commuting zone density levels, higher than 5% of the average density level (equivalent to 3.5 students per square km). For a test-taker, the treatment indicator takes the value 0 if the commuting zone it is in has a higher density than the nearest neighboring commuting zone. The treatment takes the value 1 if the density of the commuting zone it is in is lower than that of its nearest neighbor.[11] The associated continuous forcing variable is then distance of the residence of the test-taker to the boundary in meters: a negative distance if the student observation's zipcode is in the higher density commuting zone of the pair and a distance greater than zero if it is in the lower density one, so the sign of the forcing variable fully determines treatment (a sharp RD design).

Even though quality of schools are strong predictors of residential choices, the advantage of using commuting zones (similar to media markets or historic borders no longer in place) is that they do no correspond to hard boundaries that are physical, demographic or administrative discontinuities. Developed by census researchers, they are arbitrary lines with no administrative consequences that reflect commuting patterns. There is no hard

[11] Ideally, the treatment would be sensitive to its dosage, that is, the size of the drop in density at the boundary. However, current regression discontinuity models only handle binary treatments rather than continuous or even factor treatments. This is a clear avenue for extensions of those methods and for the implementation of the model.

limits that commuting zone boundaries impose that would stop participation in neighboring labor markets, say. One way of understanding the role of the boundary is that it forces people that fall on each side to participate in different local education markets without affecting social relations or their commuting lengths. It is worth remembering that these boundaries are far from the center of commuting zones where the Tiebout sorting is likely to be more intense and there are many districts in close vicinity. Instead, the boundaries arguably put residents in different education markets without them actively making a very careful decision about it. Along these boundaries, we should not see systematic strategic choice of residence on either side of the boundary and the assumption of random assignment of commuting zone around the boundary appears warranted. Below, we also provide some evidence that it is likely to hold in this case through showing that test takers along boundaries look very similar, at least on observable characteristics.

Moving to the implementation of the design, I base the residence of test-takers on their zipcode, a fairly precise estimation of their location as there are 43,000 zipcodes, so each covers an average of 178 square km or a radius of 7 km. I use a nonparametric approach (Cattaneo et al. 2017, 47) where the global function that relates the running variable and the outcome are left unspecified and simply is approximated locally around the boundary with a linear model. The estimation of a treatment effect of the drop in density at the boundary is based on the difference between the predicted test score levels as the distance to the boundary approaches zero from values lower than zero (in the higher density commuting zone) and the predicted values of the outcome as distance approaches zero from positive values (in the lower density commuting zone). In short, I predict these limit values through estimation of separate local regressions on either side of the boundary and compare the point-estimates at the boundary.

These estimations can be affected by choices about the local estimation procedure. Following common contemporary practice (see Cattaneo et al. 2017, 80) I use a local linear polynomial with a uniform kernel (which weighs all observations within the bandwidth equally) to predict values at the boundary when approximated by either side. The decision on the bandwidth to use determines the range of observations that are considered close enough to the boundary for estimating the local discontinuity. Rather than using an ad hoc bandwidth, I use mean square error (MSE)-optimal bandwidth. This finds the optimal value for the bandwidth that minimizes the tradeoff between the bias driven by using observations far from the boundary and the variance driven by using too few observations.

Instrumental variable strategy

Next, I turn to an alternative and complementary empirical strategy. I use a series of instrumental variables specifications in order to assuage concerns about reverse causality or omitted variable biases that may cast doubt on the estimates. As is common in the literature on agglomeration economics, (see for example Combes et al. 2010 or Nunn and Puga, 2012), I first focus on the nature of the terrain and its role in enabling the settlement of different population levels. A plausible instrument is then the fertility of the land together with the closeness to sea, in so far as it conditioned the capacity to feed large numbers of people in an agricultural economy. This provides a historical determinant of contemporary density levels that cannot be due to the quality of education system. Since these physical determinants of density have little immediate relation with the structure of the economy today and possible differences across groups, and in particular with the importance of human capital in economy, reverse causality is less of a concern.

A second instrument is suggested by a separate argument that seeks to explain presence of greater public school choice in denser areas is made by Fischel (2009) to the effect that school districts were by and large fixed during the high school movement (1910-1940) to be of sufficient size to be able to sustain a high school. This meant that the geographical size of districts today is heavily influenced by their density during that period (in turn related to geographical determinants). Density in the 1930s thus influences the geographical size of districts today and so, the availability of commutable districts in a given area.

This narrow effect of density on these institutions also means it is unlikely to have effects on other predictors that may drive the divergence across groups in education outcomes. Probing it further, the main concern about the use of this instrument is that these longstanding determinants set agglomeration processes in motion in a way that even if the relationship has originally little to do with education, denser places over time become different places in ways that may be related with education outcomes. It may be that they attract people from more extreme parts of the distribution of skills (e.g. those who are innately higher achievers and relative low achievers), for instance, that historically denser areas are the first to have the critical mass to create schools and universities that benefit and attract higher socioeconomic status groups. Most of the potential biases for this instrument suggest its estimates may, if anything overstate the effect of density on the socioeconomic gradients in student outcomes.

A third instrument attempts to produce estimates free of the biases that these longstanding processes may generate. Instead, we use shorter term predictors of density of the student body: the local number of students by cohort 8 years before (population in 2000) combined with national fertility levels to predict student density in 2007.[12] Predicted density of K-12 students at time *t* is then given by the (national) fertility rate at the start of the period *t-x* (x=8 in the base case) for each age cohort, multiplied by the density of the females in each age cohort-area.[13] This latter number is given by the ageing by *x* years of the cohorts of females present in the district in time *t-x.* The predicted density would match density exactly if there was no migration from the areas, fertility rates remained the same in the x years in the period and, given that we use national rates, if there was no across-district variation in rates.

With this instrument, the variation used is the predicted part of contemporary density levels, discounting any short-term adjustments potentially due to the quality of the education system and also recent migration of people with different backgrounds and economic fluctuations that may affect the education system. The remaining variation that the use of predicted density will not take into account is thus the short-term changes in the attractiveness of areas or districts. Arguably, migration adjustments across commuting zones are driven in the short term by families seeking new job opportunities and so with high commitment levels to education. For that reason, I would expect the relation between predicted density and outcomes, rid of gradient-increasing short-term movements of people to understate the true causal relation between density and outcomes.

[12] This is similar to Maestas et al.'s (2016) instrument for the ageing of the population and inspired by Bartik (1991)

[13] Specifications using x=18, which use data from the 1990 census lead to similar results.

I use then three different, long- and short-term instruments which in principle may bias the coefficient of interest in different directions. They then provide bounds for the magnitude of the true effects.

Results

Descriptive Results

I briefly document the variation in average performance across different parts of the country before turning to establishing its relation with density levels. There are very substantial differences between the average performance levels across different parts of the country. These differences across commuting zones are reflected in the finding shown in column 5 of Table 1 that geographical areas are at least as explanatory as basic demographics, as shown in the doubling of the R^2 when, in addition to individual controls, we add commuting zone and district fixed effects. This high explanatory power of geographical area mean effects can be seen more directly: if we take the distribution of the commuting zones effects in the models with commuting zone fixed effects, the difference between the average effect of being in a commuting zone that performs at the 75th percentile and those at the 25th percentile is .26 standard deviations in student test scores, after the addition of demographic controls. The difference between the 90th and 10th percentile is half of a standard deviation in test scores. This is shown in panel A of Table 2. By contrast, the average white non-white gap in our sample is .32 SD. To give a tangible sense of what the commuting zones are and how they stack in terms of both density and performance, we also show the top 10 commuter zones in terms of density in Panel B of Table 2. They all feature in the top 20% of commuter zones by average student outcomes.

I turn from the description of the differences across commuting zones in outcomes of students, to the role that geographic agglomeration has in explaining these differences. I look first into whether there is a relation between density and average effects (prediction 1). Figure 3 plots individual level data in 30 bins along the log density axis without (top chart) and with demographic controls (bottom chart), which suggests a positive relation between log density and student outcomes, on average. In regression form, column 1 of Table 3 shows that before we add any individual controls, there is no clear pattern between density and average scores. As I add linear individual controls, and state fixed effects, a stronger positive relation between density and outcomes emerges (α= .029 for reading and α= .025 for math in the fully specified model 4).

The second prediction is that average and relatively small in magnitude positive relation masks significant heterogeneity across the different socioeconomic groups. As a first approximation to the effects for different groups, we use quantile regression to break down the effects for the first 9 deciles of the distribution of outcomes (the 10^{th} is too imprecisely estimated). 45 shows that while the average effect of density may be positive, the effects actually differ substantially along the distribution of outcomes. While the point estimates are *negative* for those that are at or below the 30^{th} percentile of the distribution of outcomes, the relation is *positive* and significant for all those with predicted outcomes above that third decile. The positive effect of density is also larger the higher the decile. Denser commuting zones are therefore more unequal: along the distribution, low performers do worse and high performers do better.

So far I have not characterized the groups that behave differently and just used their position in the distribution of outcomes. Prediction 2 is, more specifically, that differences in test scores by socioeconomic status get exacerbated in denser areas. In Table 4, I show the results for both reading (panel A) and math (panel B). When I divide the sample by the available indicators of socioeconomic inequality the results match the prediction: poorer students do worse in denser areas, while richer students do better: for both outcomes, model 1 of Table 4 shows a negative and significant interaction effect of density with being a recipient of free and reduced lunch and, similarly, a positive and significant coefficient of the interaction between density and having parents who attended college (model 3). These are the preferred estimates since specifications that include demographic characteristics would attenuate results by socioeconomic status, as demographic controls are correlated with indicators of socioeconomic status. The results, however, are directionally robust to the addition of individual demographics in models 2 and 4. These are relatively large differences: to take differences in reading (Panel A), from columns 1 to 4 we can see that whether we measure socioeconomic status by free or reduced lunch status (models 1 and 2) or parental college attendance (models 3 and 4), being in a 10% denser commuter zone is related to a .2-.4% SD increase in the outcome inequality across groups, or between 1-2% of the average gap in outcomes between groups. In each specification, this is driven by the higher performance of those of high socioeconomic status coupled with the lower performance of those of low socioeconomic status: concretely, the effect of a 10% increase of density for those not on free and reduced lunches is a .2% standard deviations on reading (from model 1 of Table 4, α= .020), while for those on free and reduced lunches it is -.2% (in the same model, $\alpha + \gamma = -.024$).[14]

In Figure 5, we see graphically the pattern of differential effects of density on outcomes once we divide the sample by four binary demographic indicators. The pattern of diverging fortunes as density increases is clear by our main two indicators in charts A (free and reduced lunch) and B (parents who attended college) of Figure 5. In both of them, the advantaged group's test scores rise as density increases, while it becomes lower for less dense groups. Looking at racial groups, the advantaged group (whites and Asians) see their outcomes increase with density, while Blacks and Hispanics do not seem to have a density gradient in either direction (chart C). The two remaining indicators, being an English learner and having a disability are the least reliable indicators of socioeconomic status and do not lead to divergences between the groups along the density gradient (D and E). When taking just a summary measure of socioeconomic status in an index with equal weight for each indicator in plot F, we observe the predicted pattern of divergence along the density axis of the groups with above median levels of deprivation compared to those with below median levels of deprivation. The size of the effect is relatively large, with the gap between the high and low-SES groups increasing by about 50% over the support of the data.

Geographic regression discontinuity specification results

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[14] I am able to replicate these results using data (compiled by Reardon et al., 2016) of all state exams results in the country through grades 3-8 in math and English, Language and Arts. This data contrasts with the NAEP sample but is only available in aggregate form for district. I am forced to use average income levels and average test scores in districts or commuting zones. The results from these district level regressions, however, are consistent with those found for the individual level ones. The model in Table A1 reproduces directionally the findings of Table 4. Taking model 2 (reading) at average levels of Free and Reduced Lunch students (42%), district density is positively associated with test outcomes. This relation is negative for districts above the 92th percentile of FRL (81%). In Table A2, I am able to use average district household income as a continuous proxy for socioeconomic status. In model 2, the relation is similarly positive at mean levels of average district household income (57,649) and above and is negative for districts below the 48th percentile of average household income (57,011). Although it need not be the case that average district scores bear the same relation with density as individual level scores it is likely that they are, gicen the sorting in districts by groups of similar income. It is reassuring therefore that the results are consistent across these datasets.

One of the advantages of any geographic regression discontinuity design is that it has a clear visual representation. Figure 5 displays the full support of the data (in 50 equally sized bins on each side of the boundary) and we can inspect visually the discontinuity of average student outcomes across the commuting zone density discontinuity. Analytically, the commuting zone boundaries I use look as follows. Of the 152,388 reading test-takers for whom there is zipcode information, 135,113 observations are such that the student density level difference between the commuting zone they are in and the nearest commuting zone is greater than 3.5 students per square kilometer. The average distance to a commuting zone boundary in our sample is 28 km for those in denser commuting zones and 22 for those in less dense commuting zones than their neighbors. The average drop in density across boundaries is a substantial 142 students per square km, higher than the mean density in our sample of 115 and about half of the density at the 90^{th} percentile level (291 students per square km).

Visually, in Figure 6, it is clear that along with the drop in density across the boundary, there is a drop in quality. Zooming in closer to the boundary and looking at the inequality across different groups, in the two panels of Figure 7, I look separately at the effect of the drop in density treatment for test takers who receive free and reduced lunches and those who are not. As predicted, the effect of a drop in commuting zone density across the boundary is accompanied by an increase in scores for students on free and reduced lunches but a drop for those who do not.

I turn to the numerical estimates of the effect of the drop in commuting zone density levels. For full transparency and simplicity of the specifications, rather than estimating models where density is interacted with indicators of low socioeconomic status, I run separate regressions for the disadvantaged and advantaged of these groups, and then take the difference between the value at which both local regressions intersect with the y axis, i.e. the difference between predicted $\hat{Y}(x=0)$ for each of the estimations, as $x \uparrow 0$ and $x \downarrow 0$.

The results are presented in Table 5. They collectively suggest that around the optimal bandwidth for each indicator of socioeconomic status, the effect of a drop in density across the boundary is negative for high socioeconomic status students, while it is positive for low socioeconomic status students. First, for students that are recipients of free and reduced lunches, being in a commuting zone that is less dense than the one the test-taker is in and closer than 2.3 km leads to an increase of .32 standard deviations in reading test scores -and this is highly statistically significant. The converse is true, for those that do not receive free or reduced lunches: there is a decrease in test performance across boundaries when there is a drop of density of about .26 standard deviations. The effects on inequality across cleavages are smaller for differences in parental education: .12 SD for non-college educated parents and a not statistically significant -.01 for college-educated ones. For racial cleavages, the effects are larger and significant, .54 for blacks or Hispanics and -.27 for whites and Asians. For inequality around English learner status, we find a weak pattern in the opposite direction: -.01 for English learners and .06 for non-English learners. For the cleavage that does not intuitively reflect socioeconomic status, disability, there is an effect in the opposite direction from what I predict for socioeconomic cleavages: the effect for disabled students of a drop in density is negative (-.12), while it is positive if not significant for non-disabled students (.08). For the summary index of socioeconomic status that averages these measures, the effect on the cleavages around average values of that division conforms with the expectations: .21 SD effect for below median SES test-takers and -.07 effect for high SES, according to the index.[15]

I look at two main potential threats to the validity of the estimates for these geographic regression discontinuity estimates. The first are concerns of the strategic positioning of observations on either side of the boundary and I look at whether there is bunching on either side of the boundaries. If there were different numbers of observations across the boundaries, this would suggest strategic positioning on one of the sides and it would be harder to defend the idea that the positioning on either side is as good as random and so, that the respondents on either side of the boundary are no different. In Figure 8 I plot the frequencies of observations around boundaries. There is a slightly greater concentration of observations just inside of denser commuting zones, but the difference is small. A formal test of the equality of density above and below the cutoff reassuringly shows that I cannot reject the null hypothesis of equality of frequencies on both sides of the boundary (p-value of .31).

[15] Note that these estimates are, generally speaking, larger than the OLS estimates. Part of the explanation is that the average drop in our subsample of within bandwidth observations is very large. The estimated local average treatment effects in the RD specification therefore comes from a very specific set of observations, contrasting those in the edges between suburban or exurban observations and rural areas.

The second threat to the validity of any regression discontinuity design is the discontinuity in covariates that may be related to the outcomes, which may then confound the effect of the treatment. I look at individual-level covariates. No significant difference with the number of males (p-value of .71), free and reduced lunch status (.69), individualized education programs (.96), college parents (.99), although there are significant differences for English learners (.02), white or Asian (<.01). These differences are somehow reassuring, as many variables do not have a significant difference across the subset of boundaries. In all the specifications where they do not act as cleavages to be investigated, adding indicators for white or Asian as well as English language learners as controls does not alter the results.

In conclusion, the local estimates of the effect of the drop in density around commuting zone boundaries are directionally consistent with the ordinary least square estimates for the whole sample of test-takers. Hence they provide support for the main empirical contention that density is related to greater levels of average test scores and socioeconomic inequality in test scores.

Instrumental variable specifications results

Table 6 presents results from instrumenting density with the three instruments described. In panel A, I present the instrumental variable estimates with no further commuting zone controls. In panel B, I include commuting zone controls in order to block potential mechanisms that are different from those that are related to the channels of exit and voice and may be related to the instruments. These include economic characteristics, such as the share of the regional economy that is knowledge-based (measured by the share of routine jobs), as well as other social characteristics of the commuting zone, such as differences in social capital, violent crime and share of foreigners. Both panels show, as expected, larger coefficients on the interaction term for density levels in the 1930s and the nature of the terrain (models 2 and 3), while they are about the same size as the OLS estimates when using as instrument for density short-term predictors of density using the sizes of previous cohorts (model 4). For all models, the coefficients on log density are somewhere in between .02 and .07. That the instrumented models chosen for their differently signed biases turn out not to change the magnitude or significance of the simple OLS estimates substantially should give confidence that true estimates across the support of the data should be in that region.

Exit and voice as explanatory mechanisms

The evidence thus far suggests that in fact density seems to be associated with greater inequality of outcomes. I turn now to whether the data is consistent with the role I claim for the exit and voice mechanisms.

Exit mechanism in denser districts

I explore first whether it is the case that the exercise of the exit mechanism is indeed easier in denser areas. According to prediction 3, denser areas should have more exit opportunities. In Table 7, I run regressions (aggregated at the commuting zone level) of the number of students, the number of schools and of districts on the density of the commuting zone. I find first that denser areas in fact have more students in absolute levels, and that there is indeed a strong positive relation between the density of the commuting zone and the exit opportunities available in it through a greater number of schools and districts.

The more substantial prediction 4 is about the patterns of segregation that those denser geographies are associated with. Concretely, the prediction is that the greater exit levels entails that there is less pooling of different types of people into the same schools. This means that there will be more homogeneous schools and districts as well as greater differences across schools and school districts in denser areas. While it is difficult to use good evidence about schools (for instance, no detailed data on family income at the school level is available), there is better data from school districts. Using income data distribution at the district level, in panel A of Table 8 I regress three indicators of inequality across districts within commuting zones and commuting zone density. These are the ratios in income between districts within the commuting zone at the 90^{th} and 10^{th} percentile of average income (model 1), 90^{th} and 50^{th} percentile (model 2) and 50^{th} and 10^{th} percentile (model 3). Panel B does the same by looking at the same income ratios *within* districts, using the mean of these ratios in the commuting zone as dependent variables.

The positive and significant coefficients in panel A and negative and significant coefficients in panel B shows that while there are greater differentials in average district income within denser commuting zones (higher income ratios across districts), there is more homogeneity within school districts (lower ratios within districts). This finding is consistent with the prediction that higher density leads to greater socioeconomic segregation across districts. [16]

This socioeconomic segregation will have an impact on students if there are positive peer effects that poor students miss out on by not being in the same schools as richer students. But this impact will be exacerbated if it is matched by greater inequality in school characteristics in denser areas along socioeconomic divides. There is in fact some suggestive evidence that, in denser areas, the types of school inputs that students of different socioeconomic status go to are more different. In panel A of Table 9 I regress positive characteristics of teachers serving poor and rich families by the density of their commuting zone: whether they have done Professional Development activities in the previous year, experience as a teacher and Master's or above degree. The positive coefficients on the interaction between density and free school lunches suggests that directionally at least that the density gradient in positive characteristics of teachers that students have differs for low- and high-SES students: in denser areas, the characteristics of the teachers are more different for rich and poor students. As for the scholarly characteristics and behaviors of students and their schools in areas of different densities, Panel B of Table 9 regresses student attributes in denser and less dense areas by socioeconomic status: the number of books they have at home, newspapers, whether they talk about studies at home and whether they talk about studies with friends. All but especially the last two measures will be a combination of student and school differences, as better schools would encourage parents to be involved in their children's studies and greater discussions and group work among peers. I find that while students with higher socioeconomic status seem to have more books, talk more about studies at home or with friends in denser areas, that is not the case of students on free or reduced lunches. In each

[16] Alternatively, county-level data coming from tax returns has been made available by Chetty et al. (2014). This has the advantage of coming from administrative data and thus, includes all or most of the population, decreasing any biases there may be in the survey data, such as from censoring. The results analogous to Table 8 for counties are in Appendix Table A3, indicating that similar dynamics result from density differences at the county level.

case, this suggests that the gap in scholarly characteristics and behaviors between richer and poorer students is greater in denser areas.

Voice mechanism

Turning to voice, in line with prediction 5, I expect that there is no compensating voice mechanism for poorer families to make up for the increased segregation they experience in denser areas. Table 10 relates nationally representative survey evidence on participation in and knowledge about school matters with density and socioeconomic status. In models analogous to the descriptive individual-level regressions for test scores above, the main relation between the two is in line with longstanding general findings about political engagement: there is a positive correlation of engagement with income and education (e.g. Brady et al. 1995), which implies lower levels of voice for poorer parents. Models 1 and 2 of panel A, show a positive and significant coefficient of being a college graduate on board election participation and attention paid to education: the more socioeconomically advantaged group pay more attention to education and tend to vote more in school board elections. This is despite not having a different assessment of the quality of their local or national schools (models 3 and 4).

I then look at whether these differences across groups change in areas with greater density levels. In particular, I am interested to see if the detrimental effect of the exit mechanism for richer families is tempered through the increased use of the voice mechanism by poorer students (facilitated by the greater potential for organizing in denser areas)[17] The empirical models shows that density does not have a positive effect on lower socioeconomic status respondents (using the terms from equation 2, this is α in panel A, models 1 and 2) and so, they do not increase their participation –even though we have established test score performance is, on average, worse. Higher socioeconomic status families, however, seem to get *less* involved or exercise less voice in denser districts ($\alpha+\gamma$ is negative), although only by a small amount: a 10% increase in density would only be associated with a

[17] Identification is, of course, a problem, and there are no obvious exogenous sources of variation in the availability of voice such as differences in presence of school boards. In addition, these typically vary, like many education policies, by state, further reducing the empirical leverage of using such variation.

reduction of the gap in voice between high and low density places of about 1.6% (.0029/.18).

In panel B of Table 10, I look at other measures of activity and opinions that may conform to a broader definition of voice. For instance, greater concern for underperforming schools may be related to having stronger opinions in favor of policies that involve substantial departures with current practices. I exploit differences across groups in attitudes towards a number of very specific policies related to education reform such as advocating for more choice in the form of vouchers or charters and for an increased variable portion of teacher pay. The patterns are mixed: in panel B of Table 10 the support for measures of reform towards education are overall not very different between college graduates and those who are not, suggesting similar policy preferences. We do observe that these reforms are more popular in denser areas, although these are not driven particularly by higher or lower socioeconomic status groups: pressures for reform are no different, in denser areas, for districts or schools attended by low socioeconomic status individuals (there is no significant interaction γ between density and SES indicators).[18]

In summary, there is no countervailing increase in voice for disadvantaged groups that responds to the lesser outcomes they experience in denser areas. The analyses suggest that for poorer families there is no density gradient in the exercise of voice, no different assessments of quality of schools and no different levels of support for education reform. Low socioeconomic status families do not do anything differently, despite their children doing worse in schools. By contrast, higher socioeconomic status individuals do use voice mechanisms less in denser areas. Given the patterns of school segregation we identified, in denser areas there will be less participation in worse performing poorer districts as more vociferous families exit and others do not increase their participation. But there will also be less participation in high performing richer districts, as families participate less. Taking these findings together the clear cleavage between the exercise of voice between groups with different socioeconomic status is somehow reduced in denser areas, but only because higher socioeconomic status individuals exercise it a little less. There is no evidence that

[18] One simple explanation for why we may observe people in denser areas to be more supportive of education reform overall is the higher feasibility of policies such as vouchers and charters in denser areas.

greater availability of information, media outlets, ease of organization and, ultimately, less quality of schooling results in greater voice in denser areas for low SES groups.[19]

Testing directly the importance of mechanisms in explaining the relation between density and outcomes

So far I have provided evidence of how the specific mechanisms of interest, exit and voice are related to density and, indirectly, how they may explain some of the results. This is suggestive but gives no sense of their importance compared to that of other potential mechanisms, such as the economic characteristics (and hence incentives available) or the non-school or social characteristics that density may be related to. I do a simple test that includes in the main individual-level regressions (parents who attended college variables) ones that include proxies for the strength of those mechanisms. These proxy variables for each of the mechanisms are, for choice, number of schools and of districts; for voice, average attention paid and board election participation; for economic characteristics, the share of routine jobs in the local economy; for social characteristics, violent crime levels, a measure of social capital[20], racial and economic segregation levels.

If any of these were indeed a mechanism or mediator, when the corresponding variable was included in the regression analysis, the effect of density for either the high or low SES group (or both) would be significantly attenuated. The results are shown in Table 11. Starting with the basic OLS model 1 (replicating model 3 of panel A, Table 4), I add in each model successive variables related to mechanisms. We see that the density coefficient

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[19] I provide an imperfect test of the general proposition, defended by Hirschmann, that exit and voice are to an extent substitutes and that there is an inverse relation between the two. If exit and voice were independent (no arrow 4 between exit and voice in the diagram above), there would be no question that density had a positive impact on educational inequality. In line with the prediction, I do find some suggestive evidence that there is on average an inverse relation between exit and voice, as Hirschman postulated. In Appendix Table A4 (panel A, models 1 and 2), we see that there is a negative relation between the number of districts (our measure of exit) and the amount of voting in school board elections. Controlling for their opinion on the quality of the school, respondents seem to be more likely to participate in school board elections if there are fewer exit options in their district. This seems to be moderated by the level of racial segregation in the commuting zone (model 2) and income segregation (model 3). Given the differential benefits we observe of being in denser areas, it may be that this responsiveness of the exercise of voice to exit is very different for different groups.

[20] The measure of social capital is a standardized index combining measures of voter turnout rates, the fraction of people who return their census forms, and measures of participation in community organizations. For details, see Rupasingha and Goetz (2007). For the other measures and definitions, see Chetty et al. (2014).

for low SES is attenuated as I add choice (model 2), voice (model 3) and social cohesion indicators (model 5), although not when I add difference on the typology of the economy in denser areas (model 4). This is also the case for the fully specified model 6, with all variables. Choice in particular seems to explain the bulk of the negative effect of being in denser areas on student outcomes for low socioeconomic status groups (the coefficient on log density goes from -.0159 to an insignificant .00884 when we include choice measures) with a smaller change for voice. The change in the coefficient when I include social characteristics such as violent crime, social capital and segregation measures is large too and signals that denser areas are very different from others in other ways not directly related to schools. However, throughout all specifications, including the fully specified model 6, where I add all variables, I do find that there is a strong positive and persistent effect of density on outcome inequality that our mechanisms do not fully explain.

In Table 12, the same analyses done with variables aggregate at the aggregate district level suggests that the largest mechanism explaining the relation between density and the level of variation in district-level inequality in school outcomes is related to school choice, as the inclusion of school choice indicators is the only one that makes the coefficient on density insignificant (column 2). This may be partly explained accounted for by the difference between a density gradient on the binary indicator of socioeconomic differences (parental college graduation) being too coarse in capturing the type of inequality associated with density. Unlike Table 11, the aggregate analysis in Table 12 does not impose a particular individual socioeconomic indicator and focuses on inequality alone.

Interpretation and policy implications

This paper has documented differences in the heterogeneity in student outcomes across local areas in the United States and tried to isolate the effects of variation in density levels within a theoretical framework that considers how socioeconomic groups benefit differentially from being in denser areas. In short, denser areas seem to increase both average levels and inequality in outcomes and this appears to be importantly mediated by the higher levels of choice available to families in these areas. This benefits many families but particularly richer ones. They harm poorer ones who, in less jurisdictionally fragmented areas benefit from attending the same schools. Geographic separation facilitates the divergence in the education that students of different backgrounds receive. More student separation and less pooling facilitates differences in school finances, types of teachers, the management and culture of the school or classroom practices that are subsumed in the variety of mechanisms included in the segregation explanation. With the limited data available, I have shown some evidence that there are in fact divergent inputs and experiences in schools in denser areas across socioeconomic groups. The result is that at least in the case of public schools, a harmonious balance between exit and voice as mechanisms for ensuring high quality public schools is not available to all and results in greater inequality in student outcomes. Greater exit in denser areas allows high socioeconomic status families to choose the best schools and districts, while both exit and voice break down for poorer families, who are unable to take advantage of exit or to exercise voice in an effective way. This is likely due to a combination of barriers to exit through house prices and barriers to voice given by information, time commitment and other challenges, independent from density.

Concerns about inequality in school outcomes in denser areas such as the larger metropolitan areas should lead to policies that tackle these structural differences. The geo-demographic mechanisms presented here result in stable, difficult to change economic segregation levels not traceable to pernicious school policies, which likely means there are no easy policy solutions. However, three types of policies may be able to contribute towards mitigating such dynamics. The first group of policies involves diminishing the impact of the increased opportunities for exit that richer families enjoy in denser areas. One way of achieving this would be to remove or weaken the jurisdictional barriers that enable and exacerbate the economic segregation of schools. Busing across areas of different socioeconomic levels and open enrollment within metropolitan areas ought to be considered. Given that residential segregation by economic status is an long-established and important part of American society and the political challenge of coordinating whole metropolitan areas with many jurisdictions, this may ultimately prove very hard to make progress on –although it should be noted a form of open enrollment limited to the core cities of certain metropolitan areas such as New York or Boston is already in place.

The second group of policies focus on ensuring exit options for the poor are available (rather than suppressing opportunities for the rich). Private school choice in the form of charters or voucher programs could ensure that the jurisdictional barriers to public school choice are less important. Moreover, the introduction of such private choice programs has been shown to improve public schools (Figlio and Hart, 2014). By contrast, given the well-established differences across groups in the exercise of voice, any measure that tries to introduce a more effective exercise of voice through increased information or organizational support is likely not to be very effective, unless it is given a new form. Technology available to parents from all socioeconomic groups can be leveraged to provide more targeted information through, e.g. report cards that are more frequent, more user friendly and that are pushed to parents. A third group of policies that does not try to mitigate the mechanisms described but instead tackles the consequences of those mechanisms would be dedicated compensatory mechanisms for the schools that are more likely to be doing less well due to the inequality I have documented. In this sense, beyond compensatory spending should likely move the focus to creative policies that ensure that the inputs into different districts are of the same quality: e.g. that teachers are similarly qualified and experienced. An even less interventionist way of mitigating those differences that goes back to the heart of the puzzle of the lack of extension of high quality schooling across the country would be measures that ensure continuous collaboration sharing of practices, facilities or resources across nearby schools serving different communities may be beneficial.[21] Digital education and initiatives such as virtual schools, can be an easy way to provide access to high quality content for disadvantaged schools in dense areas and, especially, for rural schools that are on average lower performing. Lastly, we have seen that it is likely that there are differences in the families and social environments that disadvantaged students experience in denser areas, beyond the schools they attend. It is no surprise then that successful urban school models serving disadvantaged students such as the Harlem's Children Zone, provide all kinds of services from health, nutrition, guidance, after-school programs and others (Dobbie and Fryer, 2011). While disadvantaged students

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[21] A scheme of sponsorship of academies in the UK whereby successful private schools (among other entities such as universities or businesses) can sponsor new academies has been running for almost two decades. There is emerging evidence of the success of such sponsorships in improving student performance (Eyles and Machin, 2015)

may benefit less from pooling with richer students in dense areas, the potential of efficient offerings of supplementary services in those areas given agglomeration economies could in principle be an opportunity.

Limitations and possible extensions

This research suggests naturally several extensions that would build on the limitations of the present study. First, deepening the study of mechanisms would require a focus on a wider range of differences across schools attended by different socioeconomic groups that perpetuate the gap that we observe in test scores. Rich local data on the functioning of urban and rural school systems attended by similar socioeconomic groups and ethnographic insights about the actual interactions between students and teachers in places where there is socioeconomic pooling and where there is greater socioeconomic segregation could illustrate the mechanisms I suggest are at play.

Second, the promise of density as a driver of greater exercise of voice by all groups failed to materialize in this study. For a closer look at the importance of the voice mechanism it would be necessary to look at instances where they may be sharper and exogenous variation on the availability of "voice" across different areas, such as differences in whether school boards are elected or appointed or integrated in multi-domain city governments or not, the types of elections in which they are elected, as well as differences in political traditions of facilitators of voice, such as the thickness of media markets or the introduction of new communications technologies. This should also help to establish more definitively whether policies to increase voice in school matters of low socioeconomic status groups are potentially useful in improving the quality of schools.

Lastly, education is the largest locally provided service in the United States, but similar dynamics may arise in other contexts, both in terms of policies or where the intensity of school segregation mediated by residence is less acute. Many developed countries with no Anglo-American heritage are likely to have less local control of schools and more centralized funding as well as management of schools, and one may expect that this would limit the density gradient on inequality across groups. Similarly, even in the United States, we may expect that other policy domains such as healthcare provision, where residential sorting may be less intense and provision more concentrated in fewer places. How representative K-12 education in the United States is of broader dynamics applicable to urban-rural divides in all domains and institutional contexts remains an open question. Understanding these differences would likely bear important insights into general propositions about the importance of the exit and voice dynamics. It should also inform jurisdictional and policy design, as the US and other countries urbanize.

Conclusion

I have presented a partial explanation for the differences in educational outcomes across commuting zones and of the extent of inequality across different economic groups in different areas. I document that density or agglomeration, a phenomenon that has been found to have almost unanimous positive consequences across a number of outcomes also has a positive average effect on education outcomes, but at the same time is a driver of greater inequality. I estimate these relations between density of outcomes using a geographic regression discontinuity strategy and a series of instrumental variables and find support for a causal interpretation of these claims. While the average effect of density is indeed positive for educational outcomes, districts at the 90th percentile of performance gain from increases in density about twice as much as those at the 70th percentile and the point-estimates of the effects of density are negative below the 30th percentile. Evidence presented of more fragmentation of school districts and more income segregation in denser areas is consistent with the view that the availability of more public school choice is at least partially driving the results. I also present some direct evidence that school choice can explain part of the relation between density and negative outcomes for low socioeconomic students. My results suggest that denser areas do not "lift all boats" equally but that children who are disadvantaged on observable characteristics do less well in denser areas, by no longer being pooled with more advantaged peers, or no longer being in the same boat as them.

I also present some evidence that the greater exit mechanism in denser areas that benefits higher SES students is not compensated by greater accountability of public services or "voice" by families with lower socioeconomic status in denser areas, even though density levels should facilitate it. In both dense and less dense areas participate less in activities that may contribute to improving school districts. At least for poor families, voice does not get exercised more by those that are left behind through the exit mechanism. Exit and voice mechanisms are not directly substitutable for each other for this group, even if we do see some evidence that the more exit rich families exercise the less they get involved in exercising accountability.

This paper constitutes the beginnings of a research agenda that roots education inequality on persistent institutional characteristics, such as the geographically-determined fragmentation of school catchment areas through differentiated school districts. It is, naturally, connected to the stark differences that different metropolitan areas experience in intergenerational mobility levels and that has been documented by Chetty et al. (2014) and will need further exploration. The expected increase in urbanization of the United States and throughout the world means these dynamics will become more important in the future. No easy policy solutions are available for what are deep tensions between separation and equality that are rooted in demographic and jurisdictional conditions that are difficult to change. Understanding these dynamics at a finer level and in different contexts and developing and testing creative policy solutions that keep the positive average effects of density but mitigate inequalities it generates should become a high priority for scholars.

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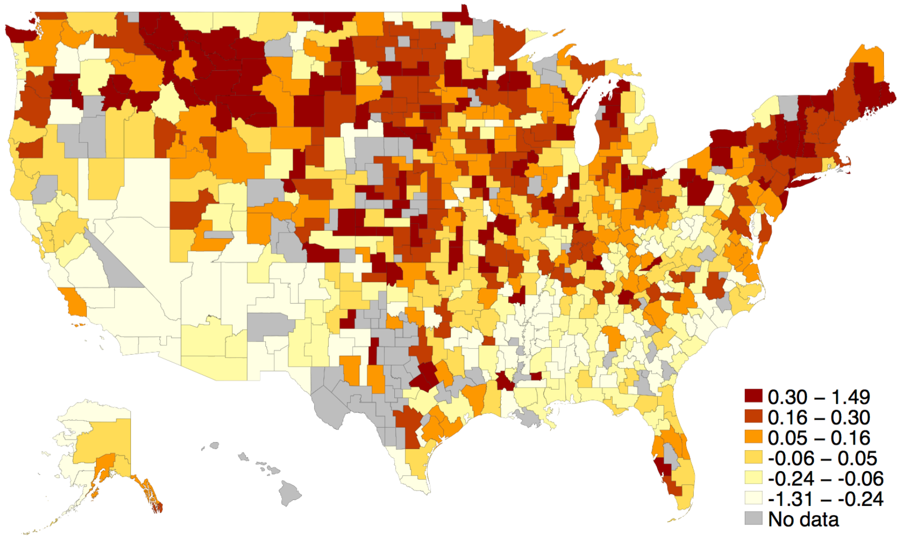
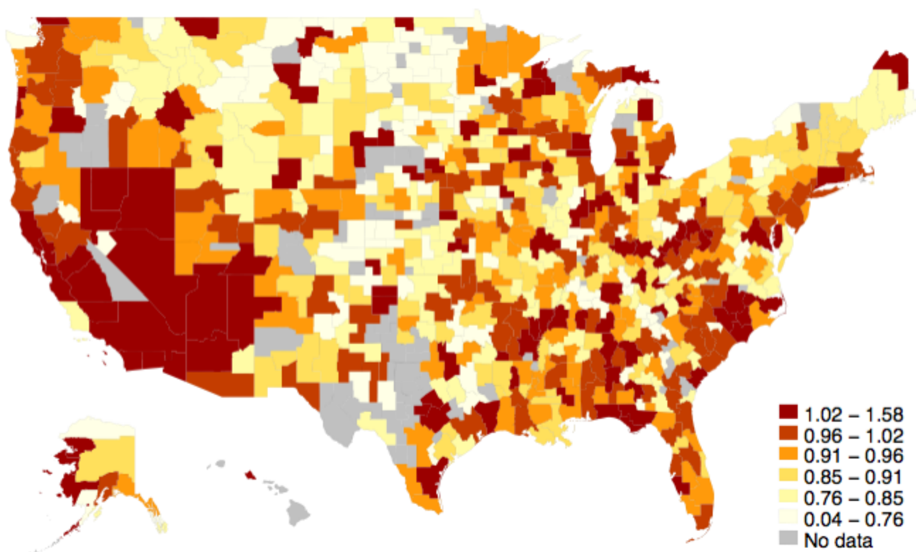
Figures



Panel A: Average levels in commuting zone



Panel B: Variation within commuting zone

Figure 1: Average level and variation of individual student outcomes within commuter zones.

Darker colors signify greater variation within the area, measured by the standard deviation of z-scores in reading within each commuter zone. (N=159,304, 741 commuting zones)

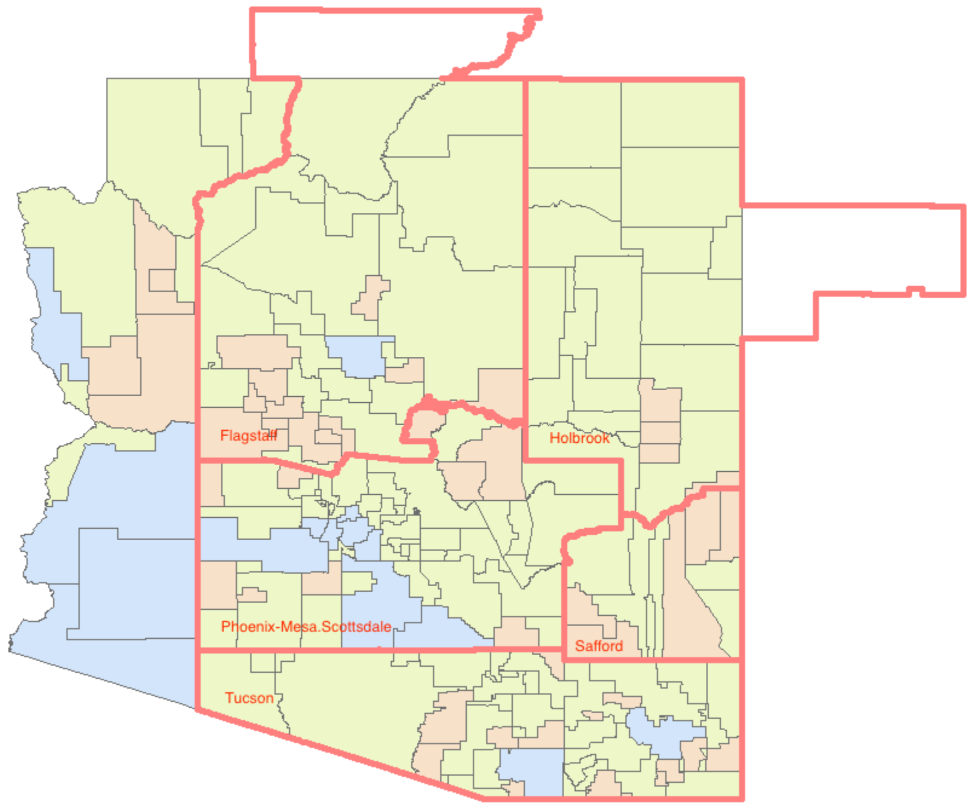


Figure 2: Commuting zones and school district fragmentation in Arizona

Black lines indicate school district boundaries, and red lines commuter zone boundaries. Blue shading indicates unified school districts, green are secondary school districts and pink are elementary only school districts (if secondary and elementary school districts overlap, only secondary school district is shown). Source: NCES Education Demographic and Geographic Estimates Program (EDGE).

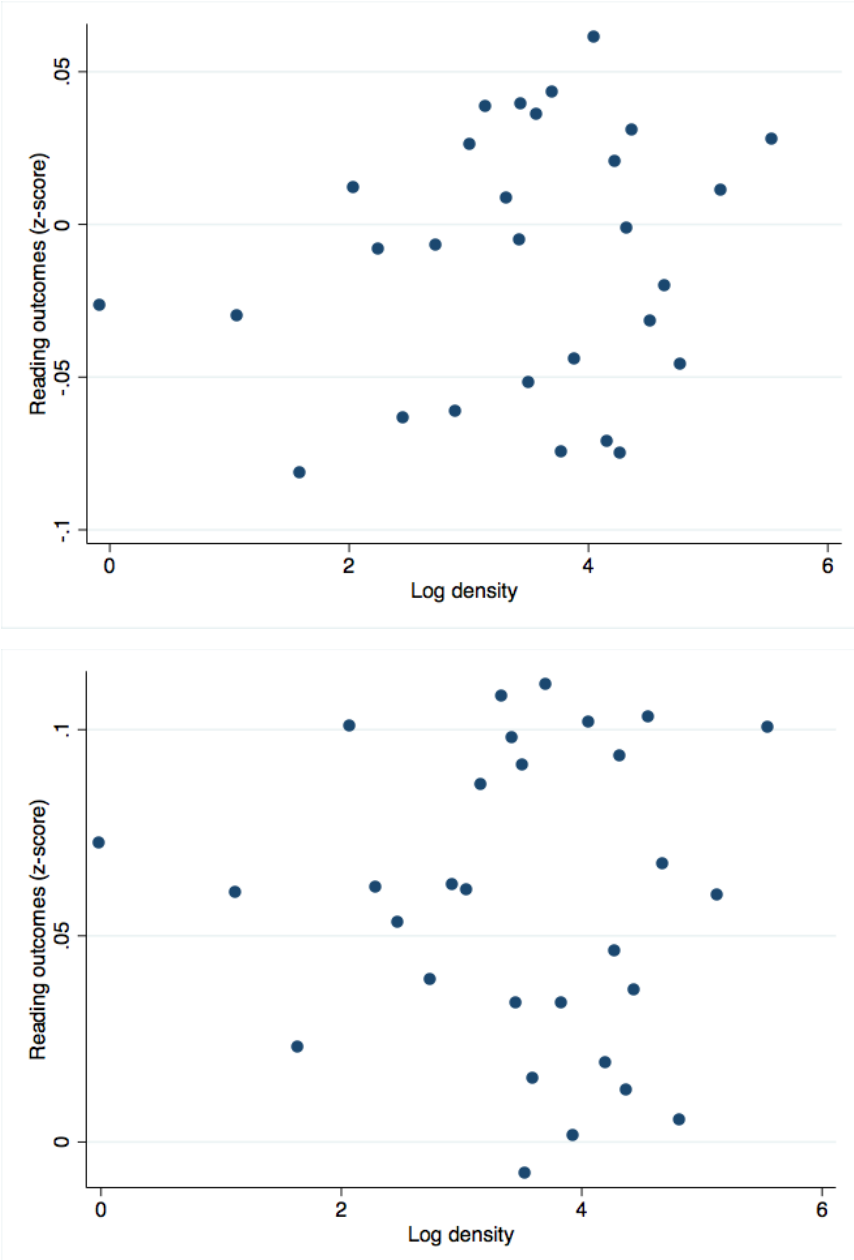


Figure 3: Student outcomes by level of population density.

Plot of relation between log density of student enrollment and reading z-scores with state fixed effects and no demographic controls (top) and log density with state fixed effects and parents' college attendance as the sole demographic control (bottom). Each of the dots represents the average z-score of the observations in 30 each equally sized intervals of the variable in the x-axis. (N=159,304)

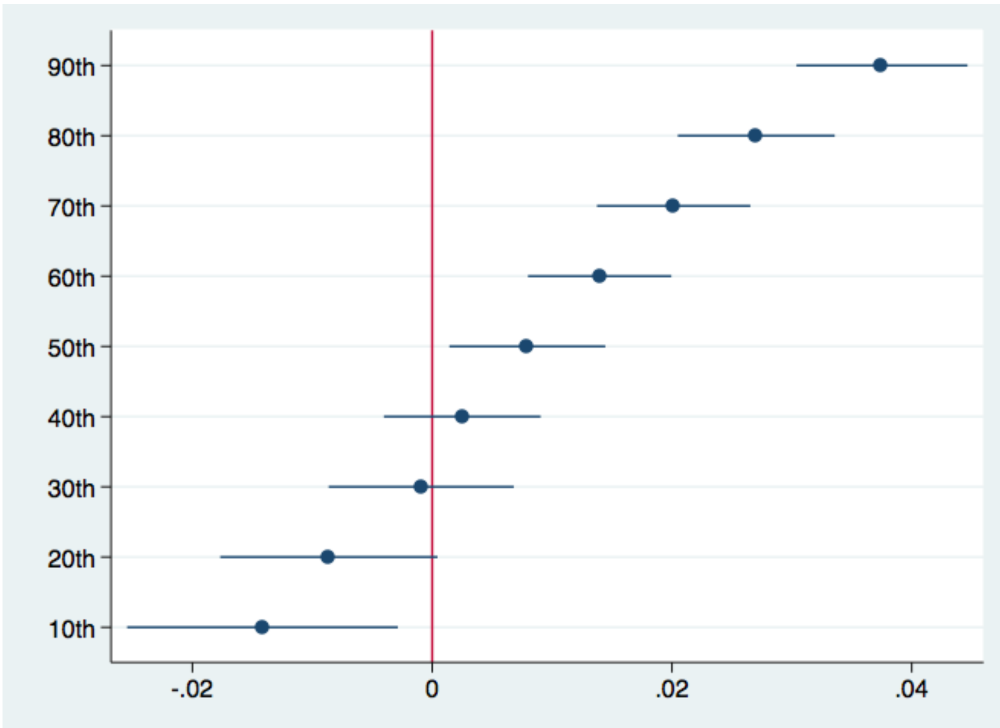
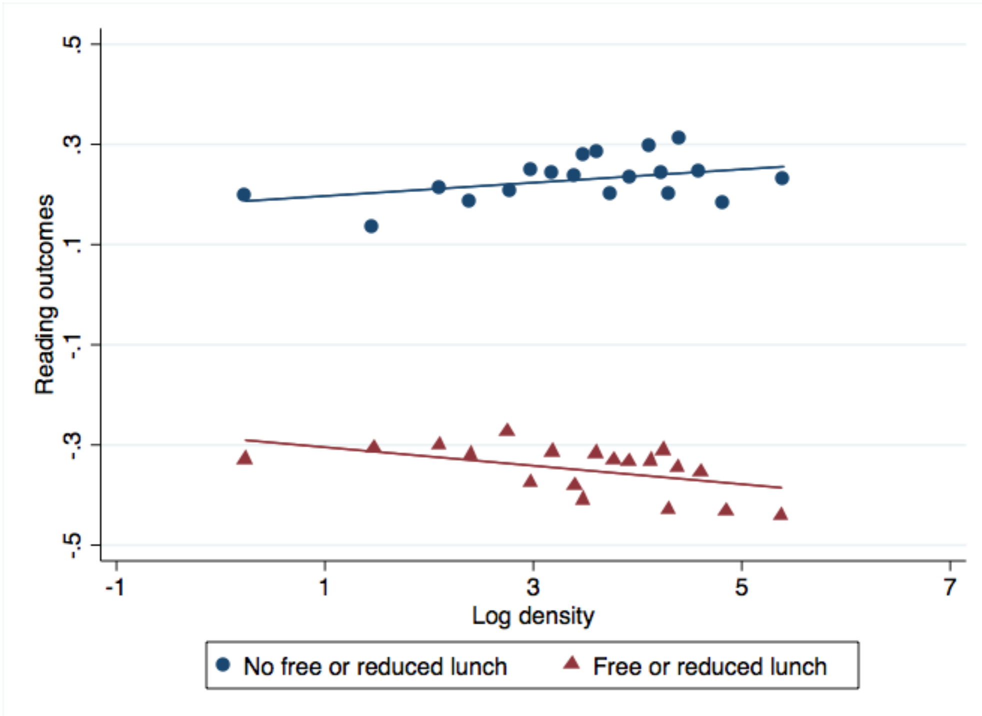
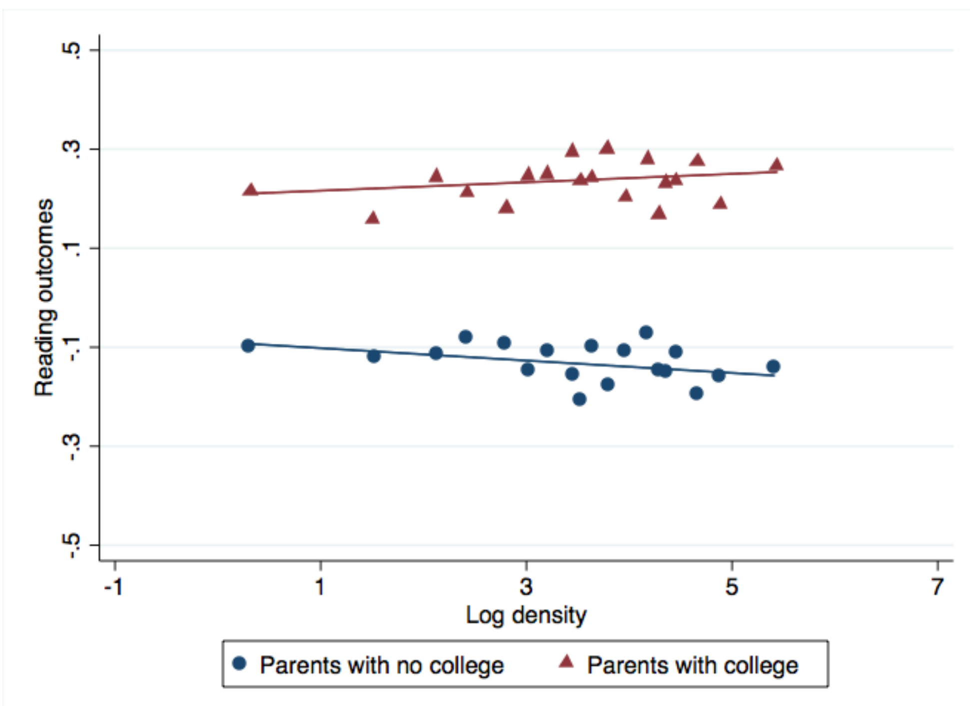


Figure 4: Effect of density for students along the distribution of outcomes

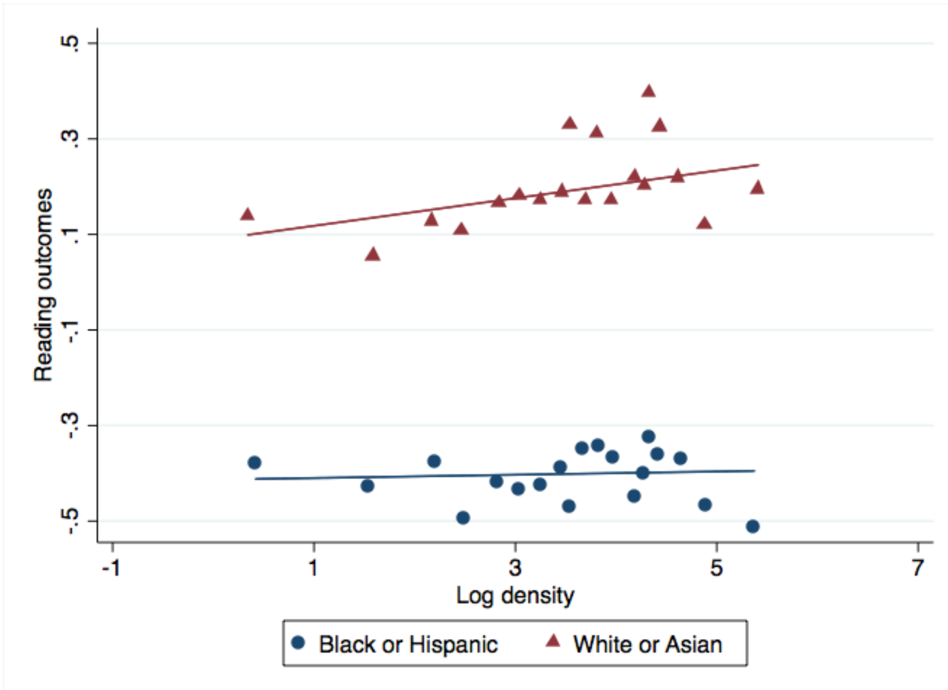
Plot of coefficients from a series of quantile regressions between reading zscores and district log density. Each dot represents the average effect of log density for that quantile. Includes state fixed effects, but not individual demographic controls. (N=159,304)



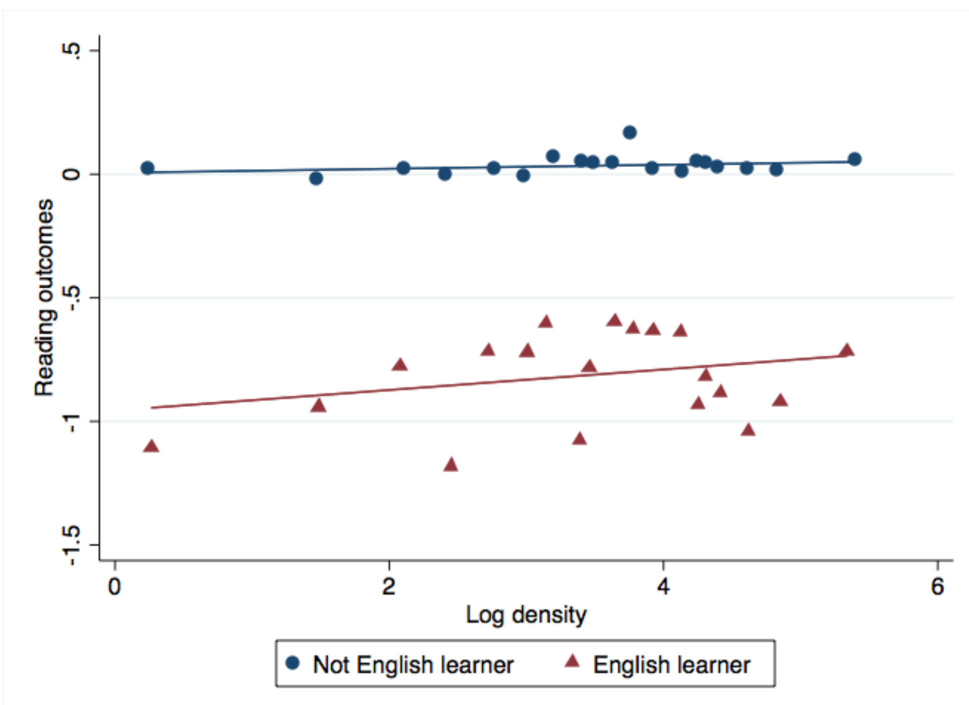
A: By Free and Reduced lunch status



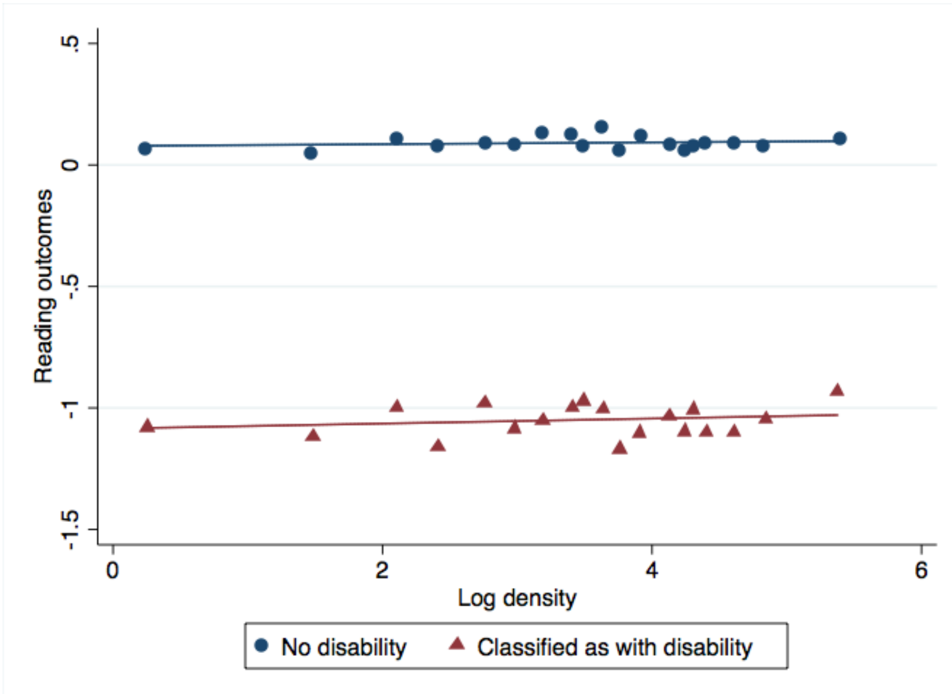
B: By parents who have attended college



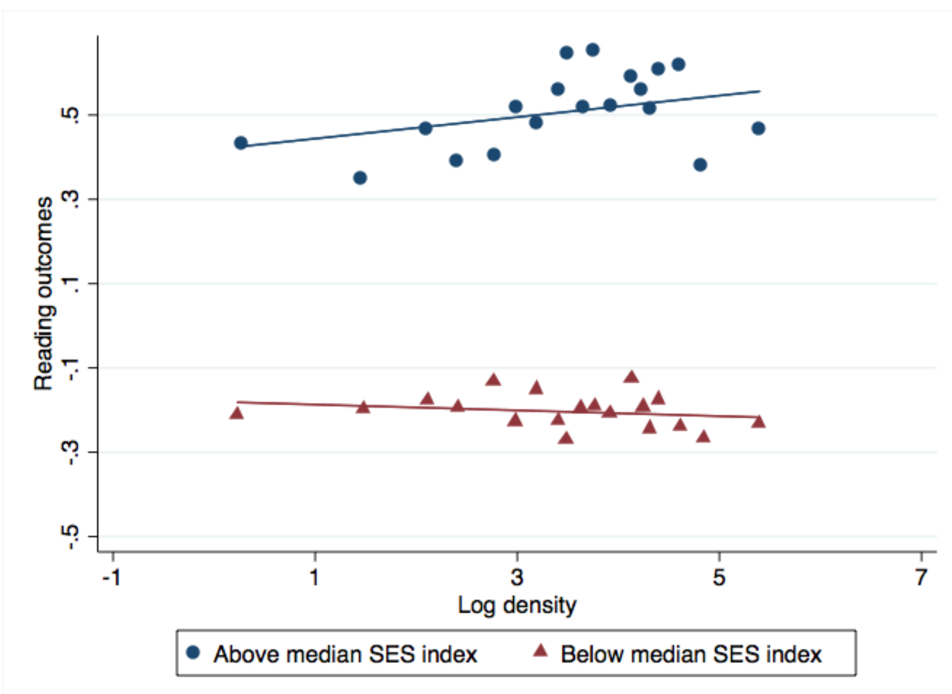
C: By racial group



D: By English learner status



E: By disability status



F: By index of socioeconomic status

Figure 5: Relation between density and outcomes for students and four binary socioeconomic status indicators (Free and reduced lunch, parents who attended college, racial group, English learner status and disability status as well as an index of all five indicators.)

Plots reading outcomes and log density, with observations binned in 20 quintiles for each population subgroup, estimated from regressions with no additional controls. For the index, the two groups divide commuting zones into those with below- and above-median number of ones on the other binary indicators. (N=159,304)

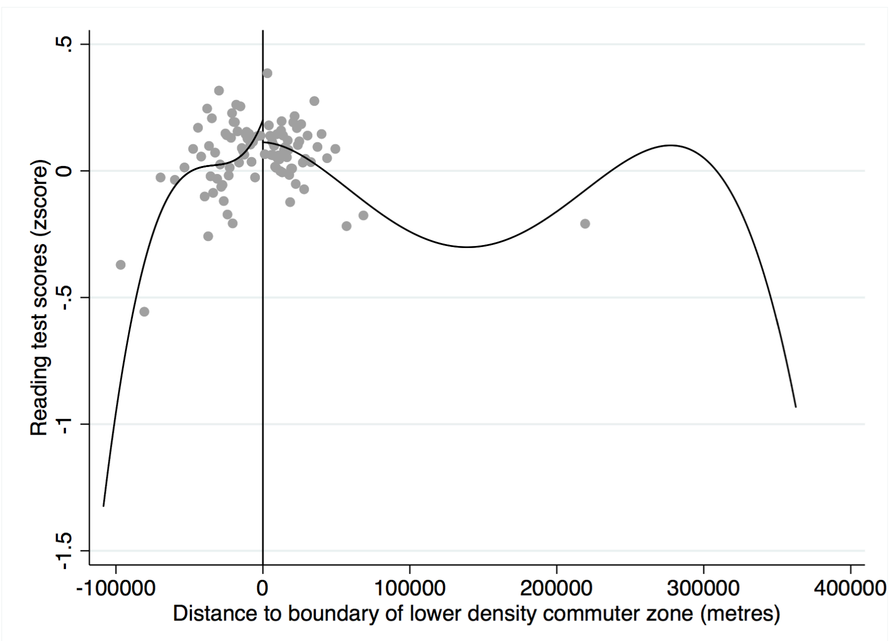
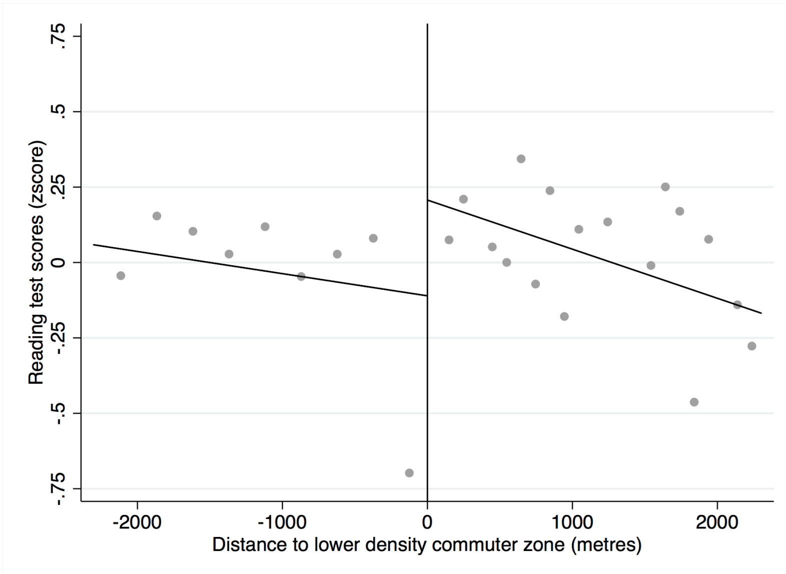
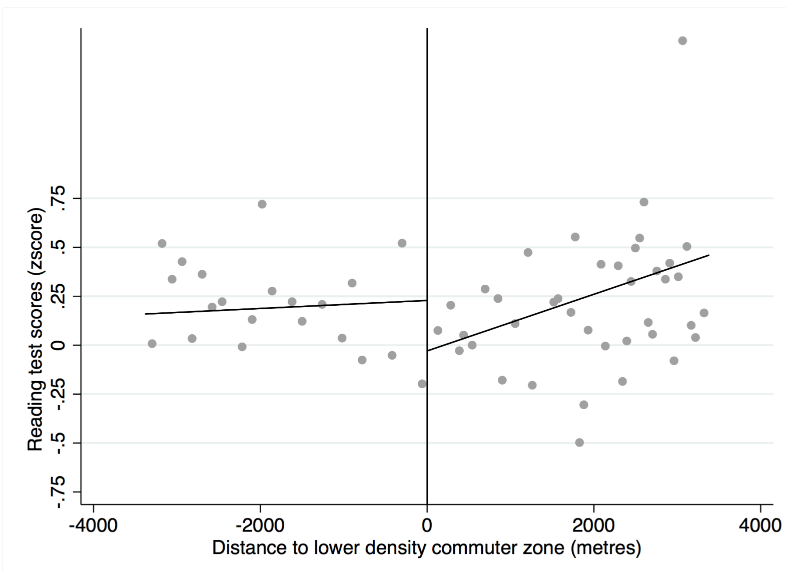


Figure 6: Distance to lower density neighboring commuting zone and reading test scores (zscore)

Negative values of the x-variable indicate observation is from test-taker in a higher density commuting zone that its neighboring commuting zone, positive values indicate that it is in a lower density one. Includes 135,113 observations grouped in 100 equally sized bins (50 on each side of x=0) and plots two 4^{th} degree global polynomial on either side of x=0.



A: Test-takers who receive free and reduced lunch



B: Test-takers who do not receive free and reduced lunch

Figure 7: Distance to lower density neighboring commuting zone and reading test scores by socioeconomic group (zscore)

Negative values of the x-variable indicate observation is from test-taker in a higher density commuting zone relative to its neighboring commuting zone, positive values indicate that it is in a lower density one. Panel A includes 76,277 observations and Panel B includes

55,182 grouped in each case divided in 50 equally sized bins around the MSE-optimal bandwidth (25 on each side of x=0) and plots a local linear regression.

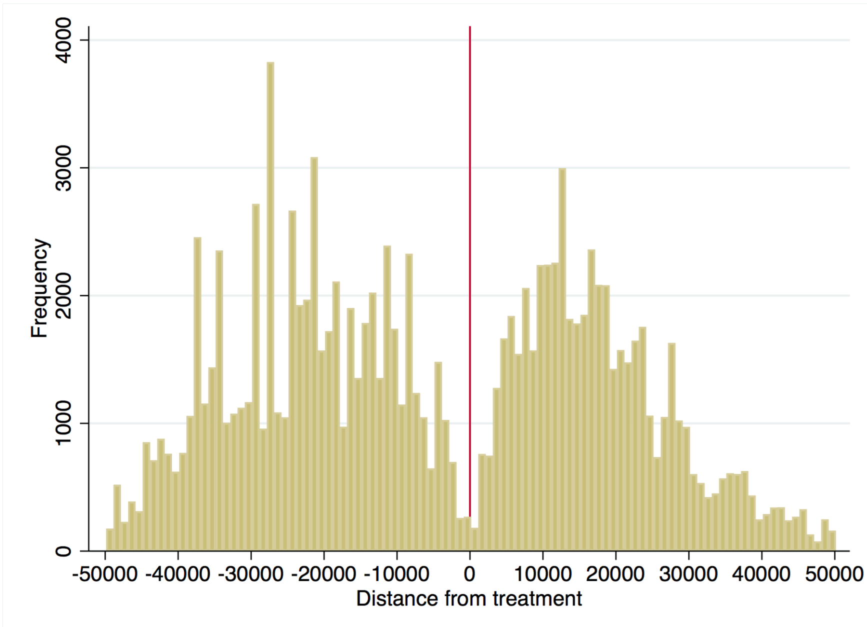


Figure 8: Histogram with frequency of observations by distance from the commuting zone boundary.

Negative values of the x-variable indicate observation is from test-taker in a higher density commuting zone that its neighboring commuting zone, positive values indicate that it is in a lower density one. N=135,113. Observations are grouped in 100 bins, one for each 1,000 meter interval.

Tables

Table 1: Relative explanatory power of outcome differentials by individual demographics and geographical areas

	(1)	(2)	(3)	(4)	(5)
Basic demographics	X				X
State FE		X			
Commuting Zone FE			X		X
District FE				X	X
R^2	0.110	0.032	0.053	0.176	0.233

Results from models regressing z-scores of individual reading scores as a dependent variable and individual demographics and area dummies (as indicated) as independent variables. Source: NAEP microdata 2009

Table 2: Descriptive differences across commuter zones of different levels of density

Panel A: Differences in average performance by commuter zone

	Model without controls	Model with controls
Maximum CZ coefficient	2.30	2.03
Minimum CZ coefficient	-0.03	-0.78
Difference	*2.33*	*2.80*
Quartile 90 CZ coefficient	1.17	0.58
Quartile 10 CZ coefficient	0.46	0.06
Difference	*0.71*	*0.51*
Quartile 75 CZ coefficient	2.22	0.47
Quartile 25 CZ coefficient	-0.03	0.20
Difference	*2.25*	*0.26*

Panel B: Top 10 commuter zones by student density levels and performance rank

CZname	**Average student density**	**Effect Rank**
Chicago-Naperville-Joliet, IL	1,259	125
New York-Wayne-White Plains, NY-NJ	852	103
Philadelphia, PA Metropolitan Division	487	155
Phoenix-Mesa-Scottsdale, AZ	366	67
Washington-Arlington-Alexandria, DC-VA-MD-WV	311	53
Los Angeles-Long Beach-Glendale, CA	291	58
Houston-Baytown-Sugar Land, TX	274	159
Milwaukee-Waukesha-West Allis, WI	254	66
Dallas-Plano-Irving, TX	210	50
San Diego-Carlsbad-San Marcos, CA	206	133

Panel A: Coefficients on commuter zone dummies from regressions of student outcomes (624 commuter zones). Panel B: Effect rank is the rank of the coefficient dummies in regression of student outcomes with individual controls.

Table 3: Effect of commuter zone density on the average performance in reading scores

Panel A: Effect on reading test scores

	(1)	(2)	(3)	(4)
CZ log density	0.00618	-0.000404	0.0100	0.0286***
	(0.0179)	(0.0122)	(0.00652)	(0.00415)
Free or reduced lunch		-0.680***		-0.478***
		(0.0168)		(0.0120)
White or Asian				0.435***
				(0.0145)
State FE			X	X
Observations	148950	148950	148950	148950
R^2	0.000	0.110	0.032	0.159

Panel B: Effect on math test scores

	(1)	(2)	(3)	(4)
CZ log density	0.00992	0.00201	0.00497	0.0247***
	(0.0170)	(0.0119)	(0.00821)	(0.00535)
Free or reduced lunch		-0.724***		-0.508***
		(0.0188)		(0.0122)
White or Asian				0.477***
				(0.0146)
State FE			X	X
Observations	141700	141700	141700	141700
R^2	0.000	0.126	0.040	0.190

Coefficients of OLS model regressing z-scores of individual reading (Panel A) and math (Panel B) in 8th grade NAEP test scores on commuter zone density levels. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 4: Relation between commuting zone density and the socio-economic gradient of performance in reading scores

Panel A: Reading test scores

	(1)	(2)	(3)	(4)
CZ log density	0.0204***	0.0360***	-0.0159*	0.0285***
	(0.00536)	(0.00605)	(0.00634)	(0.00534)
CZ Log density X	-0.0434***	-0.0134		
Free Reduced Lunch	(0.00790)	(0.00907)		
Free or reduced lunch	-0.471***	-0.397***		
	(0.0265)	(0.0289)		
CZ Log density X			0.0407***	0.0165*
Parent graduated college			(0.00758)	(0.00700)
Parent graduated ollege			0.242***	0.258***
			(0.0254)	(0.0236)
Individual demographics		X		X
Observations	136734	136716	119383	119365
R^2	0.127	0.196	0.074	0.175

Panel B: Math test scores

	(1)	(2)	(3)	(4)
CZ log density	0.0240+	0.0499***	-0.0121	0.0396***
	(0.0124)	(0.00987)	(0.0151)	(0.00888)
CZ Log density X	-0.0513***	-0.0272**		
Free Reduced Lunch	(0.00896)	(0.00978)		
Free or reduced lunch	-0.520***	-0.336***		
	(0.0300)	(0.0306)		
CZ Log density X			0.0525***	0.0277***
Parent graduated college			(0.00797)	(0.00691)
Parent graduated College			0.289***	0.248***
			(0.0248)	(0.0228)
Individual demographics		X		X
Observations	136734	136716	119383	119365
R^2	0.127	0.196	0.074	0.175

Coefficients of OLS model regressing z-scores of individual reading (Panel A) and math (Panel B) in NAEP 8th grade test scores on commuter zone density levels and socioeconomic status. Includes individual demographic controls as indicated and state fixed effects in all cases. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 5: Geographic regression discontinuity estimates of effect of drop of commuting zone density on reading test scores, by low and high socioeconomic groups

	Low SES: estimate	*High SES*: estimate	*Low SES*: Bandwidth (km)	*High SES*: Bandwidth (km)	*Low SES*: N	*High SES*: N
Free reduced lunch	0.318**	-0.258**	2,302	3,377	55,182	76,277
	(0.011)	(0.006)				
Parents who attended college	0.120**	-0.008	2,761	1,735	51,723	57,067
	(0.012)	(0.021)				
Race	0.536**	-0.269*	2,584	918	40,675	87,978
	(0.011)	(0.013)				
English learner	-0.006	0.056	6,350	740	9,377	123,108
	(0.075)	(0.075)				
Disability status	-0.119*	0.081	4,271	841	18,090	114,396
	(0.036)	(0.066)				
SES index	0.209***	-0.070**	1,575	4,236	97,310	35,181
	(0.004)	(0.011)				

Displays, for each indicator of socioeconomic status, the RD estimates of the effects of being in a lower density commuter zone than its nearest neighbor, by low and high socioeconomic status group. Standard errors are in parentheses. It also displays the MSE-optimal bandwidth and the number of observations included in the bandwidth, for each group. * p<0.05, ** p<0.01, *** p<0.001

Table 6: Instrumental variable estimates of effect of commuter zone density on the socio-economic gradient of performance

Panel A: Models including individual demographics and state controls alone

	(1) OLS	(2) IV 30s density	(3) IV terrain	(4) IV density predicted by earlier cohorts
CZ log density	0.0285***	0.00853	0.0277	0.0214*
	(0.00534)	(0.0101)	(0.0174)	(0.00930)
CZ Log density X Parent graduated college	0.0165*	0.0475***	0.0347*	0.0187+
	(0.00700)	(0.0138)	(0.0163)	(0.0104)
Parent graduated college	0.258***	0.129*	0.193**	0.249***
	(0.0236)	(0.0524)	(0.0598)	(0.0387)
Observations	119365	112952	104315	107941
R^2	0.175	0.178	0.167	0.176

Panel B: Models including commuter zone characteristics as controls

	(1) OLS	(2) IV 30s density	(3) IV terrain	(4) IV density predicted by earlier cohorts
CZ log density	0.0439***	0.0687**	0.128*	0.0241
	(0.0125)	(0.0231)	(0.0629)	(0.0232)
CZ Log density X Parents graduated college	0.0164*	0.0528***	0.0325*	0.0184+
	(0.00641)	(0.0148)	(0.0152)	(0.0104)
Parent graduated college	0.257***	0.102+	0.195***	0.251***
	(0.0223)	(0.0573)	(0.0582)	(0.0393)
Share routine jobs	-1.379*	-2.859**	-5.065+	-0.522
	(0.636)	(1.014)	(2.652)	(0.968)
Social capital index	0.0569***	0.0576***	0.0569***	0.0437***
	(0.00941)	(0.0105)	(0.0115)	(0.00932)
Violent crime rate	-35.81**	-36.89**	-33.05**	-43.80***
	(11.85)	(13.21)	(10.94)	(11.64)
Foreign-born rate	0.646***	0.284	-0.169	0.808***
	(0.173)	(0.212)	(0.555)	(0.235)
Observations	123858	107503	101842	102515
R^2	0.178	0.175	0.158	0.175

Coefficients of OLS and 2 stage least squares models regressing z-scores of individual reading test scores on commuter zone density levels and socioeconomic status. In the IV columns, commuter zone density is instrumented by the variables indicated at the top of the table (see text for how the variables are constructed). Individual demographics controls and state fixed effects are included in both panels. Panel B additionally includes the commuter zone demographic characteristics shown as well. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 7: Relation between commuting zone density and measures of availability of exit mechanism

	(1) Log students	(2) Log no. schools	(3) Log no. districts
Log density	1.074***	1.223***	0.437***
	(0.0209)	(0.0407)	(0.0162)
Observations	625	625	625
R^2	0.905	0.756	0.793

Coefficients of commuting zone regression models regressing dependent variables (from Common Core of Data) on commuter zone density levels. Regressions include state fixed effects. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 8: Relation between commuting zone density and economic inequality

Panel A: Inequality of income across districts within commuter zones, and commuter zone density

	(1)	(2)	(3)
	Ratio 90th-10th pctile income of districts within CZ	Ratio 90th-50th pctile income of districts within CZ	Ratio 50th-10th pctile income of districts within CZ
Log density	0.145***	0.0534***	0.0466***
	(0.0129)	(0.00558)	(0.00572)

Panel B: Inequality of income within districts and commuter zone density

	(1)	(2)	(3)
	Ratio 90th-10th pctile within district	Ratio 90th-50th pctile within district	Ratio 50th-10th pctile within district
Log density	-0.297***	-0.0314***	-0.0843***
	(0.0348)	(0.00435)	(0.0111)
Observations	306728	306728	306954

Coefficients of regression models regressing district income distribution measures (A) and commuting zone income distribution measures (B) on commuting zone density. In panel A, the dependent variables are ratios of the xth to the yth percentile of median district incomes in the commuting zone (cz regressions), while in Panel B they are ratios of the xth to the yth individual income percentile within a district (district level regressions). For each school district, there are 5x6 observations, one for each year 2009-2013 and each grade 3-8, in s from ACS on commuter zone density levels. Models include state and year fixed effects. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 9: Socioeconomic differentials in school inputs in denser commuter zones

Panel A: Teacher characteristics in denser areas

	(1)	(2)	(3)
	PD activities	Years as teacher	Above Bachelor's
CZ log density	0.121***	-0.552***	0.0258***
	(0.0340)	(0.109)	(0.00584)
CZ Log density X Free Reduced Lunch	-0.0389+	-0.0158	-0.00599
	(0.0235)	(0.0832)	(0.00383)
Observations	145480	120255	120063
R^2	0.019	0.020	0.121

Panel B: Student characteristics in denser areas

	(1)	(2)	(3)	(4)
	Books at home	Newspaper at home	Talks about studies at home	Talks about readings with friends
CZ log density	0.00621***	0.00375	0.0110***	0.00558**
	(0.00123)	(0.00324)	(0.00197)	(0.00206)
CZ Log density X Free Reduced Lunch	-0.00762**	-0.0144**	-0.00341	-0.00134
	(0.00242)	(0.00461)	(0.00250)	(0.00285)
Observations	133448	133642	133260	131043
R^2	0.046	0.020	0.008	0.003

Coefficients of regression models for individual students. Data on student habits comes from NAEP student stuent survey and on teacher characteristics comes from the NAEP teacher survey. Specifications includes state fixed effects. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 10: Opinion about schools, density and participation in public schools and socioeconomic gradient.

Panel A: Opinion about schools, density and participation in school elections

	(1) School board election participation	(2) Attention paid to education	(3) Grade given to local school	(4) Grade given to national schools
Log density (CZ)	0.000692	0.0216	-0.00103	0.00572
	(0.00631)	(0.0148)	(0.00786)	(0.00855)
Log density X College	-0.0292**	-0.0758***	0.0157	0.00868
	(0.00904)	(0.0202)	(0.0128)	(0.0136)
	(0.0128)	(0.0136)	(0.0202)	(0.00904)
College graduate	0.187***	0.708***	0.00210	0.0236
	(0.0402)	(0.0859)	(0.0617)	(0.0642)
Observations	11475	15983	24317	22864
R^2	0.269	0.040	0.081	0.025

Panel B: Support for reform measures

	(1) Reform index	(2) Support for vouchers	(3) Support for charter schools	(4) Support for variable pay
Log density (CZ)	0.0310	0.0425*	0.0325*	0.0238*
	(0.0158)	(0.0198)	(0.0126)	(0.0111)
Log density X College	-0.00557	0.0384	-0.0249	0.00420
	(0.0263)	(0.0275)	(0.0178)	(0.0190)
College graduate	-0.00180	-0.330*	0.214*	-0.247**
	(0.112)	(0.130)	(0.0857)	(0.0864)
Observations	11475	15983	24317	22864
R^2	0.269	0.040	0.081	0.025

Coefficients of OLS models regressing individual survey responses, with demographic controls. Responses coded as follows: Panel A: 5 Highest opinion/participation; 1 Lowest opinion/participation. Panel B: 5 Highest Support; 1 Lowest support. Grade given to schools (Panel A) coded as a z-score centered on zero. Dependent variables data comes from pooled EdNext survey 2007-2015. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 11: Simple tests of the importance of commuting zone mechanisms in the relation between density and education outcome inequality: DV is individual level outcomes

	(1) No mechanisms	(2) Choice	(3) Voice	(4) Economic characteristics	(5) Social characteristics	(6) Model with all mechanisms
CZ log density	-0.0159*	0.00884	-0.00971	-0.0315**	0.0254*	0.0137
	(0.00634)	(0.0149)	(0.00687)	(0.0108)	(0.0125)	(0.0175)
CZ Log density X Parent graduated College	0.0407***	0.0397***	0.0410***	0.0411***	0.0416***	0.0409***
	(0.00758)	(0.00765)	(0.00826)	(0.00764)	(0.00755)	(0.00826)
Parent graduated college	0.242***	0.246***	0.236***	0.240***	0.238***	0.236***
	(0.0254)	(0.0256)	(0.0285)	(0.0256)	(0.0256)	(0.0287)
Log no. districts		0.00651				0.0387*
		(0.0143)				(0.0151)
Log no. schools		-0.0192*				-0.0107
		(0.00868)				(0.00743)
Attention paid average			-0.0390+			-0. -0.0116
			(0.0196)			(0.0120)
Board election average			0.105*			0.0698+
			(0.0461)			(0.0377)
Share of routine jobs				1.260+		0.837
				(0.714)		(0.654)
Violent crime index					-40.60**	-41.37**
					(13.75)	(12.86)
Social capital					0.0783***	0.0683***
					(0.0143)	(0.0157)
Racial segregation					-0.393***	-0.474***
					(0.0957)	(0.101)
Income segregation					-0.497	-0.228
					(0.551)	(0.565)
Observations	119383	119383	104930	117025	113957	100029
R^2	0.074	0.074	0.073	0.074	0.080	0.080

Coefficients of OLS model regressing z-scores of individual reading test scores on commuter zone density levels and socioeconomic status. Column 1 reproduces model from Table 2, Panel A, column 3, while the rest include in addition potential commuter zone level mechanisms. Choice variables come from Common Core of data. Voice variables from EdNext survey data 2007-2015, pooled. Economic characteristics variables come from Autor, Dorn (2013) and social characteristics data from Chetty et al. (2014). All models include state fixed effects. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table 12: Simple tests of the importance of commuting zone mechanisms in the relation between density and education outcome inequality: DV is variation in individual level outcomes in the commuting zone

	(1) No mechanisms	(2) Choice	(3) Voice	(4) Economic characteristics	(5) Social characteristics
Log density	0.0230***	0.00379	0.0233***	0.0327***	0.0177*
	(0.00458)	(0.00677)	(0.00478)	(0.00523)	(0.00712)
Number of districts		-0.000120			
		(0.000107)			
Log no. of schools		0.0251***			
		(0.00440)			
Board election voting average			0.0452+		
			(0.0237)		
Share of routine jobs in the economy				-0.501+	
				(0.303)	
Violent crime					10.75
					(7.434)
Social capital index					-0.0156**
					(0.00550)
Segregation of income					0.203
					(1.098)
Segregation of poverty					0.0701
					(1.198)
Observations	656	656	505	641	616
R^2	0.071	0.137	0.073	0.095	0.118

Coefficients of OLS models regressing standard deviations in reading outcomes for commuter zones, as in panel A of Table 4. Additional variables are included as commuting zone aggregates. Choice variables come from Common Core of data. Voice variables from EdNext survey data 2007-2015, pooled. Economic characteristics variables come from Autor, Dorn (2013) and social characteristics data from Chetty et al. (2015). All models include state fixed effects. Standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Appendix tables

Table A1: Relation between average exam results in the district, commuter zone density and average district income

	(1)	(2)	(3)	(4)
	Reading	Reading	Math	Math
Log density	0.0317*	0.0626***	0.0239^{+}	0.0649***
	(0.0128)	(0.00971)	(0.0127)	(0.00994)
Log Density X	-0.0842**	-0.0764***	-0.0404^{+}	-0.0715***
Pct free and reduced lunch	(0.0294)	(0.0155)	(0.0225)	(0.0179)
Pct free and reduced lunch	-0.921***	-0.635***	-1.073***	-0.667***
	(0.127)	(0.126)	(0.102)	(0.125)
State dummies		X		X
District demographics		X		X
Observations	303785	278316	296852	273481
R^2	0.457	0.551	0.376	0.488

Coefficients of OLS models regressing district averages in exam outcomes in the subject indicated, grades 3-8, in years 2008-2009 through 2012-2013, in 4th and 8th grade. Unlike in the main model of Table 4, dependent variables are average levels in the district for the (standardized) state exams for all students (see Reardon et al. 2016). For reference, the average share of Free and reduced lunch students in the observations is .42. District-subject-grade-year observations are weighted by the number of students taking the test. Robust standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table A2: Relation between average exam results in the district, commuter zone density and average district income

	(1) Reading	(2) Reading	(3) Math	(4) Math
Log density	-0.504***	-0.380***	-0.215+	-0.368***
	(0.121)	(0.0947)	(0.130)	(0.0912)
Log Density X Log Income	0.0430***	0.0347***	0.0178	0.0340***
	(0.0107)	(0.00867)	(0.0119)	(0.00829)
Log income	0.565***	0.468***	0.641***	0.470***
	(0.0456)	(0.0350)	(0.0541)	(0.0371)
Constant	-6.068***	-5.299***	-6.936***	-5.334***
	(0.498)	(0.379)	(0.584)	(0.392)
State dummies		X		X
District demographics		X		X
Observations	303785	278316	296852	273481
R^2	0.457	0.551	0.376	0.488

Coefficients of OLS models regressing district averages in exam outcomes in the subject indicated, grades 3-8, in years 2008-2009 through 2012-2013, in 4th and 8th grade. Unlike in the main model of Table 4, dependent variables are average levels in the district for the (standardized) state exams for all students (see Reardon et al. 2016). For reference, the average household log-income is 10.96 ($57,526). District-subject-grade-year observations are weighted by the number of students taking the test. Robust standard errors, clustered by commuter zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table A3: Relation between exit and voice

Panel A: Number of districts and voice

	(1)	(2)	(3)
Log No. districts CZ	-0.0152*	-0.0125	-0.00340
	(0.00709)	(0.0150)	(0.0219)
Grade given to local school	0.0211**	0.0212**	0.0213**
	(0.00690)	(0.00691)	(0.00688)
Log No. districts CZ X		-0.00513	
Racial segregation		(0.0510)	
Segregation of race		-0.0186	
		(0.220)	
Log No. districts CZ X			-0.105
Income segregation			(0.219)
Segregation of income			0.213
Observations	9576	9576	9576
R^2	0.289	0.289	0.289

Panel B: Number of schools and voice

	(1)	(2)	(3)
Log No. schools CZ	0.00235	0.00684	0.0166**
	(0.00343)	(0.00417)	(0.00515)
Grade given to local school	0.0206**	0.0210**	0.0211**
	(0.00690)	(0.00686)	(0.00686)
Log No. schools CZ X		-0.0555*	
Racial segregation		(0.0249)	
Segregation of race		0.102	
		(0.166)	
Log No. schools CZ X			-0.125*
Income segregation			(0.0612)
Segregation of income			-0.710
			(0.527)
Observations	9576	9576	9576
R^2	0.287	0.289	0.292

Dependent variable is school board election participation (5: Highest participation; 1: Lowest participation), from pooled EdNext survey 2007-2015. Coefficients of OLS models regressing individual survey responses. Standard errors, clustered by commuting zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001

Table A5: Relation between exit and voice, parents only

Panel A: Number of districts and voice

	(1)	(2)	(3)
Log No. schools CZ	0.0124		
	(0.0129)		
Log No. districts CZ		-0.104	-0.188**
		(0.0580)	(0.0669)
Grade given to local school	0.0400	0.0357	0.0392
	(0.0269)	(0.0267)	(0.0266)
Log No. districts CZ X		0.249	
Racial segregation		(0.257)	
Segregation of race		-0.550	
		(1.072)	
Log No. districts CZ X			1.667*
Income segregation			(0.707)
Segregation of income			-5.104*
			(2.550)
Observations	9576	9576	9576
R^2	0.289	0.289	0.289

Panel B: Number of schools and voice

	(1)	(2)	(3)
Log No. schools CZ	0.0124	0.0153	0.0433*
	(0.0129)	(0.0128)	(0.0176)
Grade given to local school	0.0400	0.0391	0.0398
	(0.0269)	(0.0267)	(0.0259)
Log No. schools CZ X		-0.143	
Racial segregation		(0.122)	
Segregation of race		0.733	
		(0.662)	
Log No. schools CZ X			-0.119
Income segregation			(0.279)
Segregation of income			-2.311
			(2.094)
Constant	-0.286	-0.339	-0.362*
	(0.180)	(0.173)	(0.174)
Observations	9576	9576	9576
R^2	0.138	0.143	0.152

Dependent variable is school board election participation (5: Highest participation; 1: Lowest participation). Coefficients of OLS models regressing individual survey responses. Standard errors, clustered by commuting zone, in parentheses. * p<0.05, ** p<0.01, *** p<0.001