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Who Benefits from Local Financing of Public Services? A Causal Analysis

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September 16, 2019

Abstract

Tiebout theorizes that local public services are provided more efficiently if costs are paid out of local revenues rather than by inter-governmental grants. But if local politics is not as pluralistic as Dahl has argued, citizens of higher socio-economic status will exercise greater influence, resulting in higher inequalities in service provision. We use administrative data to estimate the impacts of local revenue shares on individual performance of a nationally representative sample of over 140,000 U.S. eighth graders in math and reading. Causal effects are estimated with geographic discontinuity models and 2SLS models that use change in housing prices as an instrument. For every 10 percent increase in local revenue share, students perform about 0.05 standard deviations higher. Gains from local funding are less for disadvantaged students. Local financing affords better education for all but widens achievement gaps.

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1 Introduction

Fiscal federalism theorists do not agree on the desirability of inter-governmental grants. Tiebout (1956) and his followers theorize that services will be provided efficiently only if residents choose among tax and service packages offered by competing local governments (Ostrom, Tiebout and Warren, 1961; Buchanan and Wagner, 1977; Fischel, 2001; Weingast, 1995). Oates (1972, 1999) and his followers theorize that local governments will under-provide redistributive services financed by local revenues if benefits spill over local boundaries (Kessler and Lülfesmann, 2005; Musgrave et al., 1959; Peterson, 1981).

Causal evidence bearing on these contrasting theories is limited. To extend the empirical literature, we estimate causal effects of variation in the share of revenue from local sources (as opposed to inter-governmental grants) received by school districts on 2007 math and reading performances of nationally representative samples of 8th grade students. Outcomes are measured with individual student level data made available to licensed scholars by the National Assessment of Educational Progress (NAEP), which is administered by the National Center of Education Statistics (NCES).

We estimate effects of local financing of K-12 schools on outcomes with Ordinary Least Squares (OLS), geographic regression discontinuities, and two-Stage Least Squares (2SLS) models. Districts near borders of states with contrasting inter-governmental grant policies are used to estimate geographic discontinuities. The instrument used for 2SLS models is the change in average housing prices in a school district between 2000 and 2007. To assess potential mechanisms, we also estimate effects of local financing on the allocation of school resources among instructional and administrative services and estimate the "Tiebout choice" effects on achievement of inter-district competition within commuter zones.

Results support propositions derived from both Tiebout's and Oates' theories. Consistent with Tiebout, OLS estimations show that for every 10 percent increase in the share of revenues received from local sources 8th grade math and reading performances are in the range of 0.05 to 0.06 standard deviations higher. Effects are heterogeneous by socio-economic status

(SES). Local funding lifts the performance levels of students from both lower and higher SES backgrounds, but, consistent with Oates, gains are larger for high SES students than for disadvantaged ones. Allocation of resources toward classroom instruction as distinct from school administration may be one channel linking school finance to policy outcomes. Competition among districts within a commuting zone has positive mean effects for districts with larger revenue shares from local sources.

2 Literature

The desirability of funding local services with grants from higher tiers of government is a contested issue. Two theories point in opposite directions and a theoretically coherent resolution has not been found, leaving the matter open to empirical investigation. Yet very few empirical studies have used nationally representative samples to estimate causal effects of alternative funding arrangements on service-delivery outcomes.

2.1 Theory

Tiebout (1956) theorizes that citizens maximize their utilities by migrating to the community that provides preferred services at lowest cost (see also Ostrom, Tiebout and Warren (1961)). Local governments adjust their mix of services and taxes in order to reach an optimum size. Buchanan and Wagner (1977) theorize that a fiscal illusion results whenever there is a lack of "fiscal equivalence" between those who pay and those who benefit from public goods. Individuals who would not pay for services will consume them when paid for by others (Cutler and Zeckhauser, 2000). The greater the share of local services covered by revenues from non-local resources, the greater the moral hazard (Hines and Thaler, 1995). In the words of Rodden (2016, p. 3): "Voters face strong incentives to monitor service provision when they understand their role in paying the bill, and [they] may be willing to tolerate much higher levels of inefficiency. . . [if money arrives via] intergovernmental transfers."

In contrast, Oates (1972, 2006) theorizes that local governments will under-provide services if costs and benefits spill across jurisdictional boundaries (see also Musgrave et al. (1959); Kessler and Lülfesmann (2005). Similarly, Peterson (1981, 1995) theorizes that local governments maximize local property values. To attract residents with more resources and skills, they deliver to them higher quality services than those provided to the disadvantaged. In short, local governments seldom use local resources for redistributive purposes. Compared to Dahl (1961, p.92)'s pluralist account of a broadly representative local polity, this theory expects to find a systematic policy bias against the interests of the disadvantaged.

Hoyt (2001) resolves the conflict by proposing grants from higher tiers of government to compensate localities for spill-over effects. But Berry (2009, p.17,n.23) says grants yield efficient tax policies only if one makes "rather heroic assumptions about the central government's access to [...] information" about local fiscal policy. Keen and Kotsogiannis (2002) show that model predictions are highly sensitive to specific empirical and theoretical assumptions. "The authors are left to conclude . . . [that] whether taxes in a federation are too high or too low . . . is a question to be answered empirically" (Berry, 2009, p.18).

2.2 Empirical Studies

Yet no known empirical investigation has estimated causal effects of grant funded rather than locally funded services for a nationally representative sample of U. S. residents. Instead, a descriptive literature has used evocative metaphors–"marble-cake federalism" (Grodzins, 1966), "picket-fence federalism" (Sanford et al., 1967), and "hyperlexis" (Manning, 1976, p. 3948)–to characterize the rapid growth in the use of inter-governmental grants within the United States. Using these and other frameworks, multiple studies have distinguished categorical grants from block grants and revenue sharing (Anderson and Donchik, 2014; Peterson, Rabe and Wong, 2010). They have detected many a slip between policy cup and implementation lip (Pressman and Wildavsky, 1984; Bardach, 1977; Derthick, 1972). Scholars have also analyzed grant-making within specific policy domains in a host of studies too numerous to be documented here (Anton, 1989; Peterson, Rabe and Wong, 2010). But for all the descriptive material on inter-governmental grants, only a few causal estimates of the comparative advantages of self-financed and intergovernmental grant-financed service delivery have been attempted.

Still, a number of studies have explored the efficiency of local government services in various ways. Berry (2009) shows that expenditures increase but services do not improve when multiple local governments have access to a common fiscal pool. Emanuelson (2003) reports a similar result for services provided by park districts. Elinor Ostrom and her colleagues (Ostrom, 1983; Ostrom, Parks and Whitaker, 1973, 1974) find police services are more efficiently provided if paid for by local governments in small communities. Other studies report that higher quality services have positive impacts on local property values (Bogart and Cromwell, 2000; Weimer and Wolkoff, 2001; Black, 1999; Hayes, Taylor et al., 1996; Bradbury, Mayer and Case, 2001). Hoxby (2000), using nationally representative data, finds higher quality service delivery, as measured by student test performance, in metropolitan areas with higher concentrations of school districts. These "Tiebout choice" effects, as they have been labelled, are disputed by Rothstein (2007), with a reply by Hoxby (2007), but neither study explores the role played by local financing.

A number of "flypaper" studies have looked at the impact of grants from higher tiers of government on local policy. They find that monies granted by higher tiers of government do not substitute for local revenues but instead stick to the hands of local authorities as flies to gummy paper (Wyckoff, 1991; Hines and Thaler, 1995; Mueller, 2003). However, existing estimations based on these models make the restrictive assumption that services were efficiently provided prior to receipt of the inter-governmental grant.

Other scholars have looked more directly at the effectiveness of government services paid for by inter-governmental grants. Silkman and Young (1982) show that intergovernmental grants are associated with lower efficiency levels in the provision of school bus transportation and public libraries. Dynes and Martin (2018) report that officials are less likely to misappropriate revenues and more likely to spend them on services citizens prefer if they come from local sources rather than inter-governmental grants. In Brazil external grants generate greater levels of corruption as measured by public audits, (Brollo et al., 2013). Similar results are found in Bulgaria by Nikolova and Marinov (2017). However, Litschig and Morrison (2013), exploiting exogenous discontinuities in the formulas for allocating federal funding, report that "flypaper" effects in Brazil produce higher educational outcomes.

Finally, a number of studies have looked at redistributive questions. Jackson, Johnson and Persico (2015) find that state grants that equalize expenditures across school districts have positive and disproportionately large impacts on long-term outcomes of low SES students. Ejdemyr (2017) finds that revenues generated by close local bond elections are directed to schools with more affluent students. Others identify public opposition to the negative impact on property values of affordable housing developments (Hankinson, 2018; Fischel, 2001; Gerber and Phillips, 2003). Trounstine (2018) finds a clear bias toward higher SES groups in urban planning and zoning policy. In case study research, (Molotch, 1976; Logan and Molotch, 2007; Stone, 1993) show that local public officials place a greater emphasis on economic growth than redistribution. Despite these and other studies of inter-governmental grants and local policy, much remains to be learned about the impact of funding arrangements on local service outcomes.

3 The Education Sector

The K-12 education sector in the United States provides an opportunity to estimate the consequences of alternative fiscal arrangements. In 2007, expenditures in the education sector came to $477 billion, 35 percent of all local government spending (US Bureau of the Census, 2019). Forty-four percent of this expenditure was funded out of local revenues, 45 percent came from state grants and 11 percent came from federal grants (NCES, 2019*b*).[1]

[1] Local expenditures include all expenditure by county, municipal, and township governments as well as by school districts and other special districts. The K-12 sector excludes higher education spending.

The share of funding by inter-governmental grants has increased over time. In 1920, 83 percent of all revenues came from local revenues, but with the consolidation of school districts, and the growth of the inter-governmental grant system, this percentage fell to 44 percent in 2007 (Berry and West, 2008). Still, that percentage is more than twice the average of 22 percent for all member countries of the Organization for Economic Cooperation and Development (OECD, 2014). The locally funded share of total district revenues in 2007 for districts in our data set ranges from one percent to 92 percent with an inter-quartile range of 31 percentage points.

Accordingly, the education sector provides an opportunity to estimate the effect of alternative local financing arrangements on the efficiency and redistribution of local service production. We identify the efficiency of service delivery by estimating the effects of funding arrangements on performances of students in 8th grade. When adjusted for individual background characteristics, aggregate test results are a proxy for efficacy of service delivery, because they correlate with long-term outcomes widely believed to be of major importance: college enrollment and degree attainment, earnings in adulthood, teen-age pregnancy rates, and rates of criminal activity (Chetty, Friedman and Rockoff, 2014*a*,*b*). Performances on school tests have also been shown to be causally related to national gains in economic growth (Hanushek and Woessmann, 2012).[2] Redistributive effects are identified by estimating effects on test performance by student SES characteristics.

4 Data

Outcome variables are aggregated by school district of state-representative samples of individual performances on the 2007 NAEP math and reading tests (Rogers and Stoeckel, 2008).[3] A large number of state-representative observations has encouraged us to assume, as do other

[2]However, the tests do not directly measure other desirable educational outcomes, such as socio-emotional learning, grit, trustworthiness, or civic-mindedness.

[3]Researchers with restricted-use data licenses may obtain NAEP individual-level microdata from the NCES, which has approved for disclosure all results reported in this paper.

scholars, the representativeness of these observations at the district level (Lafortune, Rothstein and Schanzenbach, 2018; Reardon, Kalogrides and Shores, 2019; Jackson, Wigger and Xiong, 2018).

All outcomes are reported in standard deviations, which are calculated by converting test scores into z-scores relative to sample means. The sample consists of 143,030 observations of math performance and 160,670 observations of reading performance in the 50 states.[4] The year 2007 is selected because it was not affected by the subsequent financial crisis, recession and federal stimulus package, which together altered funding arrangements for educational services.

Two variables, income and education, are used to estimate a student's SES background. The classification of 44 percent of sampled students as low-income rather than high-income is based on administrative records of eligibility for participation in the free and reduced lunch program, which in 2007 was limited to those from households with incomes of no more than 180 percent of the poverty line. The classification of 52 percent of students as having parents with a high rather than low educational attainment level is estimated from reports by students as to whether at least one parent has earned a four-year college degree. Other demographic information includes gender, special education status, English language learner status, and disadvantaged minority (neither white nor Asian) status (Rogers and Stoeckel, 2008).

School district revenue, expenditure and demographic information for the school year 2006-07 are drawn from the NCES Common Core of Data (NCES, 2019*a*). The 741 commuting zones (CZs) are defined by Bureau of the Census based upon the contrast in the intensity of self-reported commuting patterns within and across counties in 1990 (Tolbert, Sizer et al., 1996). For other scholarly uses, see Chetty et al. (2014) and Autor and Dorn (2013).

Average house prices by zip code are estimated from the Zillow Home Value Index (Zillow,

[4]We weigh student observations in all of our analyses by the observation weighting recommended in Rogers and Stoeckel (2008, p.45), which is scaled so that weighted observations are representative of the total number of assessable students across the nation in the applicable grade.

2018) constructed privately to estimate them from sales prices and public records (Guerrieri, Hartley and Hurst, 2013). A sizeable share of zip codes within the United States does not have a sufficiently thick housing market to generate reliable estimates. The data are available for just 72 percent of the weighted observations in our sample. [5]

5 Analytical Strategy

In our OLS analyses, we describe the relation between local revenue share in the district and student performance with the following regression specification:

$$Y_{ids} = \beta L_d + \delta \mathbf{X}_i + \gamma E_d + B_s + \epsilon_{ids}, \tag{1}$$

where Y is the NAEP test score for individual i , in district d, in state s, measured in standard deviations, and L is the local share of revenues in the district. In our preferred specifications, we include $\mathbf{X}$, a vector of individual-level covariates, including binary indicators for income, education and the other demographic characteristics listed above, E is current per pupil expenditure in the district, B, state fixed effects, and is the error term, which we cluster by district d to account for interactions among student observations within a school district.[6]

When analyzing heterogeneous effects we consider cleavages driven by differences in either the income indicator or parental education, our two SES indicators, by adding the interaction term $L_d \times SES_i$ in addition to using the variables as co-variates:

$$Y_{ids} = \zeta L_d \times SES_i + \beta L_d + \eta SES_i + \delta \mathbf{X}_i + \gamma E_d + B_s + \epsilon_{ids} \tag{2}$$

[5]See Appendix Figure A3 for geographic distribution of house price changes.

[6]For the Tiebout choice effect analysis, the error term is clustered by commuting zone.

6 Results

6.1 Descriptive models

Tables 1 and 2 display the results of the following five descriptive models of the impact of alternative funding arrangements on educational outcomes: 1) simple relationships between revenue share and educational outcomes; 2) relationships after controlling for student background characteristics and state fixed effects; 3) model 2 plus inclusion of controls for per pupil expenditures, our preferred descriptive model; 4) model 3 plus inclusion of a term that interacts the income indicator with local revenue share; and 5) model 3 plus a term that interacts the education indicator with local revenue share. Models 4 and 5 describe redistributive effects.

Results for math in models 1, 2 and 3 in Table 1 are consistent with the Tiebout hypothesis that local governments are more efficient if revenues come from local sources. The simple model 1 indicates that average student math performance increases by 0.07 standard deviations for every ten percentage point increase in the share of revenue coming from local sources. That estimation is reduced to 0.04 standard deviations when student demographic characteristics and state fixed effects are introduced (model 2). When current expenditures per pupil are included in model 3 (our preferred OLS model), estimated effects increase to 0.06 standard deviations.

The two remaining models indicate more beneficial consequences from local funding for students from higher SES backgrounds. For every 10 percent increase in local share, the math performance of low-income students increases by just 0.05 standard deviations as compared to 0.08 standard deviations for high-income students (model 4). As shown in model 5, the increase for students of parents with less than a college degree is also only 0.05 standard deviations, while for students with high levels of parental education it is, again, 0.08 standard deviations.

The pattern of results for reading achievement are similar (Table 2). Here, our preferred

Table 1: Relationship between local share of revenue and student math achievement

	(1)	(2)	(3)	(4)	(5)
Local revenue share	0.0690***	0.0635***	0.0647***	0.0747***	0.0781***
	(0.0141)	(0.00441)	(0.00430)	(0.00452)	(0.00499)
Low Income X				-0.0270***	
Local revenue share				(0.00502)	
Low Education X					-0.0297***
Local revenue share					(0.00492)
Low Income		-0.327***	-0.324***	-0.213***	-0.324***
		(0.00854)	(0.00849)	(0.0205)	(0.00849)
Low Education		-0.241***	-0.241***	-0.239***	-0.114***
		(0.00760)	(0.00759)	(0.00755)	(0.0218)
Per pupil expenditure			-0.00766***	-0.00825***	-0.00815***
			(0.00332)	(0.00321)	(0.00323)
Individual controls		X	X	X	X
State FE		X	X	X	X
Number of students	143,300	113,410	113,400	113,400	113,400
Number of districts	3,320	3,270	3,270	3,270	3,270
R^2	0.020	0.305	0.306	0.306	0.306

Test scores in standard deviations. Local revenue share in 10 percentage point units. Per pupil Expenditure in thousands of dollars of current expenditure. Income indicated by free or reduced lunch and parental education indicated by college degree for at least one parent. Number of observations rounded to nearest tenth to comply with privacy requirements. Controls for disability (Individualized Education Program), English learner, Race (White or Asian) and Gender. Robust standard errors, clustered by district. Sources: NAEP 2007; NCES 2007. $^+$ 0.10, * 0.05, ** 0.01, *** 0.001

model 3 finds effects of local share on reading of 0.05 standard deviations. In model 4, observed effects for low-income students are 0.04 standard deviations, as compared to 0.06 standard deviations for high-income students. Similar results are obtained for students with high and low parental education (model 5).[7]

Table 2: Relationship between local share of revenue and student reading achievement

	(1)	(2)	(3)	(4)	(5)
Local revenue share	0.0719***	0.0505***	0.0518***	0.0609***	0.0646***
	(0.0104)	(0.00415)	(0.00406)	(0.00425)	(0.00473)
Low Income X Local revenue share				-0.0246***	
				(0.00468)	
Low Education X Local revenue share					-0.0285***
					(0.00422)
Low Income		-0.292***	-0.289***	-0.186***	-0.289***
		(0.00816)	(0.00812)	(0.0210)	(0.00808)
Low Education		-0.204***	-0.205***	-0.203***	-0.0807***
		(0.00710)	(0.00711)	(0.00699)	(0.0175)
Per pupil expenditure			-0.00709***	-0.00767***	-0.00748***
			(0.00296)	(0.00285)	(0.00287)
Individual controls		X	X	X	X
State FE		X	X	X	X
Number of students	126,900	100,470	100,470	100,470	100,470
Number of districts	3,040	2,990	2,990	2,990	2,990
R^2	0.020	0.283	0.283	0.283	0.284

See Notes to Table 1.

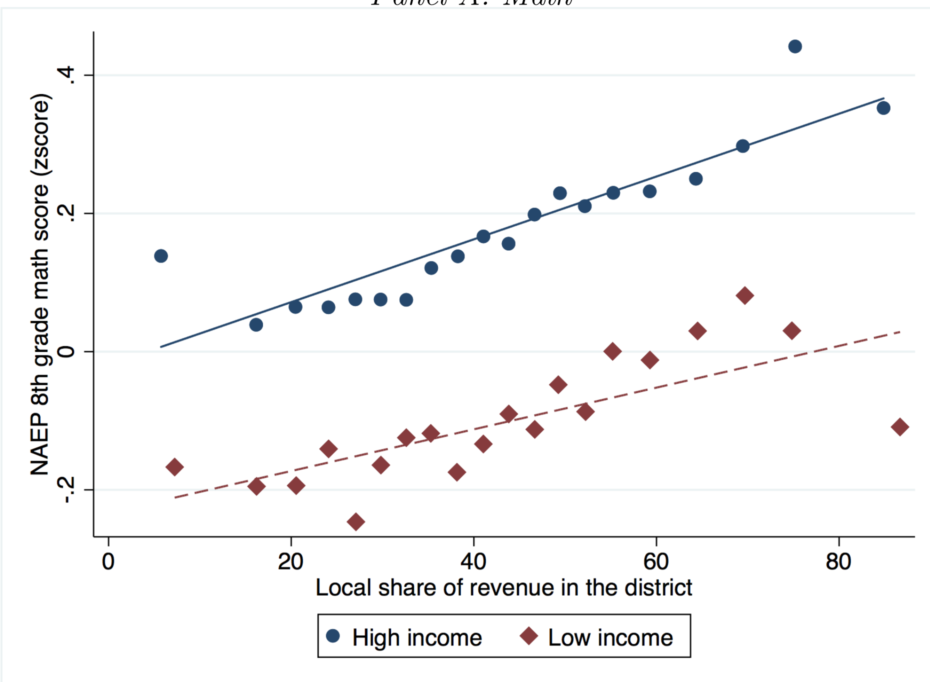
The OLS relationships we have just described in models 4 and 5 are displayed graphically in Figure 1 and Figure 2. Notice that all lines have an upward slope but diverge as the percentage of revenue from local resources increases. A local revenue stream appears to lift all boats even though luxury liners rise higher than canoes.[8]

[7]To ensure that results are not dependent upon observations at the extreme tails of the distribution, we ran all models in Table 1 and Table 2 excluding the top and bottom 5 percent of the distribution. Results are statistically indistinguishable from those reported in these tables (see Appendix Tables A1 and A2).

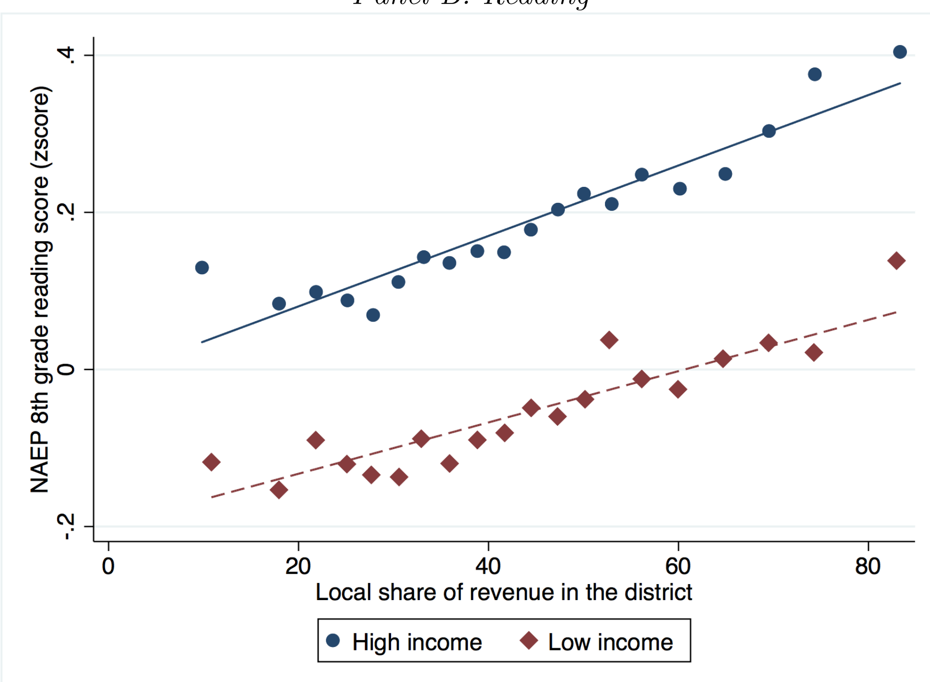
[8] Interaction terms for ethnic or racial groups similar to those in models 4 and 5 are reported in Appendix Table A3. Effects are smaller than those estimated from the income and education interactions.

Figure 1: Local share of revenue in the district and student achievement, by income level

Panel A: Math



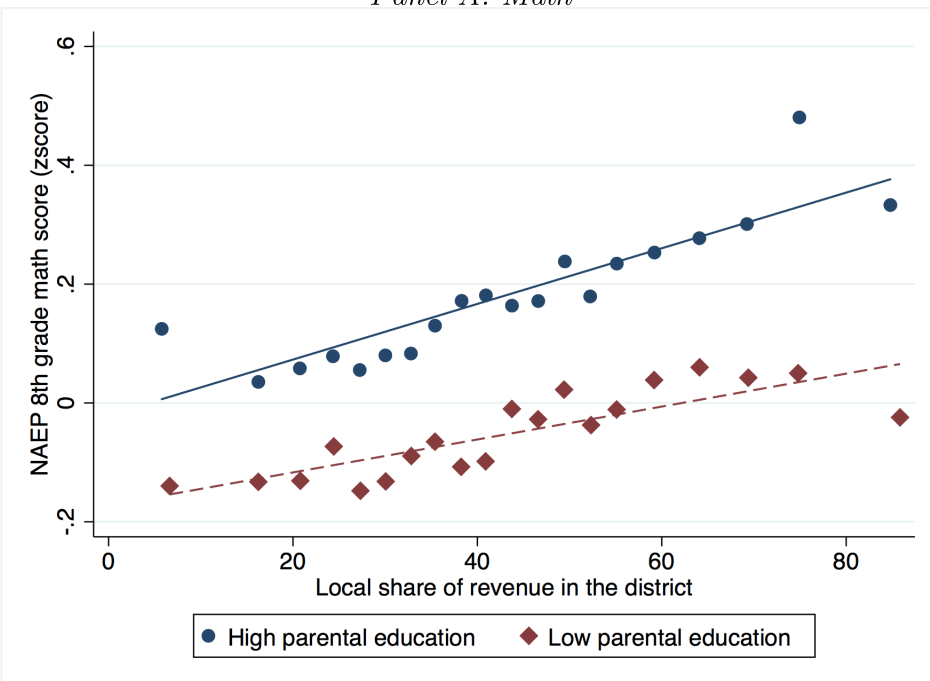
Panel B: Reading



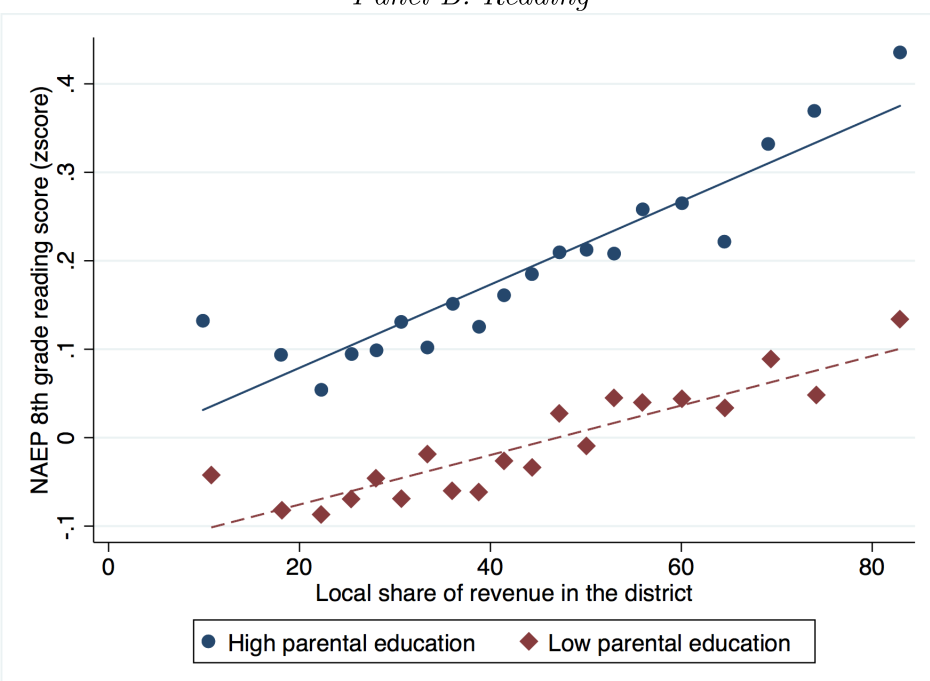
Plots models 4 in Tables 1 and 2. Observations are grouped into 20 equally sized bins.

Figure 2: Local share of revenue in the district and student achievement, by education

Panel A: Math



Panel B: Reading



Plots models 5 in Tables 1 and 2. Observations are grouped into 20 equally sized bins.

This descriptive analysis may be biased by an endogenous relationship between revenue share and student performance. Those who seek high quality schools may migrate to districts that receive more of their funding from local school revenues. Also, state and federal grants may disproportionately fund districts with a higher share of low performing students. To estimate causal effects, we use geographic regression discontinuity models that exploit funding discontinuities at state borders and 2SLS models that exploit changes in housing prices between 2000 and 2007.

6.2 Geographic discontinuity across state boundaries

Since intergovernmental grant policy is determined in good part by policies set at the state level, students attending schools close to state borders may find themselves in districts that receive disparate funding via inter-governmental grants. The discontinuity in funding shares at state borders may be used to estimate causal effects on student performance if unobserved state policies do not affect performance and if there are no unobserved differences between students located close to the border.

We restrict our sample of students to those living near the borders of states with fiscal regimes that differ by an average of ten percentage points or more.[9] Inspection of borders reveals that in some cases students differ significantly by ethnicity (white and Asian versus others). Accordingly, we, following Keele and Titiunik (2015), restrict our sample further to include only borders where differences in ethnic composition within the optimal bandwidth is less than ten percentage points. This strategy reduces the number of student observations used for math estimations of main effects to 7,390 of the 113,410 observations used for the OLS regressions. In reading, the reduction in student observations is from 100,470 to 6,750. The number of district observations is 180 in math and 150 in reading.

Our estimations control for the same individual co-variates included in OLS models. In

[9] Similar causal estimations inferred from policies or institutions with geographical variation have been used to study the effects of urban policies in US cities (Gerber, Kessler and Meredith, 2011), media penetration on political attitudes (Kern and Hainmueller, 2009), and ballot initiatives on voter turnout (Keele and Titiunik, 2015).

addition, we control for three policies expected to affect teacher quality, the school factor most closely correlated with student achievement (Chetty, Friedman and Rockoff, 2014*b*). Expenditures per pupil affect teacher compensation. The strength of teacher unions is affected by right-to-work laws, an indicator we prefer to collective bargaining agreements, because the latter are set at the district rather than the state level. Licensing and certification practices affect the flexibility with which districts can recruit teachers. Some states allow alternatives to traditional state licenses obtained by earning a given number of courses in teacher education.

To estimate a local average treatment effect of differences in local share of revenue near state borders, we employ a fuzzy geographic regression discontinuity design with linear distance to the border as the running variable. Following Cattaneo, Idrobo and Titiunik (2019, ch. 4.2), we select the bandwidth that minimizes the mean squared error (MSE) of the point estimator. In estimations of mean effects, this bandwidth is 12.2 kilometers for math and 15.3 kilometers for reading.

A geographic discontinuity analysis assumes students do not differ in relevant respects within the bandwidth at either side of the border. We estimate differences in per pupil expenditures, state right-to-work laws or state policies with respect to teacher certification. For all observables, only one of twenty differences was statistically significant, which is expected with a significance level is set at 5%. (see Table 3).

For the first stage of the discontinuity regression, we estimate the intercept of the regression line for the revenue shares of districts attended by students within the bandwidths on either side of the border. At the state border a significant difference of 15.60 percentage points in local revenue share is estimated (Figure 3).

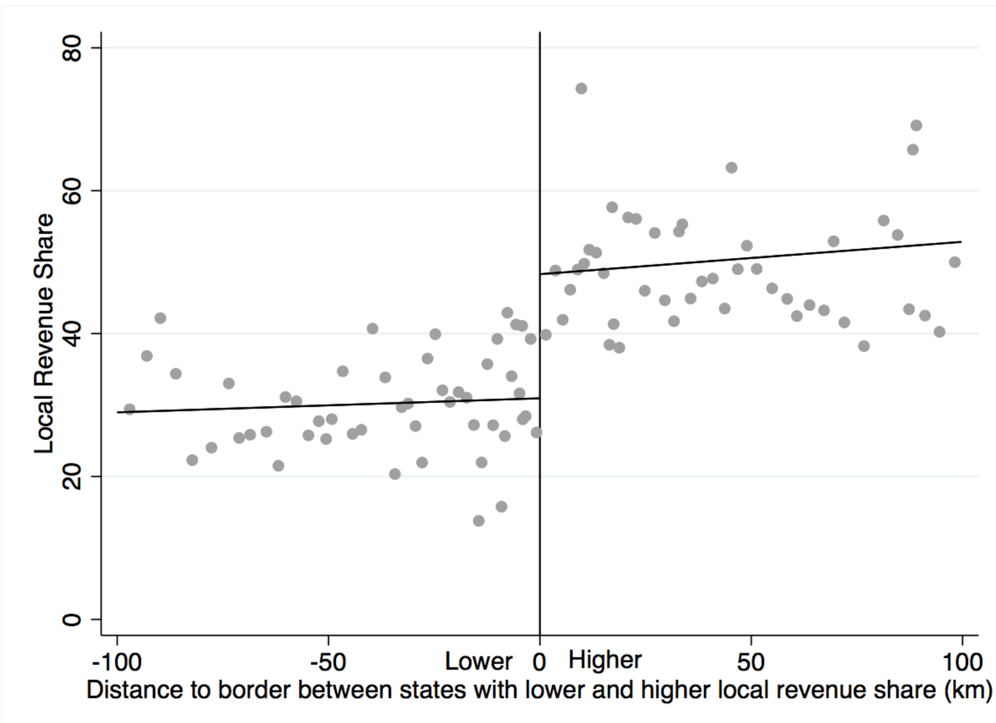
The second stage model estimates an effect of 0.122 standard deviations on math achievement of the average difference in local revenue share at the border. See Table 4 (and Appendix Figures A1 and A2). This effect size, which is equivalent to a 0.08 standard deviation increase for every ten percentage point increase in revenue share, is similar to the share estimated

Table 3: Geographic regression discontinuity estimates of covariate differences at borders of states with contrasting local shares of revenue

Dependent variable	Estimated effect of location in a high local share of revenue state	
	Math	Reading
Low Income	0.01334	0.03069
	(0.03687)	(0.03121)
Low Education	-0.03697	0.03685
	(0.04005)	(0.03406)
White or Asian	-0.0081	-0.03407
	(0.03172)	(0.02552)
Disabled	-0.03339	-0.01385
	(0.02277)	(0.01902)
English Learner	-0.04905*	0.00612
	(0.01905)	(0.01568)
Index of disadvantage	-0.02029	0.01931
	(0.01605)	(0.01366)
Male	-0.03859	0.05555
	(0.04178)	(0.03543)
Expenditure per pupil	0.8989	0.76797
	(0.5193)	(0.5180)
Right to work state	-0.09093	-0.08324
	(0.1245)	(0.7453)
Alternative certification	-0.03661	-0.02153
	(0.04556)	(0.03242)

Note: Estimations restricted to borders of states with differences in average local share of revenue of ten percentage points or more. and difference in non-white or Asian share is less than 10 percent. Index of disadvantage is the average of the listed social indicators. Uses `rdrobust` software of Cattaneo et al. (2019), implemented with the MSE-optimal bandwidth for the pooled analysis on zscores and a triangular kernel. (12.2 km bandwidth across the state border for math and 15.3 for reading). Applying Bonferroni correction for multiple hypothesis testing to the tested variables, none of the coefficients are statistically significant. Standard errors are clustered by district.

Figure 3: First stage: Effect of higher mean state local revenue share on district local revenue share



Note: Observations summarized in 50 equally sized bins on each side of the state border.

Table 4: Geographic regression discontinuity estimates of being in a state with higher rather than lower mean local revenue share

	Effect of high local revenue share	Number of individuals	Number of districts	Bandwidth (km)
Panel A: Math				
Average Math	0.12225* (0.06183)	7390	180	12.2
High income Math	0.14534*** (0.04044)	5650	460	38.7
Low income Math	0.10501** (0.10741)	5190	740	75.8
High education Math	0.13921** (0.04508)	7340	500	43.4
Low education Math	0.13799** (0.04463)	11210	760	41.3
Panel B: Reading				
Average Reading	0.05706 (0.07625)	6750	150	10.7
High income Reading	0.09069+ (0.0492)	11090	510	44.4
Low income Reading	-0.01662 (0.03765)	8760	570	53.4
High education Reading	0.06469+ (0.0375)	7560	490	43.0
Low education Reading	0.01424 (0.04431)	10110	650	59.6

Note: Specification as in Table 3, including controls as in Table 1.

from the OLS analysis (0.06). The effects in reading are 0.06 standard deviations but fall short of statistical significance.[10]

Redistributive effects are also observed. Marginally significant positive effects at the border of 0.09 standard deviations for reading are detected for students from high income households. The effect for low-income students is not significant, lending further support for the

[10]In order to assuage concerns on the use of one-dimensional measures of distance that do not account for bi-dimensional spatial distance (Keele and Titiunik, 2015), we halve the MSE-optimal bandwidth to focus on observations even closer to the state borders. We show the results in Appendix Table A4, which, as expected, find generally noisier but directionally consistent effects.

Oates hypothesis that local governments are likely to under-provide services to low SES residents. Though we do not detect significant effects in the other three estimations of SES differentials (income-reading achievement, education-reading achievement, and education-math achievement), the point estimates from these models consistently indicate that disadvantaged students gain less from increased percentages of local funding.

The causal model appears to confirm the estimation of local funding effects on achievement observed in the descriptive models. Still, geographic discontinuity models may be contaminated by non-observed differences in state policies and are, in any case, estimated for the quite limited percentage of 8th grade students who live near state borders. To estimate causal effects within states and for a larger number of observations, we use a two-stage model with state fixed effects that uses unanticipated changes in housing prices as the instrumental variable.

6.3 Housing Price Changes as Instrument

We use unanticipated, short-term changes in housing prices as an instrument for local revenue share, because the change is unlikely to affect student achievement directly or indirectly other than through its effect on local revenue share. The 2SLS estimations generate results similar to those reported from the OLS and geographical discontinuity regressions.

6.3.1 Instrumental variable.

Between 2000 and 2007 housing prices in the average zip code within the continental United States increased by 7.6 percent each year or by a cumulative 75 percent. The increases varied widely across the United States, with some zip codes reporting 25 percent increases annually. Economists do not agree on the causes (Shiller, 2007). Some attribute it to the ready availability of subprime loans (Mayer and Pence, 2008), while others think "trend-chasing" can drive up prices in specific markets (Glaeser, Nathanson et al., 2015). That prices were frothy and seemingly irrational during the period has been offered as a factor contributing to the financial crisis of 2008 (Mishkin, 2009; Taylor, 2009).

The apparently irrational and unanticipated nature of much of the growth in housing values between 2000 and 2007 makes price changes within commuting zones a useful exogenous instrument for estimating local revenue shares. While price changes can be expected to have a direct impact on revenues from the property tax within each commuting zone, they are unlikely to have any direct or indirect impact on student test scores except via their impact on local tax resources. To minimize exogeneous effects of school quality on price change, we estimate price changes at the commuting zone level rather than the school district level. To account for any remaining endogeneity between pre-existing district quality and price changes, we control for average 2000 district levels of math achievement.

Theoretically, direct effects of large changes in house prices on local revenue share are likely to be substantial. Most districts depend heavily upon the property tax. Property tax rates are sticky on the downside (Davis and Ferreira, 2017; Lutz, 2008), and local assessments of property values typically take place within two years or so of market changes in house values. These factors can be expected to boost local revenues for school districts, and they can also be expected to reduce the size of inter-governmental grants, since state funding formulas tend to favor districts with more limited taxable resources (Chingos and Blagg, 2017). The combined effect of a growth in local resources and reduced state grants in districts with rising housing values can be expected to shift upward the share of resources generated locally.

6.3.2 First stage estimations.

As theorized, increases in local house prices, conditional on math score levels in 2000, alter the dependence of districts on local rather than grant revenues (Table 5). Specifically, a ten percentage point increase in house prices generates a 5.6 percentage point increase in local revenue share.

Table 5: First stage relationship between changes in house prices 2000-07 and local share of revenue in district, 2007

	(1)
Change in house prices 2000-07	0.564***
	(0.0391)
Average math scores in district in 2000	15.89***
	(0.214)
Observations	70100
F-statistic	2758
R^2	0.683

Model shows result from individual-level regressions, with controls as in Table 1, model 3. Changes in house prices are percent changes in commuting zone. Robust standard errors, clustered by district, in parentheses. Sources: NCES 2000, NCES 2007, Zillow 2018.

6.3.3 Second-stage estimations.

In estimations that use house prices as an instrument for local revenue share, controls are introduced for current per pupil expenditures, state fixed effects, 2000 local revenue share, and 2000 math achievement levels as well as the individual background characteristics used in OLS estimations.[11] As can be seen in Table 6, the predicted effects of local finance on policy outcomes resemble those observed in OLS estimations. For every 10 percent predicted increase in revenue share, student achievement in math increases by 0.10 standard deviations and in reading it shifts upward by 0.08 standard deviations.

The 2SLS results are also largely consistent with OLS estimations of SES differentials. In three of the four predicted estimations, advantaged students register higher reading and math gains in districts with a higher share of local funding. Only the math difference between students from households of higher and lower income is not statistically significant. Otherwise, the positive impacts of a 10 percent increase in local share are about 0.02 to 0.03 standard deviations less for low SES students than for high SES students.

If these predicted estimations identify a causal relationship then, consistent with Tiebout theory, local funding is more efficacious. But, consistent with Oates theory, outcomes are

[11] NAEP reading achievement scores were not available for 2000 at the time of writing.

Table 6: Predicted relationship between student achievement and local revenue share, using house price changes 2000-07 as instrument

	(1)	(2)	(3)
Panel A: Math estimates			
Local revenue share	0.105**	0.0811**	0.0896**
	(0.0426)	(0.0356)	(0.0356)
Local revenue share 2000	-0.0359	0.0586***	0.0578***
	(0.0662)	(0.00560)	(0.00558)
Average math scores 2000	0.221***	0.133+	0.136+
	(0.0247)	(0.0793)	(0.0793)
Low Income	-0.302***	-0.269***	-0.289***
	(0.0159)	(0.0477)	(0.0215)
Low Education	-0.254***	-0.240***	-0.107*
	(0.0127)	(0.0162)	(0.0437)
Low income X		-0.00392	
Local revenue share		(0.00979)	
Low Education X			-0.0289***
Local revenue share			(0.00877)
Observations	70480	70500	70500
R^2	0.080	0.279	0.279
Panel B: Reading estimates			
Local revenue share	0.0855*	0.00622**	0.00727**
	(0.0466)	(0.00213)	(0.00315)
Local revenue share 2000	-0.0355	0.0402***	0.0400***
	(0.0701)	(0.00572)	(0.00572)
Average math scores 2000	0.188***	0.128+	0.126+
	(0.0268)	(0.0756)	(0.0756)
Low Income	-0.299***	-0.195***	-0.290***
	(0.0160)	(0.0467)	(0.0218)
Low Education	-0.222***	-0.214***	-0.0424
	(0.0130)	(0.0145)	(0.0423)
Low income X		-0.0209*	
% Local revenue		(0.00945)	
Low Education X			-0.0373***
% Local revenue			(0.00858)
Observations	68300	68440	68440
R^2	0.289	0.288	0.288

Two stage least square models regressing z-scores, instrumented by changes in house prices at the commuting zone level. Additional controls as in Table 1, models 3, 4 and 5. See Table 5 for sources. Robust standard errors, clustered by district, in parentheses.

more favorable for students from higher SES backgrounds than those from disadvantaged ones.

7 Mechanisms

Although the connection between funding mechanisms and student outcomes remains largely a black box, a sketch of some links was attempted. We searched for effects of funding sources on the allocation of school fiscal resources. Also, following Hirschman (1970), we explored the importance of voice and exit channels connecting consumer demand and policy outcomes.

7.1 Fiscal Allocation

NCES reports contain district-supplied information on the allocation of expenditures to instruction (including teacher salaries) as well as to school administrative and district administrative services. Using an OLS model similar to model 3 in Table 2, we report estimates in Table 7 showing that for every 10 percent increase in the share of revenue funded locally, districts allocate one percent more of their resources toward instructional purposes and 1.7 percent and 2.1 percent less toward school and district administrative services, respectively. Although results are not definitive, they are consistent with the intuition that grants from higher tiers of government require additional administrative resources in order to comply with regulatory, oversight and monitoring requirements. If administrative expenditure reduces resources available for instruction, and if teachers are the most important school factor affecting student performance (Chetty, Friedman and Rockoff, 2014*a*), resource allocation might be part of the explanation for higher levels of student achievement in locally funded districts.

Table 7: Relationship of share of spending by functional category and local share of revenue

	(1) Instruction	(2) School adminis-tration	(3) District adminis-tration
Local revenue share	0.956*	-1.730***	-2.082***
	(0.450)	(0.231)	(0.407)
Observations	12010	12010	12010
R^2	0.226	0.191	0.115

OLS models regress percentage share of spending per category on local revenue share (both in units of 10 percentage points) for selected functional categories defined by NCES. Controls as in as in Table 1, model 3. Robust standard errors, clustered by district, are in parentheses. Sources: NCES 2007 F-33 forms.

7.2 Voice

Voice may be exercised by voting in school board elections, participating in community groups, or attending school board meetings. Using survey data, we search for evidence that the use of these channels varies with the percent of funding from local sources, but we do not find any significant relationships (see Appendix Table A5). However, our data are weak in that they do not explore all potential channels and they come from respondents surveyed after 2007.

7.3 Exit

Hirschman (1970) hypothesizes that residents of a community can influence policy because they are able to leave one community for another in order to secure outcomes they prefer (also, see Epple and Zelenitz (1981) and Nechyba (1997)). To estimate this potential channel connecting funding shares to educational outcomes, we, building on Hoxby (2000), hypothesize that greater Tiebout choice may affect student achievement more in in areas with higher local revenue shares. To test this proposition, district density (the number of school districts) within a commuting zone is used as a proxy for Tiebout choice, which is the local opportunity to move from one school district to another. In our sample, the commuting zone median is 37 districts, and the inter-quartile range is 83 districts. The median percentage for local revenue share is 42 percent.

Using OLS models with the same co-variates used in our preferred models in Tables 1 and 2, we show in Table 8, model 1, mean achievement effects of district density. In model two, we show density effects on mean achievement conditional upon local revenue share. Models 3 and 4 estimate the redistributive effects of density effects conditional upon local revenue share.

Lines 1 and 3 of model one in Table 8, panels A and B, provides estimates for mean achievement effects of a one district increase within a commuting zone. Tiebout choice effects are positive in both math and reading, but only in the latter subject are they significant. For this subject, an increase in density of one district induces an upward shift in achievement of 0.000191 standard deviations for a district with 42 percent local revenue share. The Tiebout choice effects in reading of an increase in district density of ten districts are estimated to be 0.002 standard deviations. Across the inter-quartile range (83 districts), these effects are 0.017 standard deviations.

As can be seen from the significantly positive result for both math and reading reported in models 2 and 3 in Table 8, panels A and B, these gains from Tiebout choice are concentrated in districts with high revenue share. This is estimated by dividing districts with high and low revenue shares at the mean of the distribution (42 percent) and interacting that term by a specified increase in the number of districts. For every density increase of ten districts the estimated increase in student math achievement in districts with mean revenue share is 0.0015 standard deviations. This can be seen by multiplying line one of model 2 in Table 8 both by one tenth of mean revenue share or 4.1 percent (to allow for the coefficient estimate of a 10 percent increase in revenue share) as well as by a ten-district increase, then subtracting the negative estimate for the number of districts that have local revenue shares below the mean (shown in line 3 of model 2). For reading, the marginal effect is 0.0016 standard deviations for every increase of ten districts in those districts at the revenue mean. The effect on both

Table 8: Tiebout choice effects: Relationship between the interaction of local revenue share and district density within the commuting zone and student achievement

	(1)	(2)	(3)	(4)
Panel A: Math estimates				
Local revenue share		0.0000402**	0.0000649***	0.0000129
X No. districts		(0.0000148)	(0.0000185)	(0.0000203)
Local revenue share	0.0645***	0.0606***	0.0693***	0.0483***
	(0.00183)	(0.00229)	(0.00261)	(0.00283)
No. districts	0.000313	-0.0000151+	-0.0000306**	0.0000140
	(0.000473)	(0.00000830)	(0.00000109)	(0.0000103)
Low Income X Local rev. X			-0.0000749*	
No. districts			(0.0000294)	
Low Income X Local rev.			-0.0217***	
			(0.00338)	
Low Income X			0.000367*	
No. districts			(0.000144)	
Low Income	-0.324***	-0.324***	-0.237***	-0.324***
	(0.00588)	(0.00588)	(0.0149)	(0.00588)
Low Education X				-0.00000988***
Local rev. X No. districts				(0.00000263)
Low Education X			-0.00233***	
Local revenue share			(0.000320)	
Low Education X				0.000609***
No. districts				(0.000138)
Low Education	-0.241***	-0.241***	-0.239***	-0.151***
	(0.00513)	(0.00513)	(0.00514)	(0.0145)
Observations	121350	121350	121350	121350

Table 8 (continued).
Panel B: Reading estimates

Local revenue share X No. districts		0.0000826***	0.0000855***	0.000114***
		(0.0000148)	(0.0000184)	(0.0000194)
Local revenue share	0.0510***	0.0425***	0.0515***	0.0525***
	(0.00192)	(0.00244)	(0.00279)	(0.00294)
No. districts	0.000191***	-0.000187*	-0.000239*	-0.000389***
	(0.0000465)	(0.00000839)	(0.0000109)	(0.0000113)
Low Income X Local rev. X No. districts			-0.00000764	
			(0.0000302)	
Low Income X Local rev.			-0.0234***	
			(0.00396)	
Low Income X No. districts			0.0000996	
			(0.000149)	
Low Income	-0.289***	-0.288***	-0.195***	-0.288***
	(0.00628)	(0.00628)	(0.0175)	(0.00628)
Low Education X Local rev. X No. districts				-0.00000799**
				(0.00000270)
Low Education X Local rev.				-0.00209***
				(0.000369)
Low Education X No. districts				0.000423**
				(0.000142)
Low Education	-0.205***	-0.204***	-0.202***	-0.116***
	(0.00548)	(0.00548)	(0.00548)	(0.0169)
Observations	100470	100470	100470	100470

See notes to Table 1.

math and reading achievement of an increase in density across the inter-quartile range (83 districts) is 0.013.

In other words, the benefits of Tiebout choice on mean student achievement are concentrated in districts with a greater share of revenue from local sources. They account for about a fifth of the overall estimated impact of local funding of 0.05 standard deviations on mean student achievement.

As Oates might expect, the redistributive effects of more intense Tiebout competition are negative. In models 3 and 4 of the two panels in Table 8, the four estimates of the effects of Tiebout choice on student achievement are shown in lines 4 and 8 of both the reading and the math panels. In three of the four estimates, the effects of Tiebout choice are significantly greater for students from more advantaged SES backgrounds than for disadvantaged ones. This is indicated by the negative value of the three-way interaction terms among indicators of low SES, local share of revenue and number of districts. However, the negative value of the interaction term is smaller than the size of the mean effect. All SES groups benefit from increased Tiebout choice but not to the same degree.[12]

8 Discussion

Both descriptive and causal estimates of the achievement effects of funding from local revenue sources are consistent with Tiebout theory. Our preferred descriptive estimate, which is based upon the largest number of observations and is supported by causal models, indicates that student achievement in math and reading is higher by about 0.05 standard deviations for every 10 percent increase in local revenue share. The higher share of resources allocated toward instructional services rather than administrative ones in locally funded districts may partially explain the greater efficacy. Also, an exit mechanism seems to connect citizen

[12] Tiebout choice effects are quite robust to 2SLS estimations (see Table A6 in the Appendix). Although the predicted estimations are noisier, their direction is consistent with the OLS estimations in Table 8. In all cases we assume that the number of districts in a commuter zone are exogenous to contemporary test score performance, as the number of districts declined by less than an average of three districts per commuter zone between 1990 and 2007.

preferences to policy outcomes, as greater inter-district competition within commuting zones induces higher levels of achievement in districts with larger revenue shares from local sources. We are unable to identify a voice channel.

Oates' theory is also supported. The gains in student achievement are greater for high SES groups than for disadvantaged ones. Although estimates vary somewhat by model, one may reasonable infer from both the descriptive and the causal models that a shift in the share of grant funding to higher tiers of government from the low to the high end of the inter-quartile range would reduce the gap between students of high and low SES by 2 to 3 percent of a standard deviation.

Our work is limited in several ways. Unobserved differences among states or students in border areas could contaminate our geographic discontinuity models. Unobserved differences in the taste for education among migrants across commuting zones between 2000 and 2007 could confound our 2SLS models. It is also possible that families used additional capital generated by increases in house values to purchase additional educational services for their children.

Generalizability is another concern. Our data come from 2007, a year selected to avoid contamination by the dramatic changes that ensued the following year. Those changes may have introduced a new world where inter-governmental grants have different consequences, although current average levels of local share of revenue are similar to pre-crisis levels (Snyder, de Brey and Dillow, 2019, Table 235.10). Also, while achievement tests are correlated with desired downstream outcomes, these might be affected by finance arrangements in quite different ways. Nor can we generalize from the United States to other countries.

Despite these and other limitations, this is the first empirical study to use large administrative data sets that contain nationally representative data to provide causal estimates of propositions derived from two contrasting theories of fiscal federalism. Consistent with Tiebout theory, we find a larger share of revenue from local sources has beneficial impact on important educational outcomes. Consistent with Oates, we find that local funding is more beneficial for students from more advantaged backgrounds than for those from disadvantaged ones.

These results are relevant to contemporary policy discussions. To secure more adequate and equitable state funding, plaintiffs in many states have filed lawsuits asking for redistributive state grants to local school districts (West and Peterson, 2007). Legal scholars have made the case that the Supreme Court should reconsider *Rodriguez v. San Antonio Independent School District* (1973) so that inequities in funding across the country can be addressed (Ogletree and Robinson, 2015). A reversal would likely produce greater use of intergovernmental grants.

Our data allow for an estimate of the impact of changes in intergovernmental grant policy. Results suggest that a shift in funding of 30 percentage points (about the inter-quartile range) to higher tiers of government would have a negative impact on student performance of around 15 percent of a standard deviation.

The median student in eighth grade performs nearly one standard deviation higher than the median fourth grade student, a magnitude interpreted by some scholars to mean a standard deviation differ tests is broadly equivalent to nearly four years' worth of learning (Hanushek, 1997, e.g.). If this assumption is made, then an increase in state funding of 30 percentage points would adversely affect 8th grade student achievement by about a half of a years' worth of learning. Redistributive consequences are also noticeable. The same increase in higher-tier funding would reduce the gap between high SES and low SES 8th grade students by somewhere around 6 to 9 percent of a standard deviation, about a fourth of a year's worth of learning.

To extend this research, scholars may wish to explore further the mechanisms linking funding regimes to educational and other service-delivery outcomes. The voice mechanism is especially in need of further attention. To ascertain whether political activities differ with funding arrangements, one might collect information on participation rates in school board campaigns and elections as well as public engagement at school board and city council meetings. Researchers might survey administrators and board and council members, analyze texts of minutes and calendars, conduct deeper analyses of managerial structures, and study candidate appeals in elections.

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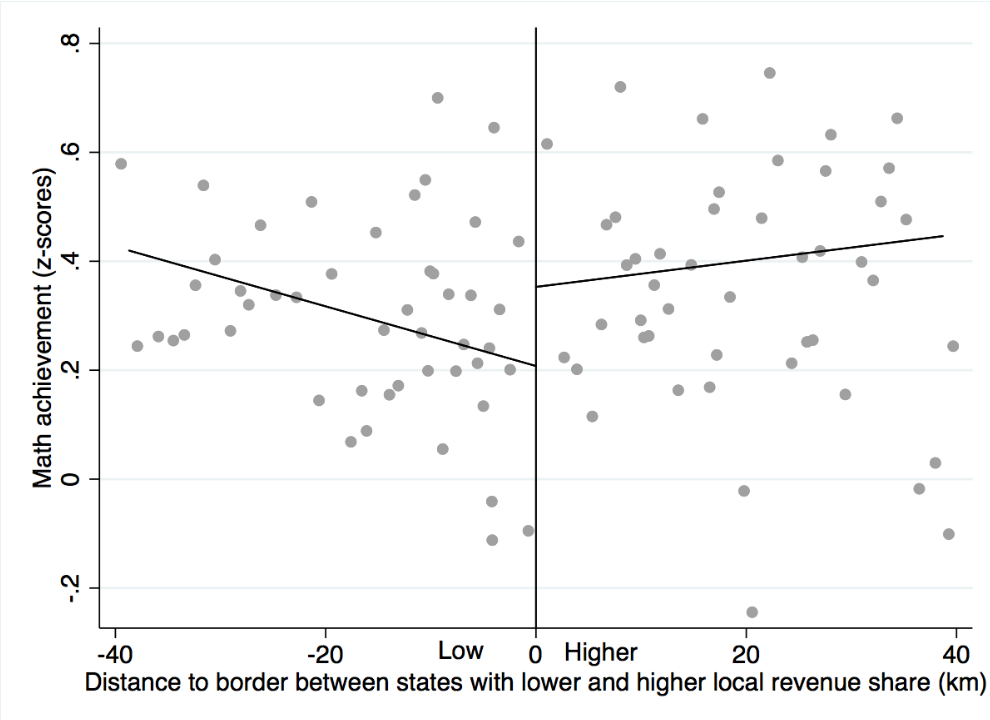
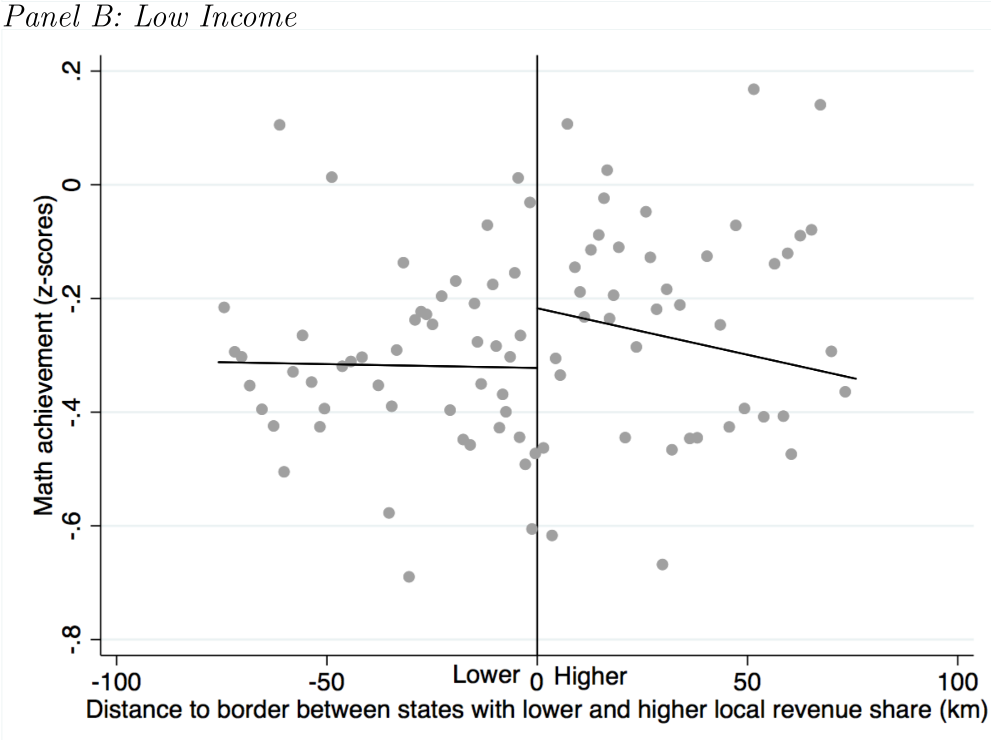
Appendix

Figure A1: Effects by income in Math

Panel A: High Income



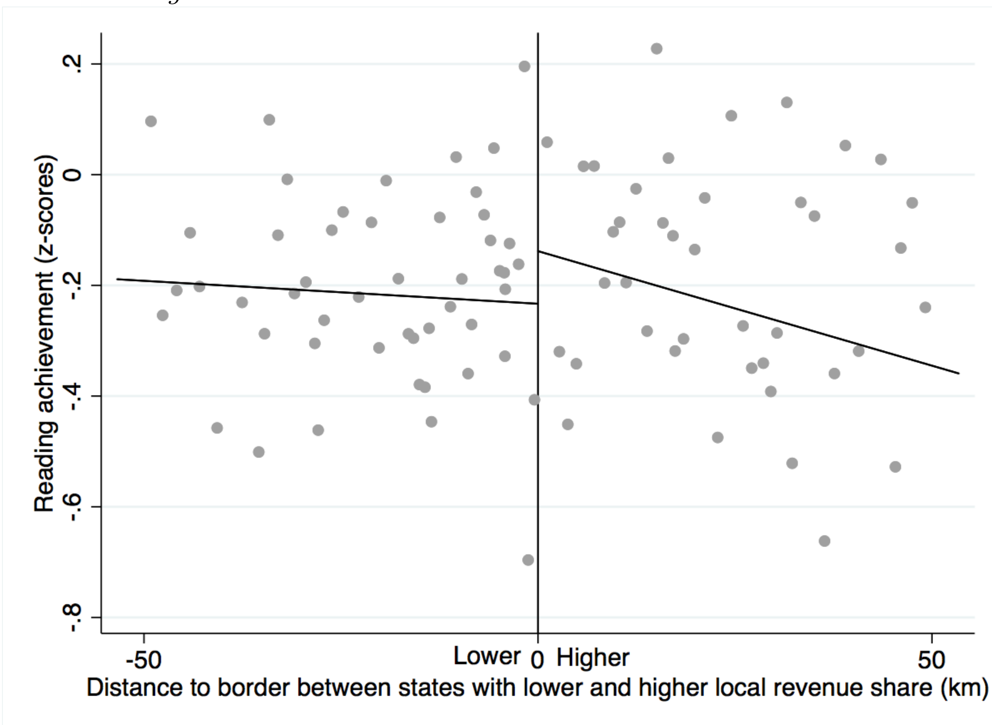
Panel B: Low Income



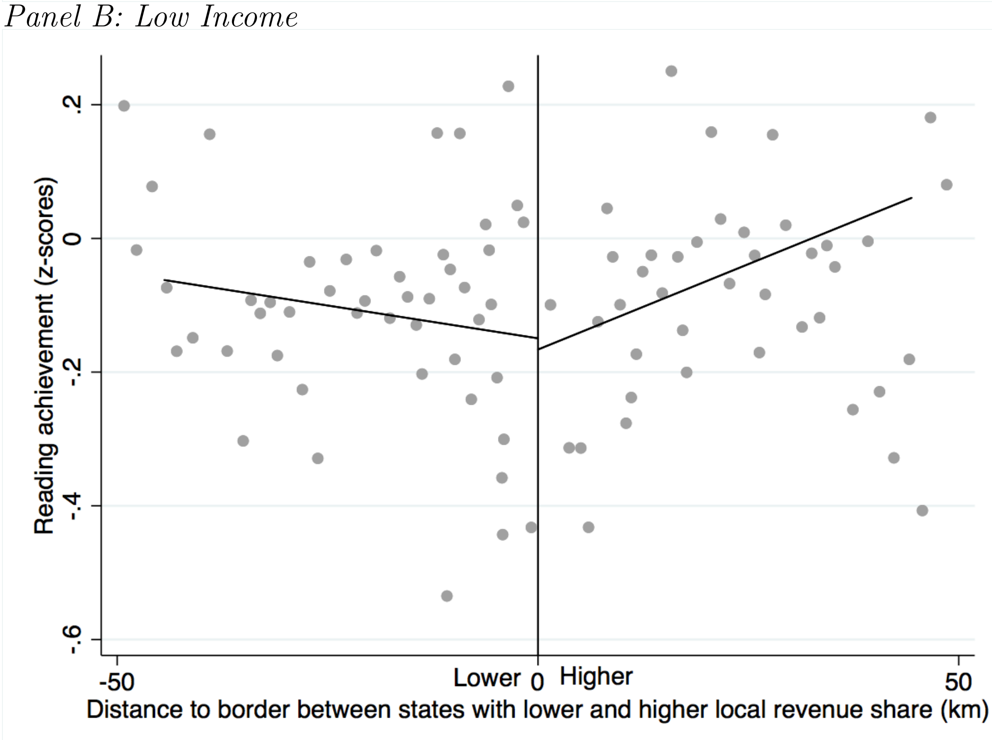
Note: displays math model for each subgroup in Table 4. For display, observations are summarized in 50 equally sized bins on each side of the state border.

Figure A2: Effects by income in Reading

Panel A: High Income

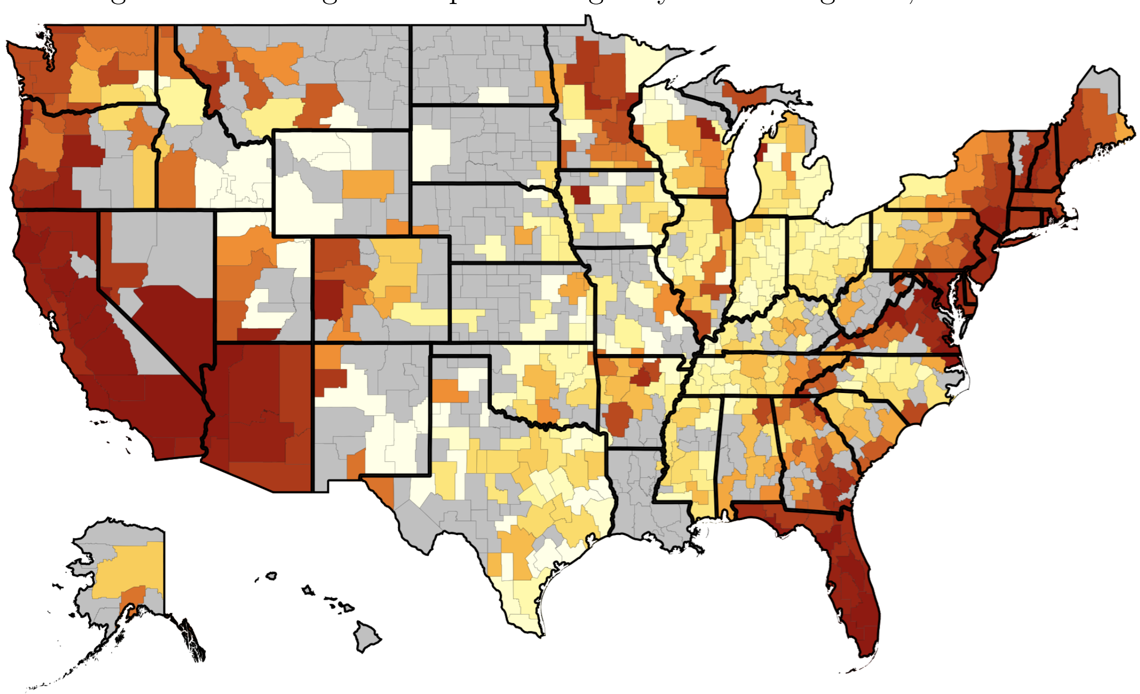


Panel B: Low Income



Note: displays reading model for each subgroup in Table 4. For display, observations are summarized in 50 equally sized bins on each side of the state border.

Figure A3: Average house price changes by commuting zone, 2000-2007



Plots average house price changes 2000-07 in the commuting zone, by averaging the zipcode-level means of house price changes in each commuting zone, divided in 20 quantiles (shades of color). Grey indicates insufficient data to determine house price levels. Source: Zillow 2018.

Table A1: Relationship between local revenue share and math achievement, excluding the top and bottom 5% of observations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Local revenue share	0.0720***	0.0455***	0.0632***	0.0646***	0.0735***	0.0524***	0.0840***	0.0602***
	(0.000176)	(0.000161)	(0.000220)	(0.000221)	(0.000263)	(0.000269)	(0.000304)	(0.000315)
Low Income X Local revenue share					-0.00204***		-0.00266***	
					(0.000339)		(0.000344)	
Low Education X Local revenue share						0.0251***		0.0262***
						(0.00326)		(0.00321)
Low Income		-0.346***	-0.319***	-0.314***	-0.233***	-0.314***	-0.202***	-0.308***
		(0.00580)	(0.00597)	(0.00599)	(0.0147)	(0.00599)	(0.0149)	(0.00593)
Low Education		-0.234***	-0.220***	-0.220***	-0.219***	-0.117***	-0.219***	0.113***
		(0.00517)	(0.00528)	(0.00528)	(0.00528)	(0.0143)	(0.00518)	(0.0141)
Per pupil expenditure				-0.0137***	-0.0135***	-0.0137***	-0.0161***	-0.0164***
				(0.00175)	(0.00175)	(0.00175)	(0.00183)	(0.00184)
Individual controls		X	X	X	X	X	X	X
State FE			X	X	X	X	X	X
Number of students	131,390	112,890	105,960	105,950	105,950	105950	111270	111270
Number of districts	2,990	2,960	2,960	2,960	2,960	2,960	2,960	2,960
R^2	0.013	0.265	0.287	0.288	0.288	0.288	0.303	0.303

Test scores in SDs. Local revenue share in 10 percentage point units. Per pupil expenditure in thousands of dollars of current expenditure. Income indicated by free or reduced lunch eligibility and parental education indicated by college attendance. Controls for disability (Individualized Education Program), English learner, Race (White or Asian) and Gender. Robust standard errors, clustered by district. Sources: NAEP 2007; NCES 2007. $^{+}$ 0.10, * 0.05, ** 0.01, *** 0.001

Table A2: Relationship between local revenue share and reading achievement, excluding the top and bottom 5% of observations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Local revenue share	0.0694***	0.0400***	0.0515***	0.0530***	0.0619***	0.0401***	0.0725***	0.0516***
	(0.00176)	(0.00161)	(0.00217)	(0.00220)	(0.00256)	(0.00283)	(0.00298)	(0.00326)
Low Income X					-0.00227***		-0.00220***	
Local revenue share					(0.000354)		(0.000358)	
Low Education X						-0.00245***		-0.00239***
Local revenue share						(0.000331)		(0.000324)
Low Income		-0.307***	-0.288***	-0.284***	-0.190***	-0.285***	-0.189***	-0.280***
		(0.00618)	(0.00644)	(0.00648)	(0.0159)	(0.00648)	(0.0160)	(0.00637)
Low Education		-0.213***	-0.198***	- 0.198***	-0.197***	-0.0926***	-0.199***	0.0974***
		(0.00547)	(0.00567)	(0.00567)	(0.00568)	(0.0153)	(0.00552)	(0.0149)
Per pupil expenditure				-0.00833***	-0.00830***	-0.00842***	-0.0132***	-0.0134***
				(0.00181)	(0.00181)	(0.00181)	(0.00184)	(0.00185)
Individual controls		X	X	X	X	X	X	X
State FE			X	X	X	X	X	X
Number of students	114,500	99,390	92,550	92,540	92,540	92,540	97,800	97,800
Number of districts	2,750	2,690	2,690	2,690	2,690	2,690	2,690	2,690
R^2	0.014	0.265	0.275	0.275	0.276	0.276	0.290	0.290

Test scores in SDs. Local revenue share in 10 percentage point units. Per pupil Expenditure in thousands of dollars of current expenditure. Income indicated by free or reduced lunch eligibility and parental education indicated by college attendance. Controls for disability (Individualized Education Program), English learner, Race (White or Asian) and Gender. Robust standard errors, clustered by district. Sources: NAEP 2007; NCES 2007. $^{+}$ 0.10, * 0.05, ** 0.01, *** 0.001

Table A3: Relationship between local revenue share, race and student achievement

	(1)	(2)
	Math	Reading
Local revenue share	0.0677***	0.0537***
	(0.00405)	(0.00412)
Black X Local revenue share	-0.0317***	-0.0113
	(0.00831)	(0.00831)
Hispanic X Local revenue share	-0.0315***	-0.0320***
	(0.00575)	(0.00721)
Asian American X Local revenue share	0.0480**	0.0293**
	(0.0173)	(0.00937)
Native American X Local revenue share	0.0110	-0.0143
	(0.0149)	(0.0150)
Other race X Local revenue share	0.0182+	0.0341
	(0.00964)	(0.0242)
Black	-0.543***	-0.521***
	(0.0365)	(0.0355)
Hispanic	-0.189***	-0.135***
	(0.0270)	(0.0319)
Asian American	0.195*	-0.00944
	(0.0817)	(0.0488)
Native American	-0.203**	-0.237***
	(0.0579)	(0.0412)
Other race	-0.184***	-0.284*
	(0.0365)	(0.121)
Observations	113400	100470
R^2	0.331	0.298

Specification and controls as in Table 1, model 3

Table A4: Geographic regression discontinuity estimates of being in a higher rather than lower average local revenue share state on achievement, using half of the MSE-optimal bandwidth.

	Effect of high local revenue share	Bandwidth (km)
Panel A: Math		
Average Math	0.34508**	6.6
	(0.1280)	
High income Math	0.16461**	19.9
	(0.06248)	
Low income Math	0.06216	38.7
	(0.05711)	
High education Math	0.11801*	21.7
	(0.05987)	
Low education Math	0.0428	20.6
	(0.07307)	
Panel B: Reading		
Average Reading	0.70787***	5.4
	(0.15044)	
High income Reading	0.05915	22.2
	(0.05919)	
Low income Reading	-0.00276	26.7
	(0.07705)	
High education Reading	0.01412	21.7
	(0.06954)	
Low education Reading	-.05005	29.2
	(0.05874)	

Note: Specification as in Table 4, including controls as in Table 1. Each model uses one half of the MSE-optimal bandwidth obtained for the pooled analysis.

Table A5: Relation between local revenue share and citizen participation in education governance

	(1) School board election participation	(2) Attention paid to education	(3) Grade given to local school (zscore)
Local revenue share	-0.000682	-0.00219	-0.000740
	(0.000439)	(0.00122)	(0.00101)
Grade given to local school (zscore)		0.0908^{***}	
		(0.0170)	
Math zscore			0.348^{***}
			(0.0419)
Constant	-0.0329	2.945^{***}	-0.0117
	(0.0409)	(0.0704)	(0.0565)
Observations	11450	12970	22690
R^2	0.268	0.050	0.097

Linear regression models include year fixed effects, college, age, income and gender. Participation and attention paid to education are on 1-5 scale of intensity. A-F grade given to school is normalized into a z-score. The math zscore control reflects the average performance in math of the district in state standardized tests, calibrated to a national scale. Robust Standard errors, clustered by district in parentheses.

Table A6: Predicted Tiebout choice effects: Relationship between predicted student achievement and interaction of local revenue share and district density within the commuting zone, using house price changes as instrument.

	(1)	(2)	(3)	(4)
Panel A: Math estimates				
Local revenue share X No. districts		0.000171* (0.0000706)	0.0000848 (0.0000823)	0.0000615 (0.0000861)
Local revenue share	0.138** (0.0498)	0.116** (0.0403)	0.112** (0.0403)	0.116** (0.0406)
No. districts	-0.000272 (0.000178)	0.000959** (0.000338)	0.000457 (0.000410)	0.000386 (0.000429)
Low Income X Local rev. X No. districts			-0.000190^{+} (0.000115)	
Low Income X Local rev.			-0.00324 (0.0130)	
Low Income	-0.292*** (0.0156)	-0.294*** (0.0191)	-0.298*** (0.0586)	-0.297*** (0.0191)
Low Income X No. districts				0.00111* (0.000540)
Low Education X Local rev. X No. districts			-0.000256* (0.0000995)	
Low Education X Local rev.			-0.0119 (0.0119)	
Low Education	-0.245*** (0.0125)	-0.251*** (0.0147)	-0.251*** (0.0147)	-0.202*** (0.0550)
Low Education X No. districts				0.00130** (0.000498)
Observations	64310	64310	64310	64310

Table A6 (continued).

Panel B: Reading estimates

Local revenue share X No. districts		0.0000839 (0.0000644)	0.000108 (0.0000768)	0.000175* (0.0000770)
Local revenue share	0.00493 (0.0466)	0.0758** (0.0281)	0.0782** (0.0289)	0.0842** (0.0287)
No. districts	0.0000515 (0.000171)	-0.0000359 (0.000321)	-0.000226 (0.000394)	-0.000542 (0.000405)
Low Income X Local rev. X No. districts			0.0000295 (0.0000964)	
Low Income X Local rev.			-0.0291* (0.0128)	
Low income X No. districts			0.000132 (0.000477)	
Low Income	-0.293*** (0.0155)	-0.291*** (0.0174)	-0.183** (0.0573)	-0.293*** (0.0174)
Low Education X Local rev. X No. districts				-0.0000799** (0.0000270)
Low Education X Local rev.				-0.0210+ (0.0117)
Low Education X No. districts				0.00114* (0.000471)
Low Education	-0.214*** (0.0120)	-0.219*** (0.0133)	-0.220*** (0.0134)	-0.132* (0.0542)
Observations	62730	62730	62730	62730

See notes to Table 1 and Table 5 .