The Effects of Market-Based School Reforms on Student Outcomes: A National Analysis of Charter Effects on District-Level School Systems

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Abstract: Prior research on charter schools has focused either on short-term participant effects or short-term competitive effects of charters on these other schools. This study is the first to examine the long-term, combined effects of these and other mechanisms, i.e., system effects. Using a matched difference-in-differences and dose-response identification strategies, we find that charter entry increases district-level student outcomes. Districts with more than 10 percent charters have increased high school graduation by 3-4 percentage points and increases test scores by 0.08-0.16 standard deviations (especially in Math, less so for ELA). All the effects are larger in urban areas and for middle schools compared with elementary grades. Additional tests, robustness checks, and comparisons with prior research suggest that these are causal effects.

Keywords: Charter schools; competition; high school graduation; student achievement

JEL Codes: H75, I21, I28

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1. Introduction

Charter schools have arguably had a greater impact on American education than any school reform in the last three decades. Charter schools are publicly funded but exempt from many of the state laws and regulations that govern traditional public schools. They are bound to a contract, or "charter," and can be held accountable for performance. Charter schools also operate with more autonomy, e.g., in hiring teachers and choosing curricula and instructional methods, allowing them to differentiate themselves from one another. These factors, combined with school choice for families, represent a mostly market-driven approach that could increase innovation, better match students to schooling options, and increase competition among schools. Traditional public schools may respond to charter entry by improving efficiency to avoid losing students--and therefore funding—and to avoid school closure. Theoretically, increasing competition is expected to improve student and school outcomes for all students, including families do not actively choose (Goldhaber and Eide 2003), or, a rising tide lifts all boats (Hoxby 2003).

Others, however, argue that charter schools game the system by selecting motivated, high-performing students (Bergman and McFarlin, 2020) and focusing on superficial improvements, such as marketing, rather than improving actual school efficiency (Lubienski 2007, Loeb, Valant, and Kasman 2011, Harris 2020). The main effect of this superficial "competition" could be to divert funds from the traditional schools and make it more difficult for them to succeed (Ni 2009, Imberman 2011). This means that we might not observe improved student outcomes, as advocates argue and, even if we do, the strategic behavior might mean those apparent improvements are illusory.

Empirical research has examined parts of these theories, but not their net effects on the market as a whole. Studies of the competitive effects of charter schools on student outcomes in traditional public schools generally find small positive effects on student achievement, but these effects vary across different contexts, methods, and measures of competition (Hoxby 2003, Bettinger 2005, Bifulco and Ladd 2006, Sass 2006, Ni 2009, Zimmer and Buddin 2009, Linick 2014, Cordes 2018, Griffith 2019), and there are a few examples where competition actually reduced student outcomes (Imberman 2011, Han and Keefe 2020). The empirical results on the competitive effects of charter schools on TPSs vary across locations. Results from Arizona (Hoxby 2003), Florida (Sass 2006), and Texas (Booker et al. 2008) suggest that there are positive competitive effects of charters on TPSs, and results from California (Zimmer and Buddin 2009) and North Carolina (Bifulco and Ladd 2006) suggest no effects. However, results from Michigan are mixed, with positive effects (Hoxby 2003), zero effects (Bettinger 2005), and negative effects (Ni 2009). Overall, the existing literature on charter schools and competition suggests likely small positive effects of charter competition on school districts. Also, note that most of the studies cover periods in which charter schools accounted for only 2 or 3 percent of enrollment. It may be unrealistic to expect so few charter schools to exert an observable competitive effect.

The second key branch of literature is on participant effects, i.e., students who attend charter schools in comparison to nearby traditional public schools. In the last two decades, there has been a rapid expansion of the number of on the participant effects of charter schools using different research designs, such as matching (Furgeson et al. 2012, CREDO 2013), fixed effects (Brewer et al. 2003, Bifulco and Ladd 2006, Sass 2006, Booker et al. 2007, Hanushek et al. 2007), and lottery-based approaches (Hoxby and Rockoff 2004, Abdulkadiroğlu et al. 2011, Curto and Fryer Jr 2014). The studies have found a mix of null, small positive, and small negative average effects across geographic locations. The one national study of charter schools suggests that the average effect is small and positive (CREDO 2013).

Another reason for these inconsistencies in results is that charter school participants effects increase as the schools themselves mature and their educators gain more experience (Bifulco and Ladd 2006, Sass 2006, Booker et al. 2007, Hanushek et al. 2007, Ni and Rorrer 2012, Zimmer et al. 2012). This reinforces that the effects of today's charter schools are likely positive, if probably small in magnitude.

While understanding competitive effects and participant effects is important, these may miss the overall effects of charter schools on the market as a whole. The list largely excludes one key potential mechanism: the closure and takeover process. Also, the various mechanisms may be interrelated. For example, participant effects are likely to be larger in systems where low-performing traditional public schools close. Also, the competitive effects might be larger in places where the participant effects are larger, i.e., charter schools might induce more improvement when they are of higher quality.

Charter schools might also have more indirect and long-term effects that are not captured in the design of studies that focus on specific mechanisms. For example, charter entry might induce changes in the teacher labor market induced by charter entry that might affect all schools (Bruhn, Imberman, and Winters 2020, Harris and Penn 2020). Also, if charter schools induce private or traditional public schools to close, this might have unintended effects on neighborhood quality of life. All of these effects might be larger in the long-term, as they have time to develop.

But only a handful of prior studies have tried to estimate the net long-term effects of charter schools and those few have focused only on individual school districts and only one, to our knowledge, has examined these effects over a long period of time. Harris and Larsen (2016, 2019) study the New Orleans charter-based school reforms and find positive effects on student test scores, high school graduation, and college outcomes up to a decade after the reforms started. Other research considers the various mechanisms of these effects (Harris 2020).

We extend this literature from a handful of school districts to the nation as a whole, studying the short-term and long-term effects of increased district-level charter enrollment share on student outcomes using the two-decade data from the National Longitudinal School Database (NLSD), which includes nearly all districts in the U.S. from school years 1995 to 2016. Given that the New Orleans case is so unusual, in its very low baseline outcomes, the extent of reform, and the size of effects—this national panel provides an important test of the external validity of New Orleans-style reform, a reform model that dozens of cities are following.

The main threat to identification is that charter school location is not exogenous. While there is evidence about where charter schools tend to locate based on measurable factors (Bettinger 2005, Glomm, Harris, and Lo 2005, Bifulco and Buerger 2015), there may be unobserved factors that also affect both location and student outcomes. To overcome endogenous charter location, we develop two general estimation strategies. First, we use the Difference-in-Differences (DD) combined with matching methods to compare the charter effects on districts with high charter market share (ever above a threshold, e.g. 10 percent) with a matched comparison group of districts.

The above strategy relies on observable district factors to address the selection bias problem. To address unobservable factors, we carry out versions of the DD that limit the comparison group to districts in states where state laws do not allow charter schools. In addition, we compare districts in early-charter-adopting states (treatment group) to those in late-charter-adopting (control group), under the assumption that unobserved factors should be similar in these groups and that the exact timing of state policy change is effectively random.

We find that charter market share (ever above 10 percent) increases our measure of the high school graduate rate by 3-4 percentage points and improve test scores by 0.08-0.16 standard deviations (more so for Math than English Language Arts). This general finding of improved student outcomes emerges consistently across all the various identification strategies.

One limitation of even the more advanced DD versions is that the threshold for charter market share is somewhat arbitrary. To address this, we vary the thresholds from 1-30 percent charter market share and find that the effects are most pronounced in the 5-15 percent range. This suggests there may be an optimal charter market share range. As a further step to addressing the arbitrary threshold problem, we also use a Dose-Response model with district fixed effects to estimate the effects of increasing dosage (charter enrollment share). While this method assumes that the effects are linear in the share, the fact we find similar results with this alternative method reinforces the general finding that charter school entry increases student outcomes.

Finally, we examine effect heterogeneity. Prior research finds that charter schools have more positive effects in urban areas (Epple, Romano, and Zimmer 2016), a finding that we confirm. Additionally, we find that the market effects are concentrated in middle schools and high schools, perhaps because families of older students seem willing to send their children further away (Harris and Larsen 2016), thus creating more competition, and allowing better matching of student needs to school offerings, at these higher grade levels.

Section 2 summarizes the literature in more detail. Sections 3 and 4 discuss the data and DD and DR methods. We discuss our results in section 5. Section 6 discusses the mechanism and Section 7 concludes.

2. Data

2.1. Data Description

This paper uses data from the National Longitudinal School Database (NLSD), which contains a near census of all traditional public schools, charter schools, and private schools in the U.S. from 1991 to the most recent academic year.[1] The NLSD collects and merges school and district level data from Common Core of Data (CCD), Stanford Education Data Archive (SEDA), Census Small Area Income and Poverty Estimates (SAIPE), and other sources. The NLSD contains information on enrollment, school type, student test score, district's finance, estimates of school-age population and poverty rate, and relevant state and local policies.

[1] All the school years mentioned in this paper are spring school years unless specifically stated otherwise.

The dependent variables are the Averaged Freshman Graduation Rate (AFGR) and standardized Math and English Language Arts (ELA) test scores. The AFGR provides an estimate of the percentage of high school students who graduate on time. The AFGR uses aggregate student enrollment data to estimate the size of an incoming freshman class and aggregate counts of the number of diplomas awarded four years later. For example, the AFGR for a school year in 2006 is the total number of diploma recipients in 2006 is divided by the average enrollment of the 8th-grade class in 2002, the 9th-grade class in 2003, and the 10th-grade class in 2004. Standardized test scores are available in 3rd through 8th grade in Math and ELA over the 2009-2016 school years by the Stanford Education Data Archive (SEDA), and we normalize the test scores to have means of 0 and standard deviations of unity within grade, year, and subject.

We divided our data set into the AFGR sample and test score sample based the years and schools that have these data available. The AFGR sample is available for schools covering grades 9-12 from 1995 to 2010, and the test score sample is available schools covering any grade 3-8 from 2009 to 2016. Importantly, these data include charter schools, which constitute the policy treatment in this study. Specifically, we use the charter enrollment share, or the percentage of public-school students enrolled in charter schools. These measures are created separately by grade level under theory that TPS compete with charters when there is a threat their students will leave for another school.

In some specifications, we include the following (time-varying) control variables at the district level: total enrollment (log form); the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; the total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population.[2]

2.2 Descriptive Statistics

[2] The district population and poverty estimates are available 1996, 1998, 2000 and after. For the missing years of district population and poverty estimates data, we make them equal to the values of next year.

Table 2 presents the summary statistics for the outcome and control variables of our samples.[3] Compared with TPSs, charter schools nationwide tend to enroll a larger proportion of African American students and Hispanic students. Charter schools also more likely to be located in urban districts and where achievement is relatively low. However, these observable differences are minimized after matching. Specifically, the observable differences are reduced by about 80% after matching.

We are primarily interested in the effect of charter schools on long-term market-level student outcomes. The first law allowing the establishment of public charter schools was passed in Minnesota in 1991. As of fall 2020, charter school legislation had been passed in 45 states and the District of Columbia. The states in which public charter school legislation had not been passed by that time were Montana, Nebraska, North Dakota, South Dakota, and Vermont. Table 1 presents the years of charter school legislation as of 2020.

Charter schools have seen dramatic growth over the last three decades. Figure 1 presents the trends in charter school share and charter enrollment share from spring 1991 to spring 2018. During these years, the proportion of charter schools to all public schools increased from 0 to 7.3 percent, and the percentage of public charter school enrollment increased from 0 to 6.2 percent.

Table A2 in Appendix presents the Top 20 districts with the largest charter enrollment share. New Orleans tops this list, which is partly why it has been the subject of prior research (Harris & Larsen, 2018). Other districts, especially New York City, have large numbers of charter schools, but still small shares. Finally, there are some very small districts in this group that have only one or two charter schools, where the competition may still be intense. This list of schools provides a sense of the types of districts in the treatment group, which we elaborate on later.

The question of interest in this study is whether charter school entry in these districts has improved or reduced student outcomes years after they have opened, incorporating the various direct and indirect effects that charter schools may have.

3. Identification Strategy

3.1 Difference-in-Differences

[3] Table A1 in the Appendix presents the unweighted summary statistics for the outcome and control variables of our samples.

We first employ a DD strategy to evaluate the effect of charter enrollment share on student achievement. The treatment group includes those districts whose charter market share is above the threshold τ at any time during our panel period. In our baseline model, we use $\tau = 10$ percent of charter enrollment share. Thus, the districts are treated if their charter shares are ever at or above 10 percent. The first comparison group includes districts (in all states) without any charter enrollments. Districts with charter shares that are above zero but below the threshold are omitted from the analysis to create a clear treatment contrast.

We use "ever above" the threshold because traditional public schools and other local education-related organizations (e.g., university schools of education) are likely to be aware, well in advance, that their areas are going to become charter-heavy and they may therefore start reacting before districts reach the τ threshold. Since τ is inherently arbitrary, we estimate the models assuming a wide variety of threshold levels.

We estimate the effects using equations (1) and (2):

$$AFGR_{it} = \alpha + \beta(T_i \cdot Post_{it}) + X_{it}\gamma + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

$$Test_{ijt} = \alpha + \beta(T_i \cdot Post_{it}) + X_{ijt}\gamma + \mu_i + \lambda_t + \omega_j + \varepsilon_{ijt} \quad (2)$$

In equation (1), the dependent variable is the average freshmen graduation rate ($AFGR_{it}$) for district i in year t. T_i is an indicator variable equal to unity if the district i charter enrollment share ever above the threshold and equal to 0 if the district i has no charter school during the sample period; $Post_{it}$ is an indicator set to unity in the first period district i had at least one charter school and thereafter. (As noted above, traditional public schools are likely to anticipate charter entry and take preemptive action before districts reach the threshold, they are not likely to start responding before any charter schools open.) Finally, μ_i is district fixed effects; λ_t is year fixed effects; X_{it} is a vector of district characteristics; and ε_{it} is the error term. The coefficient of interest is β, which measures the charter effects on AFGR.

In equation (2), math and English Language Arts (ELA) test scores are the dependent variable, where $Test_{ijt}$ is the test score in district i grade j during the year t, ω_j is vectors of grade fixed effects, and other terms are defined same as Equation (1). In other words, this equation is the same as equation (1) except for the dependent variables and the fact that the outcome is grade-specific. In both models, standard errors are clustered at the district level and the estimates are weighted by grade level enrollment.

3.2 Matching and Parallel Trends

In some specifications, we combine our DD design with matching methods to minimize the differences between treated districts and comparison districts (i.e., to achieve common support). Specifically, we use pre-treatment district-level covariates as matching variables to match the nearest neighbor of treated units as control units. The successfully matched treated districts and comparison districts would be a subset of the original DD sample, or Propensity Score Matching (DD-PSM) sample. Each unit in the original DD sample has a propensity score that indicates its probability to be treated (aside from state laws), and we apply the inverse probability weighting technique to our DD design, and get the Propensity Score Weighting (DD-PSW) analysis. Figure 2 presents the density plots of covariates for DD, DD-PSW, and DD-PSM, respectively. The treated districts and comparison districts show different probability of being treated with charter schools in the DD. However, the difference is minimized if using PSW or PSM, as Figure 2 shows.[4]

The above models essentially average the pre-treatment period together and average the post-treatment outcomes to arrive at the DD estimates. However, it is plausible that the effects on district outcomes will arise gradually over time (Harris and Larsen 2019). We can relax this assumption using event study analyses that trace out the effects year by year. In Equation (3), $d_{i,r}$ is a dummy of the *r* years of leads or lags since district *i* initiated first charter school[5], and μ_i *and* λ_t are the district and year fixed effects The coefficients β_r are measures of cohort-specific effects compared with the control group. Similarly, Equation (4) is for Math and ELA.

$$AFGR_{it} = \alpha + \sum_{r=-m}^{q} \beta_r \left(T_i \cdot d_{i,r}\right) + X_{it}\gamma + \mu_i + \lambda_t + \varepsilon_{it} \qquad (3)$$

$$Test_{ijt} = \alpha + \sum_{r=-m}^{q} \beta_r \left(T_i \cdot d_{i,r}\right) + X_{it}\gamma + \mu_i + \lambda_t + \omega_j + \varepsilon_{it} \qquad (4)$$

In addition to showing the dynamic effects of the treatment, the event study analyses provide tests of the assumption that student achievement in treated districts would have had a similar trend as comparison districts in the absence of charter reform. Figure 3 provides initial illustrates trends in AFGR and Math, and ELA throughout the sample period for treated districts and comparison districts. A visual inspection of the raw trends in the outcome variables suggests that

[4] DD and DD-PSM are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA; DD-PSW is weighted by weight of DD times the inverse probability of propensity score.
[5] Table A3 in Appendix presents the number of districts by the year first charter initiated.

the trend of the treated group closely parallels that of the comparison group in earlier years of our sample, and the gap between them narrows down as charter enrollment share grows. The PSW and PSM trends in outcomes show a similar level between the treated group and the control group, which suggested the control groups are good candidates for comparison. These descriptive patterns are indicative of a treatment effect, but far from sufficient to establish a causal interpretation.

3.3 Dose-Response Model

The advantage of the DD approach is that it allows for a comparison of two distinct groups of districts. A disadvantage of the DD is that we are forced to set arbitrary thresholds for continuous treatment variables and make arbitrary decisions about when the treatment begins. To address these issues, we also employ a Dose-Response (DR) model using only those districts that have at least one charter school at some point during the panel. In this case, the charter enrollment share is used as a continuous measure of charter market share. We estimate the DR effects based on the following equations.

$$AFGR_{it} = \alpha + \beta Charter_{it} + X_{it}\gamma + \mu_i + \lambda_t + \varepsilon_{it} \qquad (5)$$

$$Test_{ijt} = \alpha + \beta Charter_{ijt} + X_{ijt}\gamma + \mu_i + \lambda_t + \omega_j + \varepsilon_{ijt} \qquad (6)$$

where the $Charter_{ist}$ is the continuous measure of charter enrollment share of district *i* year *t*. In some cases, we estimate the DR model using the outcome from the single year associated with the charter market share. However, because it takes four years of data to estimate a single AFGR, we also use the average charter enrollment share in the last four years (the four high school years) to estimate. In this case, we allow the charter market share to include graduation in all of the four years involved in the graduation calculation. For test scores, we use as a robustness check the prior year's charter enrollment share (same cohort) to estimate. For example, we use the charter enrollment share of grade 7 in 2010 to estimate the test score of grade 8 in 2011, as this may better reflect the timing of the TPS responses.

3.4 Threats to Identification

The main general threat to identification in this study is that charter school location may be endogenous. Specifically, we require: (1) that charter location was conditionally exogenous (i.e., that treatment was not assigned based on unobserved factors that are correlated with student outcomes); and (2) and that there were no other idiosyncratic shocks that happened to coincide with treatment.[6]

It is worth considering specific scenarios under which either of these assumptions might be violated. First, especially given the investment required to open a charter school, it may be that charter schools are more likely to locate in districts where decreases in TPS student outcomes are expected in the future (downward bias in effect estimates). Based on some prior research, this seems plausible. Charter schools are more likely to locate in districts with low student outcomes (Glomm, Harris, & Lo, 2005), signaling that we might expect charter schools to also locate where *expected* future performance in TPS is lower.

Second, charter schools might open where districts have idiosyncratic negative shocks (similar to an Ashenfelter dip), in which case future outcomes regress toward the mean (upwards bias). We do not see the second scenario as very likely because it takes several years to create an organization that can put together a charter application, submit the application and have it approved, hire personnel and purchase necessary capital, and recruit students. The timeframe from idea to opening might have been especially long in the early years of the charter reform effort when most charter organizations were first forming. In later years, charter management organizations (CMOs) and education management organizations (EMOs) could proceed through these steps more readily. But, given the unclear direction of the third scenario, we cannot rule out either upward or downward bias in the estimates.

Third, local or state policy changes (including those unrelated to charter schools) might coincide with the timing of charter entry and disproportionately affect the outcomes of either the treated or untreated districts (bias direction unclear). For example, since school districts are often charter authorizers, it may be that a change in school board politics leads to a variety of policy changes at about the same time as the introduction of charter schools, affecting district outcomes independent of charter entry.

The DD and DR analyses described above address selection on observables, including factors that are known to be correlated with charter school location. To account for possibly

[6] Since we are interested here in long run effects, it is also important to mention that idiosyncratic shocks occurring after the start of treatment, and disproportionately affecting either one group, could also create bias. The longer the analysis goes into the future, the more likely this is to occur.

time-varying unobserved factors and endogenous timing, we estimate two variations of the DD. In one, we restrict the comparison group to districts located in states that do not have charter laws up to and including the year 2016 and whose districts always therefore have charter shares of zero.[7] This limits the possibility that unobserved factors affect charter location. In the simple DD, the concern is that untreated districts have no charter schools for some (unobserved) reason, but, with this restricted sample, those unobserved factors are likely to play a smaller role because charter location is legally precluded. It is still possible that districts in non-charter-law states are different in unobserved ways from districts in charter law states, but this seems somewhat unlikely given the considerable within-state heterogeneity of school districts.

Using a similar logic, we also estimate versions of equations (1) and (2) that compare districts in early and late adopting states.[8] If there is endogeneity with regard to whether charter laws pass (see above), it may still be reasonable to assume that the timing of the law's passage is exogenous. The main disadvantage of this method is that the number of later-adopting states is small (Washington, Kentucky, West Virginia).

The assumptions are similar between the DD and the DR, but violations of the assumptions would affect the results in different ways between the two. In the DD, identification comes from comparing treated and untreated districts (before and after the assumed starting point) while, in the DR, identification is from within-district variation in the charter shares over time. Given that the source of identification differs, the effects of violation assumptions are also likely to differ.[9]

In short, if we draw similar conclusions across the various versions of the DD and DR, then this reinforces the causal interpretation of the estimates.

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7 There states are Washington, Kentucky, West Virginia, Montana, Nebraska, North Dakota, South Dakota, and Vermont. We chose the year 2016 because this is the last year of our data. We did not restrict to states that never have charter laws because this would have excluded states whose districts appear to be better comparisons (Washington, Kentucky, West Virginia).

8 The early adopter states (1991-2003) are: Minnesota, California, Colorado, Massachusetts, Michigan, New Mexico, Wisconsin, Arizona, Georgia, Hawaii, Kansas, Alaska, Arkansas, Delaware, Louisiana, New Jersey, Rhode Island, Texas, Wyoming, Connecticut, District of Columbia, Florida, Idaho, Illinois, New Hampshire, North Carolina, South Carolina, Nevada, Ohio, Pennsylvania, Missouri, New York, Utah, Virginia, Oklahoma, Oregon, Indiana, Iowa, Tennessee, Maryland. The late adopter states (2016-2019) are: Washington, Kentucky, and West Virginia. The early versus late adopter analysis omits: (a) states that passed their first charter laws in the middle years (2010-2015) (No states passed laws between 2004-2009); and (b) never adopters as of 2020 (Montana, Nebraska, North Dakota, South Dakota, Vermont).

9 Another difference between the DD and DR is that the latter (or at least our version of it) assumes an immediate effect from each incremental increase in charter share. The DR therefore assumes: (a) no preemptive action by traditional public schools or other education-related organizations; (b) no effects that arise far in the future (e.g., because of the system-level responses discussed earlier); and (c) entry timing that coincides with unrelated changed in student outcomes.

4. Results

4.1 Difference-in-Differences Results

Table 3 presents the DD estimates of the effect of charter treatment (i.e., having a charter enrollment share ever above 10 percent) on AFGR, Math, and ELA test scores. Columns (1) and (2) are estimates of the DD model with districts from all states; Columns (3) and (4) are estimates of the DD-PSW model; Columns (5) and (6) are estimates of the DD-PSM model. We find significant positive effects on AFGR, Math and ELA scores. The magnitudes of the coefficients imply that having a large share of charter enrollment (ever above 10 percent) increases the AFGR by 3-4 percentage points and improves Math and ELA scores by 0.08-0.16 standard deviations.[10]

The results are similar when using charter school share (Appendix Table A4) instead of enrollment share, except that the magnitude of estimates is smaller.[11] It is not obvious which should be preferred. The charter share measure may better reflect the number of traditional public schools that are under pressure (more small charter schools might be spread across a district, competing with more schools), but, to the degree that school size is similar across places, the enrollment share (i.e., the number of students who have left) may be a better indicator of effective competitive pressure.

The event study results in Figure 4 corroborate Table 3 and shows that the effects begin to emerge in the first period after the first charter school enters the market) and then generally increases again in the second period, followed by a general plateau. This is consistent with prior evidence on the trajectory of charter school improvement (Harris & Liu, 2018).

As a robustness check, we restrict the control sample to districts in states without charter schools before 2016 (Washington, Kentucky, West Virginia, Montana, Nebraska, North Dakota, South Dakota, and Vermont) to minimize potential endogeneity of charter reform in our main results, and Table 4 presents these results. For the AFGR and math test scores, the results are very similar to Table 3. For ELA test scores, the results are less often significant. (The sample sizes are smaller, which increases the standard errors, but the main explanation is the drop in the coefficient magnitudes.)

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[10] Note that the sample size drops dramatically in the DD-PSM because we match each treatment district to only one control district.

[11] Having a large share of charter schools (ever above 10 percent) increases the AFGR by 1-2 percentage points and improves Math and ELA scores by 0.05-0.09 standard deviations.

In another robustness check, we restrict the treated sample to early adopter states and the comparison group to late adopter states to minimize potential endogeneity of statewide charter reform in our main results. As shown in Table 5, the results of AFGR and math test scores are, again, very similar to Table 3, but the results of ELA test scores are often less significant.

We also estimated the model allowing a wide range of thresholds, from 1-20 percent charter share, to address the arbitrary nature of the treatment assignment. Figure 5 plots the point estimates along with the associated thresholds. When raising the threshold, note that a larger number of districts have $0 < Charter < \tau$, such that they are dropped entirely from the estimation, while at τ =one percent, almost all districts with at least one percent charter enrollment share are in the treatment group.

The expected pattern of results is unclear as this depends on: the source of the effects (participant versus competitive effects); whether the marginal charter school is as effective as the prior ones; the exact timing of charter entry; and whether there is effect heterogeneity that correlates with the long-run district charter share.[12] As Figure 5 indicates, there is a nearly uniform rise in effect estimates on AFGR and test scores as the threshold rises, with the most noticeable effects emerging at 5 percent charter market share and rising up to about 15 percent market share. It could be that, beyond a certain point, either the marginal charter entrant is less efficient than earlier entrants or that competition reduces the performance of TPS. This pattern is quite consistent across all the outcomes and DD strategies.

4.2. Dose-Response Results

We also use the charter enrollment share as a continuous variable with district fixed effects to estimates the effects of charter enrollment share on student achievement. The first three columns of Table 6 use the contemporaneous charter market share and implicitly assume an immediate effect of charter entry on student outcomes. With the AFGR, the latter three columns average the last four years of charter market share (because it takes four years of data to calculate a single AFGR). With test scores, the last three columns lag the charter market share by one year, in case there is a delayed effect.

The results indicate a significant effect of charter enrollment share on AFGR. The results are similar between the contemporaneous charter market share and four-year averages. A 10

[12] Also, note that we mark the start of treatment when the first charter school enters. In larger districts, more enter later and therefore probably have later effects that are not captured in these estimates.

percent increase in average charter enrollment share increases the AFGR by 1-2 percentage points.

Also, as in the DD, we generally positive effects on student test scores. Ten of the 12 estimates are positive and five of those positive estimates are statistically significant. (The two negative estimate is also very small in absolute value and imprecisely estimated.) The estimates are, again, somewhat more positive in Math than ELA.

The choice of controls seems to matter more than the choice of contemporaneous versus lagged charter market shares. In columns (3) and (6), the addition of state-by-year fixed effects increase the estimates for the AFGR and decrease the estimates for the test scores. This could reflect time-varying, state-specific changes that affect all schools, such as the implementation of *No Child Left Behind* (Dee and Jacob 2011, Harris et al. 2020).

To compare these DR with the DD results, note that the average eventual maximum charter share using the 10 percent threshold is 18.5 percent.[13] We can therefore take the DR coefficient, which captures the effect of increasing the market share by one percentage point, and multiply by 18.5 percent the average eventual max share of the DD, which yields 0.03. This is almost identical to the DD point estimates reported in Tables 3 and 4. Given that these various methods rest on different assumption, the robustness of the results reinforces a causal interpretation.

5. Effect Heterogeneity

5.1 Effect Heterogeneity: Metropolitan Areas vs. Non-metropolitan Areas

We evaluate the heterogeneous effects of charter schools by district locations, and Table 7 and Table 8 present the charter effects in Metropolitan Areas (MA) and non-MA using DD and DR, respectively. The results show that the charter effects mostly come from the MA and little effects are detected in non-MA. We find consistently significant positive effects on AFGR, Math scores, and ELA scores in MA. The magnitudes of the coefficients of DD models imply that having a large share of charter schools (ever above 10 percent) increases the AFGR in MA by 3-4 percentage points and improves Math and ELA scores in MA by 0.12-0.20 standard deviations. For DR models, a 10% increase in charter enrollment share increases the AFGR by 2 percentage points and improves Math scores by 0.03-0.04 standard deviations. MA has a higher population

[13] Table A5 in Appendix list the average charter share across different models.

density and a larger number of schools and the education market are more competitive. Charter schools in MA have more competitive effects, which could be a reason for the varying findings of previous literature based on different locations.

5.2 Effect Heterogeneity: Middle schools VS Elementary schools

We also evaluate the heterogeneous effects by school levels for test scores and report the results in Table 9 (DD models) and Table 10 (DR models). The results show significant and positive effects on both Math and ELA test scores for middle school students (grades 6-8), whereas sporadic significant effects on Math and ELA test scores for elementary school students (grades 3-5). Specifically, districts with a large share of charter schools (ever above 10 percent) improves Math and ELA scores of middle schools by 0.12-0.26 standard deviations. For DR models, a 10% increase in charter enrollment share improves Math and ELA scores by 0.02-0.04 standard deviations. It seems that charter effects are more pronounced for students in a higher grade or their later school years as the effects need to be accumulated for some years to be detected.

6. Mechanism: Effects of charter share on school closure

To further explore the potential mechanism of charter on student achievement, we evaluate the effects of charter share on school closure during the sample period (1995-2016). Since our measure of student achievement includes TPS and charter schools, we use the share of these schools in the district that close as the outcome. Table 11 presents the results.[14]

We find significant positive effects of charter share on the share of school closure. The magnitudes of the coefficients imply that having a large share of charter enrollment (ever above 10 percent) increases the share of school closure by 0.4-0.8 percentage points. A 10% increase in charter enrollment share increases the share of school closure by 0.2-0.3 percentage points. These effects are large in magnitude given that the pre-treatment mean of the closure share is about one percent. Figure A1 in appendix plots the raw trends in the share of school closure of treated districts and control districts. The closure share remains at one percent for comparison districts. However, the share of school closure in treated districts increased as the charter

[14] We do a similar analysis that focus on the share of TPS closure (out of total school of TPS and charter), and the results are presented in Appendix Table A6.

enrollment share increases, and one peak of the share hit 2.7 percent, which is nearly triple compared with the share in earlier years of the sample.

The large effects might be explained in two ways. In addition to the predicted competitive effects that induce closures in TPS, some charters are takeovers of closed TPS (Harris & Martinez-Pabon, 2020), so the relationship between charter share and closure share is somewhat mechanical. To differentiate these two effects, we use event study of DD and lag two-year charter share of DR to show that the second effects are exists and should be the mechanism to support our main results. Figure A2 in appendix presents the event study graphs, which show that the positive effects are detected not only in the same year of charter entry but persist in years after charter entry. In our DR analysis, we also use lag two-year charter share for regression, there are still significant positive effects on the share of school closure, but the coefficients are generally lower than using current year charter share. This evidence suggests that a large share of charter entry occurs simultaneously with TPS closure, which is less likely to be a result of competition. It is possible that TPS close as a competitive reaction to the prospect of charter entry, but this does not seem likely given the reluctance of school districts to close their schools and the long process involved in making and implementing those decisions.

We also consider the effects of charter entry on private school market share. We report estimated effects of charter share on the share of private schools in Table 12, focusing on the 4,590 districts that have at least one private school at baseline, and some small district without any private schools are not included in analysis. The sample period is 1996-2016 and note that the private school share data are only available biannually.

We find negative effects of charter share on the share of private school. In the DD model, the magnitudes of the coefficients imply that having a large share of charter enrollment (ever above 10 percent) decreases the share of private school by 1-2 percentage points. The event study results are presented in Figure A4 in the Appendix).

The coefficients from DR models are also almost all negative but not significant. This pattern also aligns with Figure A3 in Appendix, which shows a large decline of the share of private school in the earlier years of the sample (charter share is relatively low) but small decline of the share of private school in the later years of the sample (charter share is relatively high), which also suggest that the share of private school is less responsive of charter share than the entry of charter school.

In addition to our interest in the competitive effects of charter entry on private schools, it is worth noting that negative effect on private school market share may mean that some private school students end up in public schools and upwardly bias the estimated effects on district-level AFGR and test scores (which only capture TPS and charter schools). In future analyses, we will simulate the potential size of these effects under varying assumptions about private school achievement and the share of those students who end up in public and charter schools.

7. Conclusion

Using data from NLSD, we evaluate the effects of charter enrollment share on student achievement. Using the DD strategy combined matching methods, we find that compared with districts without charter schools, districts with high charter market share (ever above 10%) increase the high school graduation rate by 3-4 percentage points and improve test scores by 0.06-0.15 standard deviations. Using a dose-response model with district fixed effects, we find that a 10 percent increase in charter enrollment share increase high school graduate rate by 1-2 percentage points and increase middle school student test score by 0.01-0.04 standard deviations. These impacts are heavily concentrated in metropolitan areas, and the effects on the test score are more pronounced for students with a higher grade.

Prior research suggests that the district-level student outcome improvement could be partially explained by competitive and participant effects, as well as a less well recognized mechanism: the closure and takeover of low-performing schools (Bross, Harris, & Liu, 2018). While it is too early for us to draw conclusions about the mechanisms from this new analysis, this is something we will continue to explore as our work continues.

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Table 1 Year charter law passed by state

Year	State
1991	Minnesota
1992	California
1993	Colorado, Massachusetts, Michigan, New Mexico, Wisconsin
1994	Arizona, Georgia, Hawaii, Kansas
1995	Alaska, Arkansas, Delaware, Louisiana, New Jersey, Rhode Island, Texas, Wyoming
1996	Connecticut, District of Columbia, Florida, Idaho, Illinois, New Hampshire, North Carolina, South Carolina
1997	Nevada, Ohio, Pennsylvania
1998	Missouri, New York, Utah, Virginia
1999	Oklahoma, Oregon
2001	Indiana
2002	Iowa, Tennessee
2003	Maryland
2010	Mississippi
2011	Maine
2015	Alabama
2016	Washington
2017	Kentucky
2019	West Virginia
NA	Montana, Nebraska, North Dakota, South Dakota, Vermont

Data source: National Longitudinal School Database.

Table 2 Summary Statistics

Sample	AFGR (1995-2010)						Math & ELA (2009-2016)					
	ALL	DD & DD-PSW		DD-PSM		Dose response	ALL	DD & DD-PSW		DD-PSM		Dose response
		Treated	Control	Treated	Control			Treated	Control	Treated	Control	
AFGR	0.75	0.63	0.78	0.63	0.68	0.67	NA	NA	NA	NA	NA	NA
Math	NA	NA	NA	NA	NA	NA	0.00	-0.51	0.13	-0.51	-0.17	-0.40
ELA	NA	NA	NA	NA	NA	NA	0.00	-0.46	0.12	-0.46	-0.25	-0.37
White	65%	30%	71%	30%	41%	43%	56%	30%	63%	30%	40%	36%
Black	16%	23%	14%	23%	32%	22%	16%	23%	14%	23%	19%	23%
Hispanic	14%	38%	10%	38%	19%	26%	22%	42%	18%	42%	33%	34%
FRL	30%	49%	27%	49%	41%	37%	51%	65%	48%	65%	56%	61%
Special education	13%	12%	13%	12%	12%	12%	13%	12%	13%	12%	12%	12%
Ages 5–17 population	16%	24%	15%	24%	21%	19%	19%	23%	18%	23%	20%	22%
Ages 5–17 in poverty	19%	18%	19%	18%	19%	18%	17%	16%	18%	16%	17%	17%
Urban	27%	73%	22%	73%	70%	46%	27%	45%	22%	45%	47%	42%
Suburb	42%	21%	41%	21%	16%	48%	45%	46%	44%	46%	41%	51%
Town	11%	3%	13%	3%	5%	3%	12%	6%	15%	6%	8%	5%
Rural	20%	3%	24%	3%	9%	4%	17%	4%	21%	4%	10%	4%
Revenue per student	8,968	8,901	9,057	8,901	8,976	8,678	12,125	11,435	12,377	11,435	11,644	11,342
Expenditure per student	9,130	9,174	9,216	9,174	9,333	8,853	12,141	11,694	12,358	11,694	11,658	11,465
Teacher salary	79,696	91,456	78,528	91,456	86,675	83,487	99,049	101,985	98,641	101,985	102,365	100,322
Student teacher ratio	17	19	16	19	18	18	16	18	16	18	18	18
No. magnet school	5	52	1	52	7	17	6	35	1	35	6	19
No. schools	62	312	29	312	144	168	62	290	25	290	79	178
Enrollment	46,671	264,599	18,964	264,599	74,170	136,672	42,839	198,186	16,757	198,186	53,432	124,192
Observation	144,266	2,193	137,767	2,193	2,184	6,499	410,244	10,156	388,099	10,156	10,968	22,145
N (district)	9,278	142	8,858	142	142	420	10,129	298	9,831	298	298	611

Notes: This table presents weighted means of outcome variables (AFGR, Math, and ELA) and control variables. AFGR sample is weighted by high school enrollment, and Math & ELA sample is weighted by grade level enrollment. Treated group refers to the sample of districts that charter enrollment share ever above 10 percent during the sample period. Control group refers to the sample of districts without charter schools in all states for DD & DD-PSW, and it refers to the sample of matched districts (nearest neighbor) for DD-PSM. Dose response refers to all districts with any charter share in the sample period. Data source: National Longitudinal School Database.

Table 3 Effects of charter enrollment share on student achievement

	DD		DD-PSW		DD-PSM	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: AFGR						
Treated*post	0.0361***	0.0380***	0.0336***	0.0274***	0.0378***	0.0331***
	[0.0088]	[0.0109]	[0.0115]	[0.0093]	[0.0099]	[0.0102]
Pre-Treated Mean	0.64		0.70		0.64	
R-squared	0.8050	0.8086	0.8176	0.8249	0.8903	0.8984
Observations	139,960	139,960	139,960	139,960	4,390	4,390
N (district)	9,000	9,000	9,000	9,000	284	284
Panel B: Math						
Treated*post	0.1508***	0.1539***	0.1563***	0.1494***	0.1324***	0.1552***
	[0.0396]	[0.0430]	[0.0538]	[0.0512]	[0.0481]	[0.0511]
Pre-Treated Mean	-0.40		-0.17		-0.40	
R-squared	0.8459	0.8468	0.8626	0.8650	0.8690	0.8729
Observations	398,255	398,255	398,255	398,255	21,103	21,103
N (district)	10,129	10,129	10,129	10,129	596	596
Panel C: ELA						
Treated*post	0.1123***	0.1178***	0.0738	0.0752*	0.0670	0.0968**
	[0.0350]	[0.0384]	[0.0467]	[0.0432]	[0.0426]	[0.0469]
Pre-Treated Mean	-0.42		-0.21		-0.42	
R-squared	0.8819	0.883	0.8839	0.8859	0.9066	0.9102
Observations	398,255	398,255	398,255	398,255	21,103	21,103
N (district)	10,129	10,129	10,129	10,129	596	596
District, (grade) & year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	No	Yes	No	Yes

Notes: The table shows DD estimates of the effects of charter enrollment share ever above 10% on student achievement. Treated group includes districts with charter enrollment share ever above 10%, and control group includes districts without charter schools in all states; post in an indicator of period after districts started first charter school. The first two columns present the results for DD estimates; Columns (3) and (4) are estimates for DD-PSW; Columns (5) and (6) are estimates for DD-PSM. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. For DD and DD-PSM, regressions are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA; For DD-PSW, regressions are weighted by weight of DD times the inverse probability of propensity score.

Table 4 Alternative control group: districts in states without charter schools before 2016

	DD		DD-PSW		DD-PSM	
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: AFGR					
Treated*post	0.0436***	0.0408***	0.0395***	0.0350***	0.0373***	0.0323***
	[0.0091]	[0.0105]	[0.0098]	[0.0102]	[0.0101]	[0.0106]
Pre-Treated Mean	0.64		0.72		0.64	
R-squared	0.8226	0.8297	0.7673	0.7753	0.8581	0.8704
Observations	17,140	17,140	17,140	17,140	4,306	4,306
N (district)	1,123	1,123	1,123	1,123	284	284
	Panel B: Math					
Treated*post	0.1259**	0.1481***	0.1419***	0.1335***	0.1147*	0.1335**
	[0.0497]	[0.0466]	[0.0545]	[0.0475]	[0.0657]	[0.0574]
Pre-Treated Mean	-0.40		-0.19		-0.14	
R-squared	0.8232	0.8279	0.8184	0.8262	0.8022	0.8056
Observations	37,781	37,781	37,781	37,781	9,901	9,901
N (district)	1,097	1,097	1,097	1,097	288	288
	Panel C: ELA					
Treated*post	0.0695	0.0912**	0.0286	0.0629	0.0689	0.0755*
	[0.0434]	[0.0424]	[0.0462]	[0.0427]	[0.0508]	[0.0453]
Pre-Treated Mean	-0.42		-0.20		-0.08	
R-squared	0.8683	0.8712	0.8559	0.8594	0.8429	0.8452
Observations	37,781	37,781	37,781	37,781	9,901	9,901
N (district)	1,097	1,097	1,097	1,097	288	288
District, (grade) & year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	No	Yes	No	Yes

Notes: The table shows DD estimates of the effects of charter enrollment share ever above 10% on student achievement. Treated group includes districts with charter enrollment share ever above 10%, and control group includes districts without charter schools in states without charter law before 2016; post in an indicator of period after districts started first charter school. The first two columns present the results for DD estimates; Columns (3) and (4) are estimates for DD-PSW; Columns (5) and (6) are estimates for DD-PSM. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. For DD and DD-PSM, regressions are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA; For DD-PSW, regressions are weighted by weight of DD times the inverse probability of propensity score.

Table 5 Alternative identification: Early adopters VS Late adopters

	DD		DD-PSW		DD-PSM	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: AFGR						
Treated*post	0.0413***	0.0384***	0.0577***	0.0477***	0.0368***	0.0330***
	[0.0093]	[0.0106]	[0.0169]	[0.0111]	[0.0099]	[0.0101]
Pre-Treated Mean	0.64		0.71		0.64	
R-squared	0.8070	0.8161	0.8077	0.8284	0.8545	0.8659
Observations	8,574	8,574	8,574	8,574	4,233	4,233
N (district)	582	582	582	582	284	284
Panel B: Math						
Treated*post	0.1140**	0.1373***	0.1814***	0.1280**	0.1085**	0.1356***
	[0.0509]	[0.0482]	[0.0509]	[0.0534]	[0.0521]	[0.0495]
Pre-Treated Mean	-0.39		-0.75		-0.39	
R-squared	0.8265	0.8318	0.8342	0.8477	0.8371	0.8429
Observations	26,001	26,001	26,001	26,001	20,709	20,709
N (district)	732	732	732	732	594	594
Panel C: ELA						
Treated*post	0.0625	0.0898**	-0.0689	-0.0265	0.0625	0.0977**
	[0.0440]	[0.0437]	[0.1029]	[0.1001]	[0.0454]	[0.0446]
Pre-Treated Mean	-0.42		-0.58		-0.42	
R-squared	0.8776	0.8805	0.8826	0.8865	0.8879	0.8909
Observations	26,001	26,001	26,001	26,001	20,709	20,709
N (district)	732	732	732	732	594	594
District, (grade) & year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	No	Yes	No	Yes

Notes: The table shows DD estimates of the effects of charter enrollment share ever above 10% on student achievement. Treated group includes districts with charter enrollment share ever above 10% in early charter states (states with charter law during 1991-2009), and control group includes districts in later charter states (states with charter law during 2016-2020); post in an indicator of period after districts started first charter school. The first two columns present the results for DD estimates; Columns (3) and (4) are estimates for DD-PSW; Columns (5) and (6) are estimates for DD-PSM. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. For DD and DD-PSM, regressions are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA; For DD-PSW, regressions are weighted by weight of DD times the inverse probability of propensity score.

Table 6 Dose-response estimates of effects of charter enrollment share on student achievement

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: AFGR						
Charter share	Grade 9-12 share (current year)			Grade 9-12 share (Average last four years)		
Charter	0.1315*	0.1609***	0.1774***	0.1191	0.1275**	0.1738***
	[0.0735]	[0.0529]	[0.0452]	[0.0759]	[0.0605]	[0.0591]
R-squared	0.8514	0.8585	0.8994	0.8627	0.8701	0.9067
Observations	6,499	6,499	6,419	5,239	5,239	5,174
N (district)	420	420	415	420	420	415
Panel B: Math						
Charter share	Grade 3-8 share (current year)			Grade specific share (same cohort last year)		
Charter	0.4023***	0.3436***	0.0613	0.2811***	0.2240**	-0.0116
	[0.1416]	[0.1148]	[0.1146]	[0.1066]	[0.1124]	[0.1248]
R-squared	0.854	0.8581	0.8736	0.8767	0.8785	0.8905
Observations	22,145	22,145	22,145	13,808	13,808	13,807
N (district)	611	611	611	608	608	608
Panel C: ELA						
Charter share	Grade 3-8 share (current year)			Grade specific share (same cohort last year)		
Charter	0.2073	0.051	-0.0943	0.1533	0.0775	-0.117
	[0.1288]	[0.1058]	[0.1068]	[0.1021]	[0.1007]	[0.1077]
R-squared	0.9098	0.9123	0.9187	0.9221	0.9242	0.9297
Observations	22,145	22,145	22,145	13,808	13,808	13,807
N (district)	611	611	611	608	608	608
District, (grade) & year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	Yes	No	Yes	Yes
State by year FE	No	No	Yes	No	No	Yes

Notes: The table shows Dose-response estimates of effects of the continuous charter enrollment share on student achievement for districts with any charter enrollment during the sample period. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. Regressions are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA.

Table 7 Effect Heterogeneity: Metropolitan areas VS Non-metropolitan areas (DD)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		AFGR			Math			ELA	
	DD	DD-PSW	DD-PSM	DD	DD-PSW	DD-PSM	DD	DD-PSW	DD-PSM
Panel A Metropolitan areas									
Treated*Post	0.0412***	0.0425***	0.0358***	0.1705***	0.1977***	0.1576***	0.1366***	0.1269***	0.1275***
	[0.0113]	[0.0105]	[0.0110]	[0.0450]	[0.0637]	[0.0517]	[0.0400]	[0.0391]	[0.0461]
Pre-Treated Mean	0.63	0.72	0.63	-0.39	0.01	-0.39	-0.40	-0.02	-0.40
R-squared	0.8386	0.8627	0.9119	0.8731	0.8887	0.8781	0.9065	0.9056	0.9203
Observations	67,447	67,447	2,424	228,515	228,515	14,804	228,515	228,515	14,804
N(district)	4,354	4,354	158	5,847	5,847	432	5,847	5,847	432
Panel B Non-metropolitan areas									
Treated*Post	-0.0146	-0.007	-0.0143	0.0049	-0.0456	0.0692	-0.0452	-0.0455	-0.0207
	[0.0111]	[0.0090]	[0.0128]	[0.1190]	[0.0629]	[0.1249]	[0.0889]	[0.0727]	[0.0899]
Pre-Treated Mean	0.74	0.69	0.74	-0.45	-0.20	-0.45	-0.51	-0.36	-0.51
R-squared	0.6793	0.7469	0.6099	0.6760	0.7096	0.7287	0.7191	0.7430	0.7929
Observations	72,513	72,376	1,959	169,740	168,010	6,182	169,740	168,010	6,182
N(district)	4,646	4,646	126	4,282	4,282	164	4,282	4,282	164
District, (grade) & year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table shows DD estimates of heterogeneous effects of charter enrollment share on student achievement by (non-)metropolitan areas. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. For DD and DD-PSM, regressions are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA; For DD-PSW, regressions are weighted by weight of DD times the inverse probability of propensity score.

Table 8 Effect Heterogeneity: Metropolitan areas VS Non-metropolitan areas (DR)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	AFGR				Math				ELA			
Charter share	Grade 9-12 share (current year)		Grade 9-12 share (Average last four years)		Grade 3-8 share (current year)		Grade specific share (same cohort last year)		Grade 3-8 share (current year)		Grade specific share (same cohort last year)	
Panel A Metropolitan areas												
Charter	0.1929***	0.2211***	0.1927***	0.2554***	0.4096***	0.0845	0.2604**	-0.0075	0.0984	-0.0419	0.117	-0.0993
	[0.0659]	[0.0583]	[0.0709]	[0.0732]	[0.1269]	[0.1341]	[0.1297]	[0.1525]	[0.1179]	[0.1209]	[0.1155]	[0.1286]
R-squared	0.8642	0.9064	0.8773	0.9149	0.8639	0.8799	0.8845	0.897	0.9177	0.9242	0.9294	0.9351
Observations	4,485	4,422	3,615	3,564	16,279	16,279	10,009	10,008	16,279	16,279	10,009	10,008
N(district)	290	286	290	286	463	463	461	461	463	463	461	461
Panel B Non-metropolitan areas												
Charter	0.0475	0.0281	-0.086	-0.0954	0.0326	-0.0511	0.0784	-0.0201	-0.1197	-0.1092	-0.0607	-0.0944
	[0.0378]	[0.0303]	[0.0574]	[0.0691]	[0.1928]	[0.1808]	[0.1483]	[0.1331]	[0.1792]	[0.2016]	[0.1421]	[0.1416]
R-squared	0.7274	0.8112	0.7322	0.8189	0.7736	0.7896	0.7974	0.8092	0.8162	0.8265	0.8415	0.8497
Observations	2,014	1,936	1,624	1,561	5,866	5,866	3,799	3,798	5,866	5,866	3,799	3,798
N(district)	130	125	130	125	148	148	147	147	148	148	147	147
District, (grade) & year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State by year FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes

Notes: The table shows Dose-response estimates of heterogeneous effects of the charter enrollment share on student achievement by (non-)metropolitan areas. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. Regressions are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA.

Table 9 Effect Heterogeneity: Middle school VS Elementary school (DD)

	(1)	(2)	(3)	(4)	(5)	(6)
	Math			ELA		
	DD	DD-PSW	DD-PSM	DD	DD-PSW	DD-PSM
Panel A: Middle school (Grade 6-8)						
Treated*Post	0.2622***	0.2622***	0.2420***	0.1492***	0.1261**	0.1184***
	[0.0412]	[0.0583]	[0.0481]	[0.0341]	[0.0510]	[0.0405]
Pre-Treated Mean	-0.33	-0.14	-0.33	-0.34	-0.17	-0.34
R-squared	0.8869	0.895	0.9142	0.9012	0.8987	0.9317
Observations	182,260	182,260	8,632	182,260	182,260	8,632
N(district)	9,843	9,843	584	9,843	9,843	584
Panel B: Elementary school (Grade 3-5)						
Treated*Post	0.0684	0.0497	0.0738	0.0916**	0.0293	0.0630
	[0.0521]	[0.0678]	[0.0620]	[0.0463]	[0.0433]	[0.0560]
Pre-Treated Mean	-0.45	-0.16	-0.45	-0.48	-0.20	-0.48
R-squared	0.8602	0.8788	0.8953	0.9024	0.9095	0.9398
Observations	215,352	215,352	12,329	215,352	215,352	12,329
N(district)	9,924	9,924	586	9,924	9,924	586
District, (grade) & year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The table shows DD estimates of heterogeneous effects of charter enrollment share on student achievement by middle (elementary) schools. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. For DD and DD-PSM, regressions are weighted by grade-level enrollment for Math and ELA; For DD-PSW, regressions are weighted by weight of DD times the inverse probability of propensity score.

Table 10 Effect Heterogeneity: Middle school VS Elementary school (DR)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Math				ELA			
Charter share	Grade 3-8 share (current year)		Grade specific share (same cohort last year)		Grade 3-8 share (current year)		Grade specific share (same cohort last year)	
Panel A: Middle school (Grade 6-8)								
Charter	0.3455***	0.1371	0.4339***	0.1764*	0.0756	-0.0068	0.2107**	0.0537
	[0.1228]	[0.1450]	[0.1082]	[0.1032]	[0.1081]	[0.1105]	[0.0922]	[0.0873]
R-squared	0.9086	0.9200	0.9159	0.9254	0.9307	0.9381	0.9360	0.9421
Observations	9,307	9,306	7,290	7,289	9,307	9,306	7,290	7,289
N(district)	605	605	605	605	601	601	601	601
Panel B: Elementary school (Grade 3-5)								
Charter	0.3726**	0.0133	0.2730**	0.1588	0.0440	-0.1637	0.1558	-0.0731
	[0.1497]	[0.1329]	[0.1359]	[0.1396]	[0.1339]	[0.1247]	[0.1041]	[0.1138]
R-squared	0.8858	0.9103	0.9086	0.9270	0.9421	0.9504	0.9579	0.9642
Observations	12,838	12,838	6,518	6,516	12,838	12,838	6,518	6,516
N(district)	609	609	609	609	601	601	601	601
District, grade, and year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State by year FE	No	Yes	No	Yes	No	Yes	No	Yes

Notes: The table shows Dose-response estimates of heterogeneous effects of the charter enrollment share on student achievement by middle (elementary) schools Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. Regressions are weighted by grade-level enrollment.

Table 11 Effects of charter enrollment share on school closure

Panel A: DD						
	DD		DD-PSW		DD-PSM	
Treated*Post	0.0074***	0.0079***	0.0069***	0.0071***	0.0048***	0.0043***
	[0.0008]	[0.0008]	[0.0016]	[0.0012]	[0.0010]	[0.0009]
Pre-Treated Mean	0.0096		0.0102		0.0096	
R-squared	0.0825	0.0862	0.0714	0.0795	0.1189	0.1310
Observations	257,515	257,494	257,494	257,494	40,749	40,749
N(district)	11,731	11,731	11,731	11,731	1,854	1,854
District, year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	No	Yes	No	Yes
Panel B: DR						
Charter share	Same year share			Lag two year		
Charter	0.0347***	0.0304***	0.0209***	0.0293***	0.0242***	0.0159**
	[0.0051]	[0.0056]	[0.0042]	[0.0069]	[0.0085]	[0.0075]
R-squared	0.1141	0.1237	0.1898	0.1200	0.1293	0.1958
Observations	45,534	45,534	45,468	41,391	41,391	41,331
N(district)	2,072	2,072	2,069	2,072	2,072	2,069
District, year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	Yes	No	Yes	Yes
State by year FE	No	No	Yes	No	No	Yes

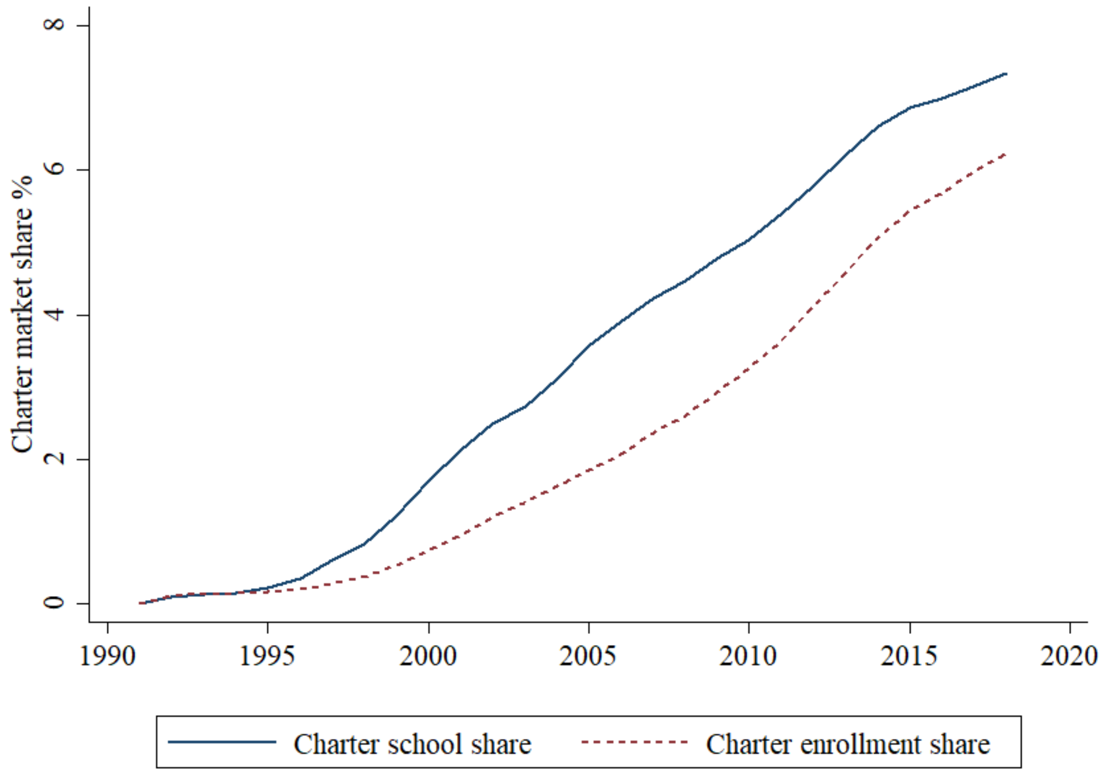
Notes: Panel A shows DD estimates of the effects of charter enrollment share ever above 10% on the share of school closure. Treated group includes districts with charter enrollment share ever above 10%, and control group includes districts without charter schools in all states; post in an indicator of period after districts started first charter school. Panel B shows Dose-response estimates of effects of the continuous charter enrollment share on school closure for districts with any charter enrollment during the sample period. Sample period is from year 1995 to 2016. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. Regressions are weighted by total number of schools.

Table 12 Effects of charter enrollment share on private school

Panel A: DD						
	DD		DD-PSW		DD-PSM	
Treated*Post	-0.0113***	-0.0095***	-0.0277***	-0.0192***	-0.0135***	-0.0102***
	[0.0031]	[0.0032]	[0.0048]	[0.0047]	[0.0037]	[0.0033]
Pre-Treated Mean	0.23		0.26		0.23	
R-squared	0.8916	0.8964	0.8799	0.8894	0.8826	0.8920
Observations	39,984	39,984	39,984	39,984	10,975	10,975
N(district)	3,780	3,780	3,780	3,780	1,019	1,019
District, year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	No	Yes	No	Yes
Panel B: DR						
Charter share	Same year share			Lag one year		
Charter	-0.0163	-0.0299	-0.0062	-0.011	-0.0212	0.0028
	[0.0584]	[0.0416]	[0.0349]	[0.0462]	[0.0348]	[0.0279]
R-squared	0.8736	0.8827	0.9049	0.8796	0.8885	0.9093
Observations	14,265	14,265	14,232	12,947	12,947	12,917
N(district)	1,318	1,318	1,315	1,318	1,318	1,315
District, year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	Yes	No	Yes	Yes
State by year FE	No	No	Yes	No	No	Yes

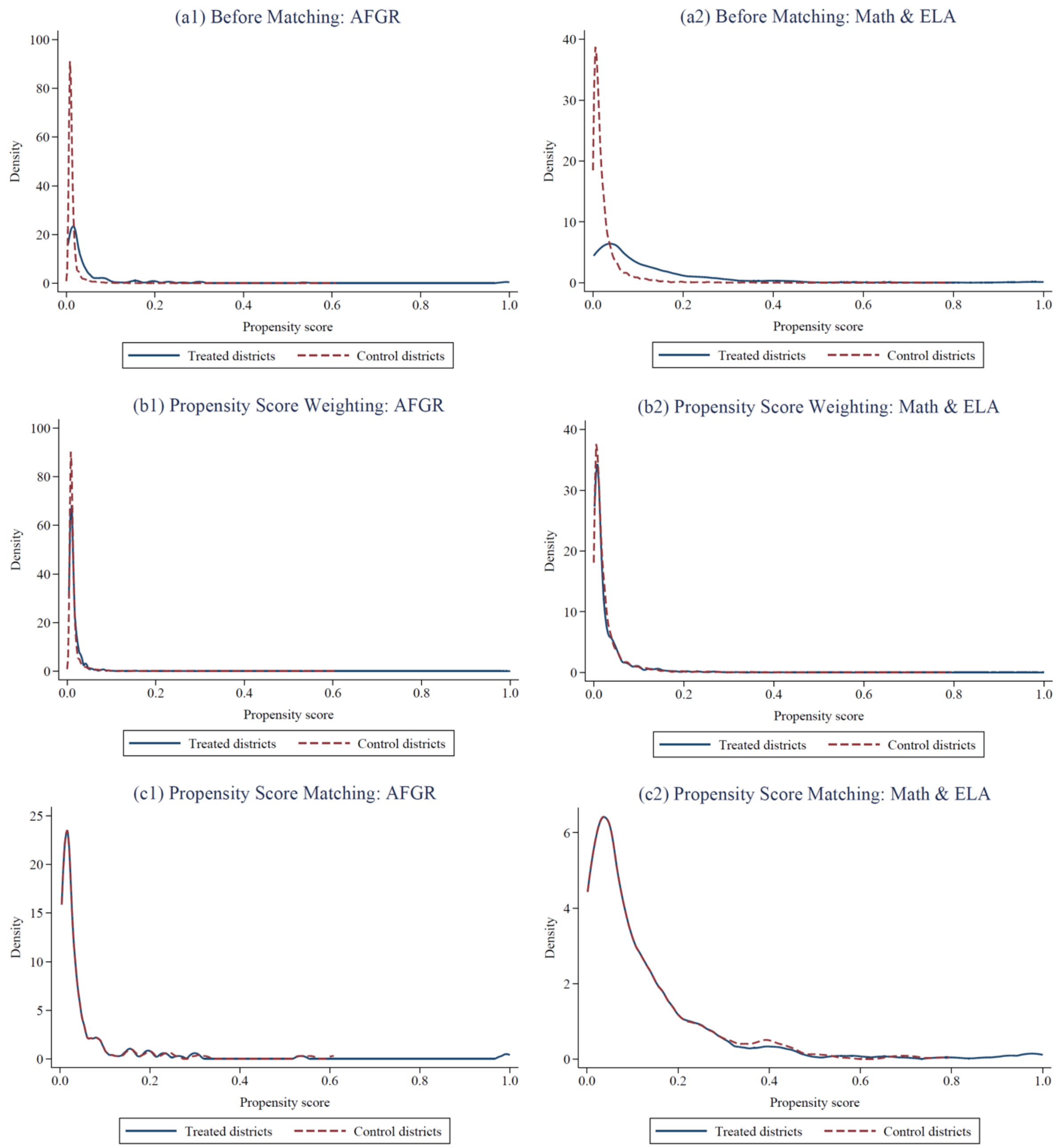
Notes: Panel A shows DD estimates of the effects of charter enrollment share ever above 10% on the share of private school. Treated group includes districts with charter enrollment share ever above 10%, and control group includes districts without charter schools in all states; post in an indicator of period after districts started first charter school. Panel B shows Dose-response estimates of effects of the continuous charter enrollment share on the share of private school for districts with any charter enrollment during the sample period. Sample period is from year 1996 to 2016 biannually. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. Regressions are weighted by total number of schools.

Figure 1 Trends in charter school share and charter enrollment share



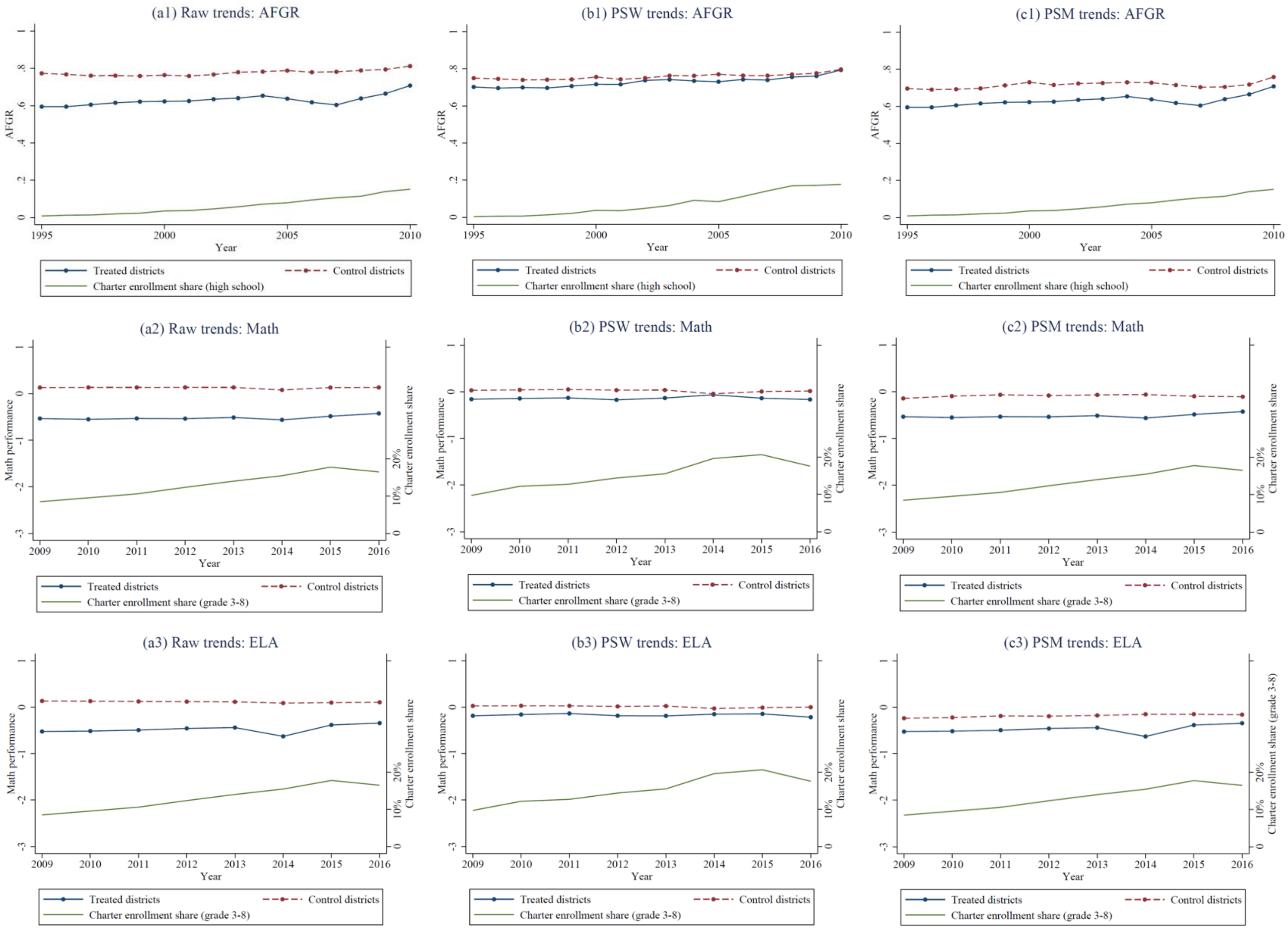
Notes: This figure plots the trends in charter school share (in the dashed line) and charter enrollment share (in the solid line).

Figure 2 Density of propensity score before and after matching



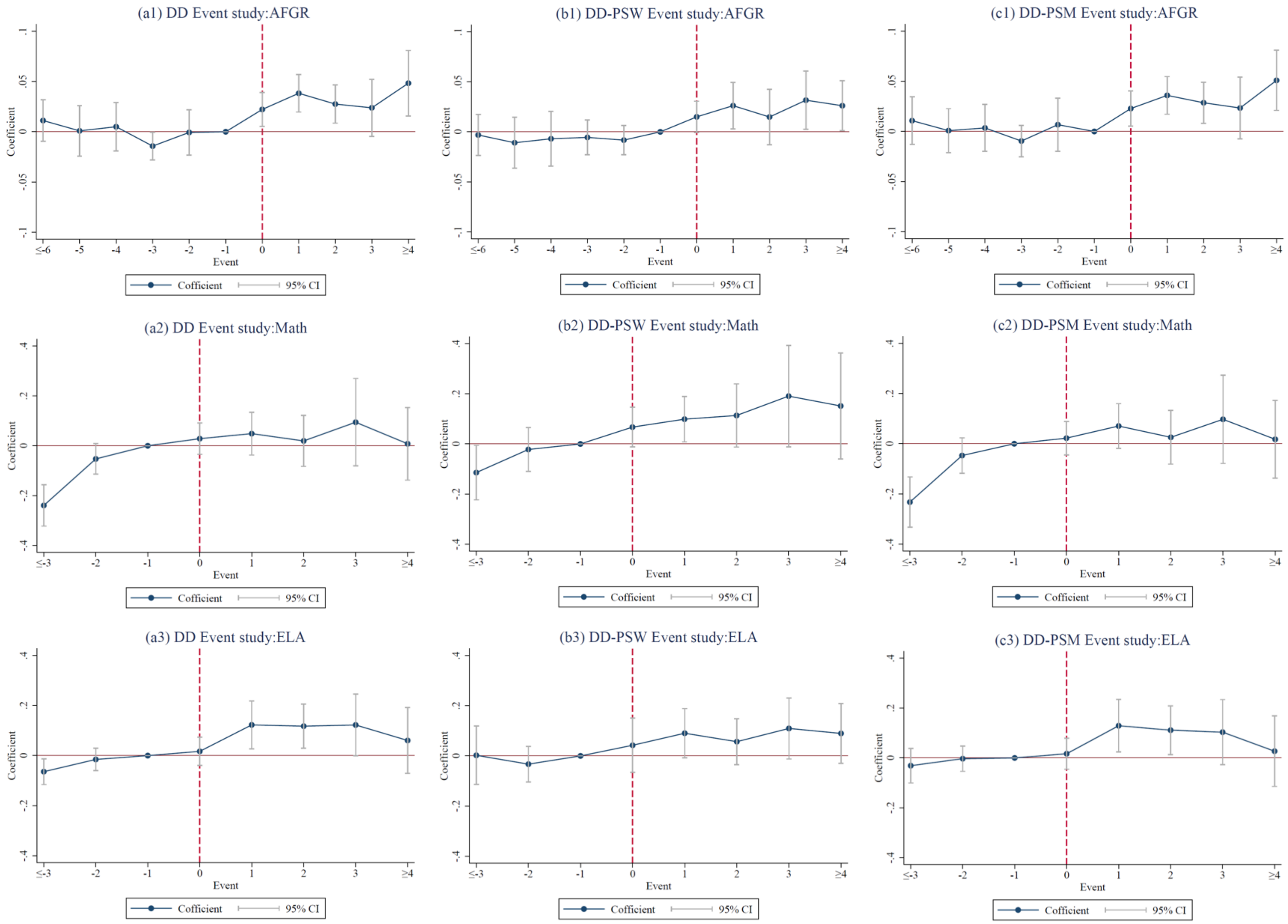
Notes: This figure plots the density of the propensity score of covariates of treated districts (in the solid line) and control districts (in the dashed line).

Figure 3 Trends in AFGR, Math, and ELA performance



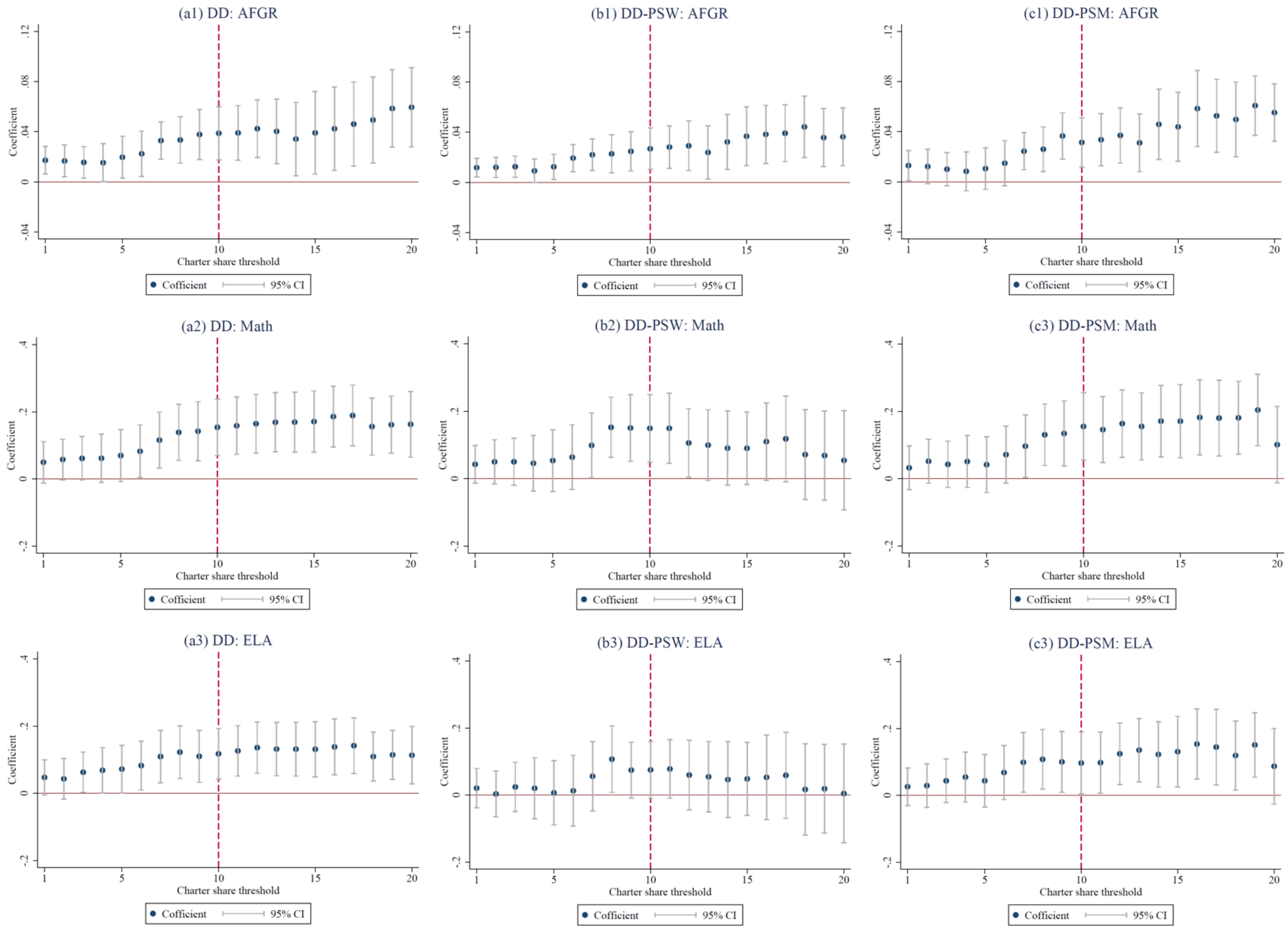
Notes: This figure plots the trends in AFGR, Math & ELA of treated districts (in the solid line) and control districts (in the dashed line). The green solid line plots the charter enrollment share of treated districts. DD and DD-PSM are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA; DD-PSW are weighted by weight of DD times the inverse probability of propensity score.

Figure 4 Event study of AFGR



Notes: This figure presents event study results of AFGR, Math & ELA. DD and DD-PSM are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA; DD-PSW is weighted by weight of DD times the inverse probability of propensity score. Zero is the first year of charter entry.

Figure 5 Plots of estimates using 1% to 20% as the threshold of treated districts



Notes: This figure plots the estimates in AFGR, Math & ELA using the charter enrollment share of 1% to 20% as the threshold of treated districts.

Appendix

Table A1 Summary Statistics

Sample	AFGR (1995-2010)						Math & ELA (2009-2016)					
	ALL	DD & DD-PSW		DD-PSM		Dose response	ALL	DD & DD-PSW		DD-PSM		Dose response
		Treated	Control	Treated	Control			Treated	Control	Treated	Control	
AFGR	0.81	0.75	0.81	0.75	0.77	0.75	NA	NA	NA	NA	NA	NA
Math	NA	NA	NA	NA	NA	NA	0.07	-0.47	0.09	-0.47	-0.30	-0.39
ELA	NA	NA	NA	NA	NA	NA	0.10	-0.39	0.12	-0.39	-0.28	-0.36
White	81%	65%	82%	65%	68%	66%	75%	59%	76%	59%	57%	56%
Black	7%	8%	7%	8%	8%	11%	9%	10%	9%	10%	10%	13%
Hispanic	7%	18%	7%	18%	14%	17%	12%	26%	11%	26%	27%	25%
FRL	30%	35%	30%	35%	35%	31%	48%	54%	47%	54%	55%	55%
Special education	13%	12%	13%	12%	13%	13%	14%	12%	14%	12%	12%	13%
Ages 5–17 population	16%	18%	16%	18%	18%	17%	18%	20%	18%	20%	20%	20%
Ages 5–17 in poverty	19%	19%	19%	19%	20%	19%	17%	15%	17%	15%	16%	16%
Urban	5%	16%	5%	16%	16%	23%	6%	16%	5%	16%	14%	25%
Suburb	22%	22%	22%	22%	18%	32%	28%	28%	27%	28%	28%	31%
Town	17%	19%	17%	19%	23%	19%	22%	28%	22%	28%	25%	25%
Rural	56%	43%	57%	43%	43%	25%	45%	32%	47%	32%	39%	23%
Revenue per student	9,276	8,975	9,307	8,975	9,270	8,616	12,883	11,238	12,970	11,238	10,996	11,360
Expenditure per student	9,354	9,068	9,382	9,068	9,398	8,754	12,795	11,280	12,874	11,280	11,058	11,404
Teacher salary	70,447	74,705	70,212	74,705	75,533	75,434	92,218	94,170	91,997	94,170	93,509	96,080
Student teacher ratio	15	17	15	17	17	17	15	18	15	18	18	18
No. magnet school	0	3	0	3	1	2	0	2	0	2	1	2
No. schools	8	29	7	29	23	33	8	26	7	26	17	31
Enrollment	4,088	18,827	3,234	18,827	10,234	22,175	4,222	15,608	3,370	15,608	9,277	19,147
Observation	144,266	2,193	137,767	2,193	2,184	6,499	410,244	10,156	388,099	10,156	10,968	22,145
N (district)	9,278	142	8,858	142	142	420	10,129	298	9,831	298	298	611

Notes: This table presents unweighted means of outcome variables (AFGR, Math, and ELA) and control variables. Treated group refers to the sample of districts that charter enrollment share ever above 10 percent during the sample period. Control group refers to the sample of districts without charter schools in all states for DD & DD-PSW, and it refers to the sample of matched districts (nearest neighbor) for DD-PSM. Dose response refers to all districts with any charter share in the sample period. Data source: National Longitudinal School Database.

Table A2 Top 20 districts with largest charter enrollment share

School District	State	NAPCS			NLSD		
		Charter Enrollment	Total Enrollment	Enrollment Share	Charter Enrollment	Total Enrollment	Enrollment Share
Orleans Parish School District	LA	46,932	49,646	95%	48,495	51,100	95%
Gary Community School Corporation	IN	5,060	10,288	49%	5,060	10,288	49%
Queen Creek Unified District	AZ	6,776	13,858	49%	5,070	12,166	42%
District of Columbia Public Schools	DC	43,393	91,528	47%	38,696	86,330	45%
Detroit Public Schools Community District	MI	38,667	83,504	46%	37,235	87,045	43%
Kansas City Public Schools	MO	11,420	26,630	43%	12,602	27,769	45%
Southfield Public School District	MI	4,543	10,697	42%	4,543	10,674	43%
Inglewood Unified School District	CA	5,193	13,594	38%	5,453	13,854	39%
Camden City School District	NJ	4,731	12,672	37%	4,892	12,616	39%
Indianapolis Public Schools	IN	15,244	42,874	36%	15,466	42,383	36%
Franklin-McKinley School District	CA	3,866	11,152	35%	3,305	10,591	31%
Dayton City School District	OH	6,652	19,745	34%	6,828	19,850	34%
Natomas Unified School District	CA	4,952	14,880	33%	4,952	14,880	33%
Philadelphia City School District	PA	64,393	195,631	33%	64,970	192,172	34%
Newark City School District	NJ	17,501	53,215	33%	17,204	52,917	33%
Alum Rock Union Elementary School District	CA	4,623	14,265	32%	5,089	14,731	35%
St. Louis City School District	MO	11,082	34,936	32%	11,022	33,958	32%
Cleveland Municipal School District	OH	16,352	54,641	30%	20,076	58,301	34%
San Antonio Independent School District	TX	18,515	62,119	30%	17,979	58,901	31%
Oakland Unified School District	CA	18,502	52,457	30%	16,070	53,018	30%

Notes: This table compares the top 20 districts (with the largest charter enrollment share among districts with at least 10,000 total students in the 2018 spring year) from a report of the National Alliance for Public Charter Schools with data from NLSD. Source: A Growing Movement: America's Largest Charter School Communities, Thirteenth Edition, January 2019.

Table A3 Number of districts by year first charter initiated

AFGR (high school)		Math & ELA (grade 3-8)	
Year first charter initiated	Number of districts	Year first charter initiated	Number of districts
Before 1994	11	Before 2009	407
1995	11	2009	20
1996	12	2010	37
1997	12	2011	31
1998	19	2012	32
1999	26	2013	27
2000	49	2014	32
2001	39	2015	16
2002	42	2016	9
2003	27	Total	611
2004	18		
2005	27		
2006	30		
2007	30		
2008	20		
2009	25		
2010	22		
Total	420		

Notes: The table presents the number of districts by year first charter initiated.

Table A4 Alternative measure of charter share: charter school share

	DD		DD-PSW		DD-PSM	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: AFGR						
Treated*post	0.0156***	0.0134**	0.0156***	0.0105**	0.0148***	0.0101*
	[0.0051]	[0.0053]	[0.0044]	[0.0043]	[0.0055]	[0.0054]
Pre-Treated Mean	0.67		0.73		0.67	
R-squared	0.8155	0.8186	0.7907	0.7963	0.8573	0.8618
Observations	143,903	143,903	143,903	143,903	12,258	12,258
N (district)	9,255	9,255	9,255	9,255	794	794
Panel B: Math						
Treated*post	0.0854**	0.0864**	0.0929**	0.0652*	0.0726*	0.0674*
	[0.0370]	[0.0384]	[0.0406]	[0.0338]	[0.0401]	[0.0390]
Pre-Treated Mean	-0.35		-0.24		-0.35	
R-squared	0.8464	0.8473	0.8630	0.8659	0.8677	0.8706
Observations	404,352	404,352	404,352	404,352	33,579	33,579
N (district)	10,285	10,285	10,285	10,285	916	916
Panel C: ELA						
Treated*post	0.0894***	0.0925***	0.0730*	0.0538	0.0760**	0.0797**
	[0.0291]	[0.0313]	[0.0386]	[0.0346]	[0.0322]	[0.0338]
Pre-Treated Mean	-0.39		-0.12		-0.39	
R-squared	0.8823	0.8834	0.8848	0.8868	0.9033	0.9054
Observations	404,352	404,352	404,352	404,352	33,579	33,579
N (district)	10,285	10,285	10,285	10,285	916	916
District, (grade) & year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	No	Yes	No	Yes

Notes: The table shows DD estimates of the effects of charter school share ever above 10% on student achievement. Treated group includes districts with charter school share ever above 10%, and control group includes districts without charter schools in all states; post in an indicator of period after districts started first charter school. The first two columns present the results for DD estimates; Columns (3) and (4) are estimates for DD-PSW; Columns (5) and (6) are estimates for DD-PSM. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. For DD and DD-PSM, regressions are weighted by high school enrollment for AFGR and grade-level enrollment for Math and ELA; For DD-PSW, regressions are weighted by weight of DD times the inverse probability of propensity score.

Table A5 Average charter enrollment share across models

	AFGR			Math & ELA		
	ALL	DD-Treated	DR	ALL	DD-Treated	DR
(a) Average charter share	0.6%	6.3%	2.7%	1.5%	12.3%	6.3%
(b) Average max charter share	1.9%	18.5%	7.9%	2.3%	18.8%	9.6%

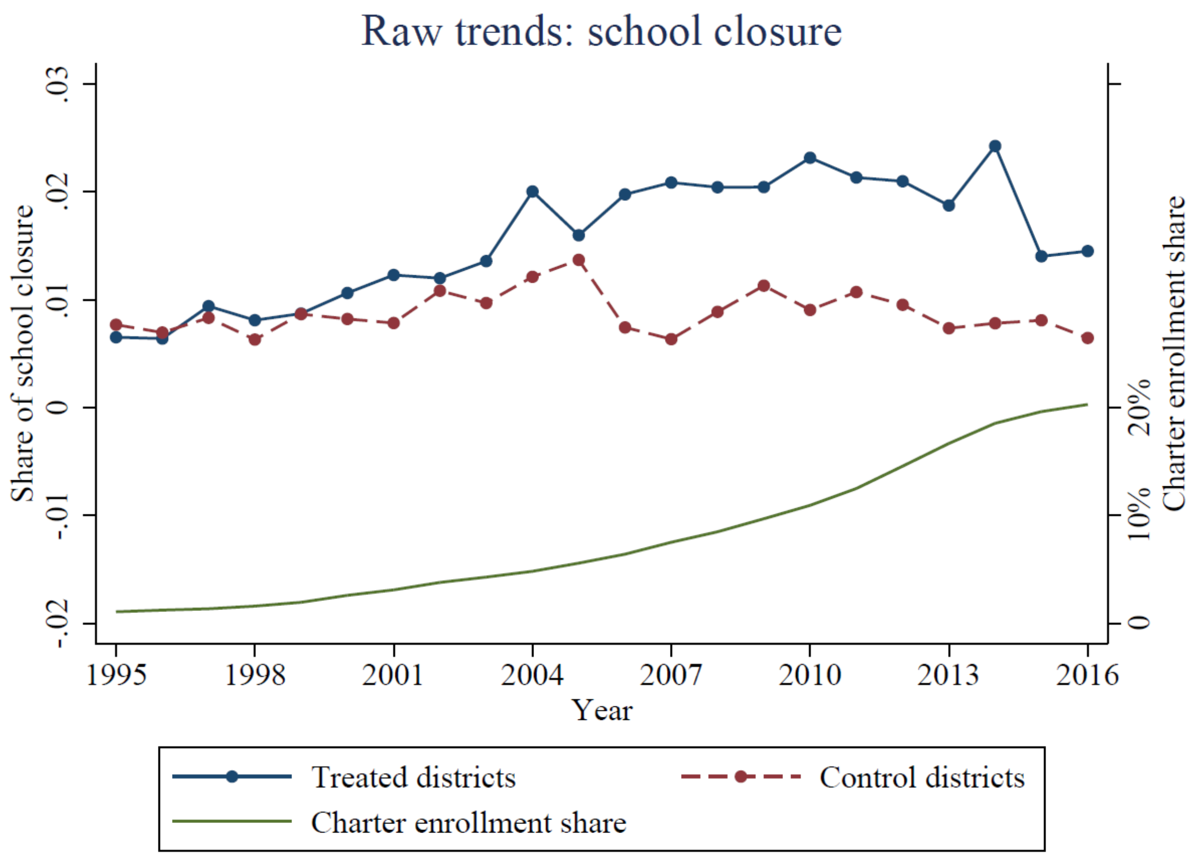
Notes: The table average charter enrollment share across DD and DR models. (a) is the charter shares averaged across years; and (b) is the averaged eventual max share (it is what we're using to place districts in the treatment group).

Table A6 Effects of charter enrollment share on TPS closure

Panel A: DD						
	DD		DD-PSW		DD-PSM	
Treated*Post	0.0045***	0.0053***	0.0042***	0.0045***	0.0033***	0.0031***
	[0.0008]	[0.0008]	[0.0013]	[0.0010]	[0.0009]	[0.0009]
Pre-Treated Mean	0.0091		0.0093		0.0091	
R-squared	0.0750	0.0786	0.0693	0.0778	0.1031	0.1136
Observations	257,515	257,494	257,494	257,494	40,749	40,749
N(district)	11,731	11,731	11,731	11,731	1,854	1,854
District, year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	No	Yes	No	Yes
Panel B: DR						
Charter share	Same year share			Lag two year		
Charter	0.0189***	0.0167***	0.0113***	0.0011	-0.0026	-0.0065
	[0.0038]	[0.0044]	[0.0039]	[0.0050]	[0.0062]	[0.0062]
R-squared	0.102	0.1112	0.1862	0.109	0.1183	0.1942
Observations	45,534	45,534	45,468	41,391	41,391	41,331
N(district)	2,072	2,072	2,069	2,072	2,072	2,069
District, year FE	Yes	Yes	Yes	Yes	Yes	Yes
District control	No	Yes	Yes	No	Yes	Yes
State by year FE	No	No	Yes	No	No	Yes

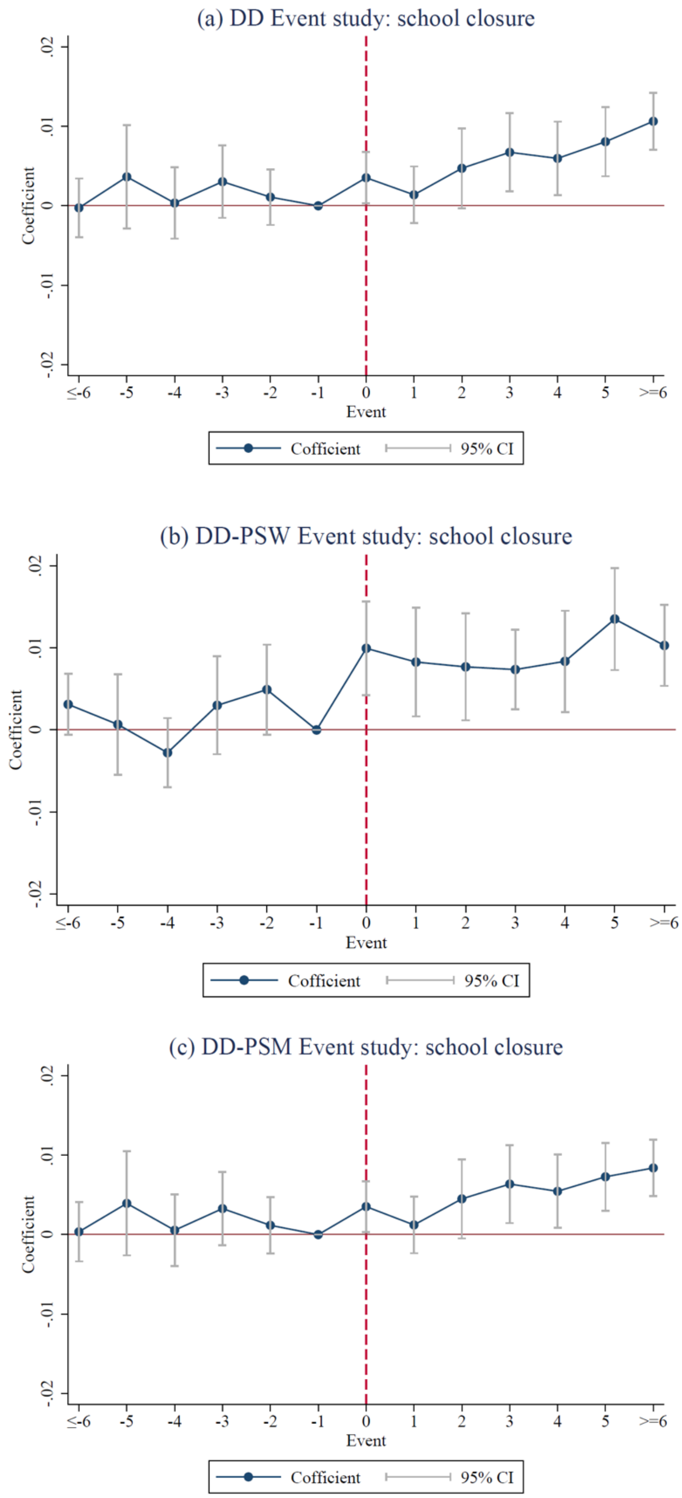
Notes: Panel A shows DD estimates of the effects of charter enrollment share ever above 10% on the share of TPS closure. Treated group includes districts with charter enrollment share ever above 10%, and control group includes districts without charter schools in all states; post in an indicator of period after districts started first charter school. Panel B shows Dose-response estimates of effects of the continuous charter enrollment share on TPS closure for districts with any charter enrollment during the sample period. Sample period is from year 1995 to 2016. Controls include the log of district enrollment; the share of students who are Hispanic, black, white; the share of students who are in special education programs; the share of students on FRL programs; student teacher ratio; average teacher salary; number of magnet school; total number of schools; the total revenue per student; the total expenditure per student; and whether the district is in an urban, suburban, town, or rural location; the estimate of the school-age population; the estimate poverty rate of the school-age population. Robust standard errors presented in parentheses are clustered at the district level. Regressions are weighted by total number of schools.

Figure A1 Raw trends in share of school closure



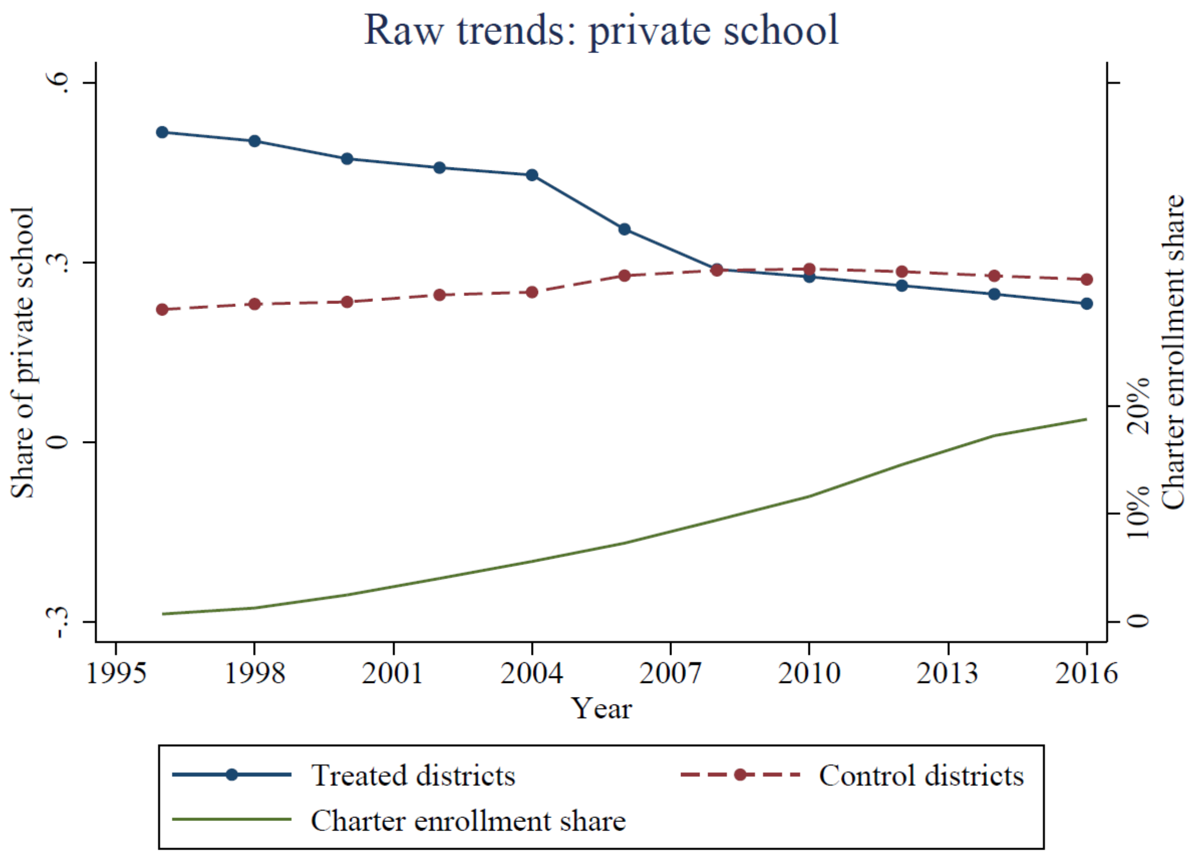
Notes: This figure plots the raw trends in share of school closure (TPS and charter) of treated districts (in the solid line) and control districts (in the dashed line). The green solid line plots the charter enrollment share of treated districts.

Figure A2 Event study graphs on school closure



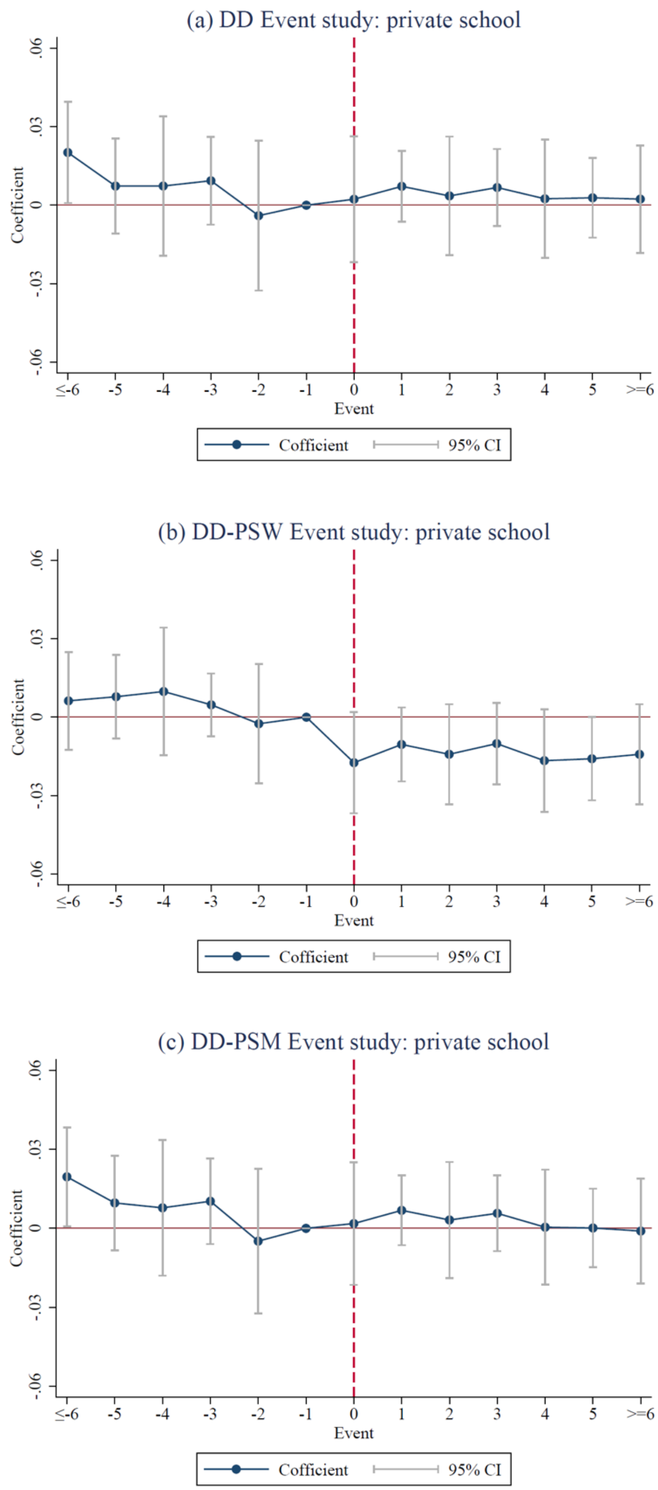
Notes: This figure presents event study results of the share of school closure. DD and DD-PSM are weighted by the number of total schools (TPS and charter) in the district; DD-PSW is weighted by weight of DD times the inverse probability of propensity score. Zero is the first year of charter entry.

Figure A3 Raw trends in share of private school



Notes: This figure plots the raw trends in share of private school of treated districts (in the solid line) and control districts (in the dashed line). The green solid line plots the charter enrollment share of treated districts.

Figure A4 Event study graphs on private school



Notes: This figure presents event study results of the share of private school. DD and DD-PSM are weighted by the number of total schools (TPS, charter, and private) in the district; DD-PSW is weighted by weight of DD times the inverse probability of propensity score. Zero is the first year of charter entry.