The Competitive Effects of Charter Schools: Evidence from the District of Columbia

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I. Introduction

One of the driving tenets of charter school policy is that the presence of charter schools will impose market pressures on traditional public schools (TPS). Advocates of school choice often claim that beyond improved educational opportunities for those that attend, charter schools will also improve the quality of nearby TPS. By injecting competition into a previously monopolistic system, charter schools are expected to drive TPS to more efficiently utilize existing resources to improve student performance.

In this paper, we study the effects of charter school competition in Washington, DC, using four years of student-level measures of academic performance and the transfer patterns of students. This study develops a new approach to estimating the response of TPS to the presence and performance of competitor charter schools. We then explore the different channels by which competitive pressure from charter schools may prompt a reaction from TPS. These "channels" of competition include measures of charter market share, attrition from TPS to charters and multiple measures of the quality of competing charter schools. To our knowledge, no previous research has investigated whether the quality of the charter schools to whom TPS lose students impacts their competitive response. Findings from our new model are also compared with results found using the more prevalent student/school fixed effects estimation method.

The results suggest that the degree of competitive response from TPS is sensitive to the performance of the charter schools with which they compete. However, TPS do not appear to be sensitive to relatively minor variations in charter quality, with broad measures of quality providing the most robust estimates of competitive effect. Competition from charter schools with higher than average quality is associated with increased growth in both math and reading at TPS. Interestingly, the simple attrition of students from TPS to charters does not appear to provoke a competitive response when modeled as the only measure of competition, but becomes positive and significant when a measure of charter quality is included. The fact that all previous research on this topic ignores the large variations in charter quality in nearly every state and city in the U.S. may partially explain the inconsistent results found in much of the previous literature. These findings suggest that TPS are unmoved by student migration alone but are attuned to quality signals, responding positively to the loss of students to high quality charter schools.

I. Motivation for the Study

Recent research on the performance of charter schools has prompted this investigation into the existence and character of their competitive effects on TPS. Across the country there is wide variation in both the density of charter schools and of their quality relative to local TPS. According to the National Alliance for Public Charter Schools, the proportion of students in charter schools by state ranges from a low of 0.2% in Virginia to a high of 45% in Washington D.C. (NAPCS, 2012). [1] The 2013 analysis of charter schools conducted by CREDO found that there is significant variation in the quality of charter schools across the country, with 29% of charters providing significantly higher quality education in math and 25% in reading than their competitor TPS. Meanwhile, 31% of charters provided significantly worse education in math and 19% in reading, with the remaining 40% of charter schools providing growth that was statistically indistinguishable from their feeder TPS in math and 56% did so in reading (CREDO, 2013). Significant variation in relative charter quality has also been identified by others (Mathematica, 2011). In their recent study, Mathematica researchers found that the performance of charter middle and high schools differed significantly, some of which was associated with community type: urban charter schools were found to have more positive results than non-urban

[1] Nine states have no charter schools and thus are excluded from these calculations.

charter schools, for example. CREDO has also found similar results suggesting higher performance in urban than non-urban charter schools in previous state-level charter school analyses.

Charter schools remain a central fixture of school reform agendas in many states, even in those where their performance record has been mixed. There is keen interest on both the direct effect of charters on enrolled students and on the indirect influence these schools exert on existing TPS. The combination of these effects position charter schools as the primary vehicle for market-based reform of public K-12 education.

There are at least three plausible mechanisms to explain the indirect impact of charters on TPS: simple market presence, charter market share and elastic TPS response to charter quality. Distinguishing among these three possibilities is important, since the policy response is likely to differ depending on which, if any, of these mechanisms are found to trigger a response in TPS. The limited body of existing literature looks only at the first two mechanisms. Probing the differences and interactions among these three mechanisms provides the primary motivation for the present study.

The first possibility is that the simple presence of charter schools creates competitive pressure as a function of their proximity to TPS or of their overall market share. These traditional measures of competitive impact presume that the number of charters, their density, or the relative distance of charter schools impacts TPS performance. Importantly, this approach assumes that all charter schools provide equivalent competition to all TPS within the same geographic boundaries. The range of influence on TPS is therefore estimated on the basis of their spatial characteristics (e.g., size or geographic location).

Previous literature on the influence of competitive pressure includes many studies that measure competition in terms of the geographic distribution of charter schools around TPS (Holmes, DeSimone & Rupp, 2003, Ni, 2005, Bifulco and Ladd, 2006, Brandon and Weiher 2007, Zimmer et. al 2009). For example, a measure of the amount of competition could be either the proximity, in miles, from a TPS to their closest competitor charter school or the number of charter schools within a specified radius around each TPS.

Findings from studies of this type generally suggest weak competitive impacts. But it is unclear whether this model is the best reflection of actual market dynamics. Given the observed variation in performance of the charter sector, it is fair to wonder if charter schools provide heterogeneous competitive effects on TPS. Variation in charter quality could reasonably be expected to exert uneven pressure on the TPS with which they compete, which simple proximity measures of competition will fail to capture

A second possibility is that competitive pressure derives from the loss of students at a TPS. This mechanism theorizes a zero-sum market with relatively fixed numbers of students. In this environment, growth in charter school enrollments would necessarily reflect declining enrollment in TPS, which could provide the necessary stimulus to prompt a competitive response. This market-share view, however, does not appear to be credible at the macro level. Districts with high proportions of students enrolled in charter schools see no greater average performance in the incumbent TPS sector. If that were the case then the District of Columbia, with 38% charter market share, should have greater performance in its TPS than Phoenix, where the proportion of students in charter schools is 18%, all else equal.

A key drawback of this approach to modeling competition is that market-wide statistics may mask variation in the underlying experience of individual TPS. For example, some neighborhoods may have higher proportions of students in charter schools than others. Where the market-wide average masks differentiated TPS experience, it will produce estimates of competitive response that may not match the experience of a significant portion of the TPS population.

Our approach to capturing competitive pressure begins with a focus on more localized measures of the influence of charter schools on TPS. Specifically, TPS in the same neighborhood or district can experience very different market contexts, both in terms of the attrition they experience and with respect to the quality of charter schools their former students attend. In this paper, measures of competition based on attrition are calculated from the percentage of students each TPS loses to charter schools each year. Measures of competition based on quality are calculated by examining the average achievement of the charter schools to which each TPS actually loses students. This level of specificity allows us to explore whether it is charter market share, charter quality or an interaction of the two (e.g. TPS lose a certain percentage of their students to charters of above average quality) that triggers a response in TPS. Investigating the features of these “mini-markets” provides a new way to consider the various forms of competitive pressure provided by charter schools and the differential response mechanisms of TPS.

This study of the Washington D.C. public school system seeks first to quantify the competitive pressure applied by charter schools to TPS, and then to determine if this pressure provokes a competitive response as evidenced by improved TPS performance (measured by growth in standardized math and reading assessments).

II. Hypothesis about Competition

For charter schools to elicit a competitive response among TPS, certain conditions must be present in an education marketplace. It is useful to describe in concrete terms what conditions an economic theory of competitive impact would contain.

Condition #1: Parents must respond to the new educational choices available to them

The first condition is that parents must recognize signals of school quality and respond to them, most importantly by removing children from poorly performing schools and moving them to better ones. If this were taking place, we would expect to find a pattern in which low performing TPS experience higher rates of attrition to charters, or conversely that high performing TPS experience lower levels of attrition[2].

Condition #2: Individual TPS must feel some degree of competitive pressure.

If an inverse relationship between school quality and student attrition is found (i.e. if condition #1 is met), we must then consider whether TPS recognize increased educational choice as competition. Private schools have existed for years in many education markets and do not appear to have provoked the kind of competitive response proponents of choice would predict. It is possible that private schools are not seen as serving the same set of students as most TPS and are therefore not perceived as competition. Since charter schools are on the public side of the public/private school divide, and in many cases explicitly serve disadvantaged students, charters may be more likely than private schools to provoke a competitive response among TPS.

[2] It is important when calculating attrition rates from TPS to charter schools that we count only those students that had the opportunity to stay at their TPS for another year. This ensures that we do not count those students who simply graduate from a TPS and move on to a charter school that does not in fact compete with their previous TPS.

Broader enrollment trends within an education market can also dilute signals of competition. In a school district experiencing rapid growth and the resulting resource strains, charter schools may be perceived as more of a “relief valve” than as a competitive threat. Therefore, an additional market level consideration for TPS to recognize charters as competition is that the education market must be static, or at least be growing more slowly than the number of available spaces in the charter sector. Of course, where the population is declining, we would expect competition to be even more acutely perceived.

Once the conditions above are met, establishing the market dynamics necessary for a TPS to recognize competition, charter schools must then provide some degree of legitimate competitive pressure. To analyze this, we measure competition in a more precise way than previous literature, utilizing information on both the number of students at each TPS lost to charter schools and the quality of the specific charter schools they left to attend. To calculate the number of students lost, we use the attrition rate of students from TPS to charter schools in each year (similar to Buddin and Zimmer, 2005). This technique ensures our measure of attrition focuses specifically on those students who exit TPS for charters, and not those switching to another TPS or leaving the Washington D.C. public education system altogether.

Our model of competitive impact presumes that student attrition is viewed negatively by TPS, due to financial loss, loss of prestige, or other related factors. There may be cases, however, where student attrition does not lead to a loss of financial resources. For example, the existence of “hold harmless” laws, ensuring uninterrupted TPS funding regardless of student attrition, or other political assurances may prevent signals of competitive pressure related to student attrition from evoking a response.[3] Thus, there may be markets in which school choice will fail to alter the behavior of incumbent TPS, who have a stake in maintaining the status quo and political assurances that they will be able to do so.

In addition to using student attrition as a signal of competition, signals of charter quality are utilized as well. Where localized charter competition is inferior, we would expect a smaller impact on TPS behavior than where their charter competitors deliver high levels of student performance. By including both "quantity" and "quality" signals of competition sent by charter schools to TPS, we aim to more fully capture the competition that each TPS experiences.

Condition #3: TPS must have the capacity to respond, and the response must be academic in nature.

The third condition necessary for charter competition to influence TPS performance is that, after recognizing they face competition, an agent at the TPS must possess the capacity to respond. Principals and school administrators are theoretically well positioned to influence school–level practices affecting student growth, but a number of human capital and institutional constraints might prevent a robust response. It is possible that a TPS simply lacks qualified personnel to substantively improve the quality of the education they provide. Schools may also have very little latitude or discretion for experimentation with curriculum, culture, labor force quality or other factors that have led to their current performance. It is also assumed that the response to competitive pressure will be academic in nature, as opposed to non-academic attempts to attract and retain students such as facilities upgrades or expanded extra-curricular activities, for example.

[3] Under "hold harmless" conditions, one might even anticipate the operation of perverse incentives; the loss of students when total budgets are guaranteed increases the amount of slack resources available to be repurposed.

III. Modeling Approach

Most empirical models that seek to measure the impact of competition on student performance compare students at TPS facing competition to students at TPS facing little or no competition. In an ordinary least squares (OLS) model, this is a "Pre vs. Post" treatment comparison which simply compares, for example, the growth rate of a student before and after their school feels competitive pressure. Consider students in a group of schools that begin with no competition in time period t_0 but that do experience competition in time period t_1. One estimation of the impact of competition (the treatment) would be:

$$\delta^T = \beta_1^T - \beta_0^T$$

where δ^T is the impact of competition, β_1^T is the treated student's record after experiencing competition and β_0^T is the treated student's record before experiencing competition. An extension of this would be to compare their results to the change in performance of another group of students who are "never treated." That is, to those students in schools that don't face direct competition in either time period t_0 or t_1. An estimation of the impact on this group (the control) would be:

$$\delta^C = \beta_1^C - \beta_0^C$$

where δ^C is the impact on students who did not face competition, β_1^C is the untreated student's record after the treated students experience competition and β_0^C is the untreated student's record before the treated students experience competition. The refined competitive impact estimator would therefore be:

$$\delta^R = \delta^T - \delta^C$$

where δ^R is the refined competitive impact estimator, δ^T is the impact of competition on treated students and δ^C is the impact of competition on untreated students. This approach controls for any general changes between t_0 and t_1 affecting student performance.

This model functions well unless there is non-random variation between the treatment and control groups, and particularly non-random variation on characteristics related to the outcome variable, in this case student level test score growth rates. Specifically, this model ignores the possibility that pre-existing differences between “treated” and “untreated” students may be related to the outcome of interest (e.g. low TPS quality creating market demand for local charter competition). If charter schools intentionally locate near TPS that are not providing a high quality education for their students, this could introduce bias into a simple OLS measure of the impact of competition. If present, the potential endogeneity of charter school location to TPS quality would likely bias the estimate of competitive impact downward, given that charters would be providing competition to a disproportionate number of poor quality TPS.

There are various econometric methods to deal with the issue of endogeneity. Two stage least squares models with instrumental variables are effective at minimizing the impact of endogeneity, but finding a suitable instrument that is related to charter school location but not student test scores is challenging. Instruments used to analyze the impact of school choice include the proximity to a university and racial heterogeneity (Bettinger, 2005). Bettinger was able to exploit the exogenous variation supplied by Michigan’s charter composition at the time, since 150 of the state’s 170 charters had been granted by universities. Including racial heterogeneity as an instrument originated from research suggesting that charter schools tend to form in areas of greater racial diversity (Glomm, Harris and Lo, 2001). For research on the impact of private school competition on TPS, the religiosity of the surrounding community has also been used as an instrument, due to the large proportion of religious private schools (Sander, 1999 and Hoxby, 1994). The utility of these instruments is highest when applied to diverse and multiple geographies; in a single and relatively small market like the District of Columbia, their value is severely diminished.

Fixed effects models are also a popular method to measure the impact of school choice, typically involving both student and school fixed effects. In the absence of suitable instruments, researchers can use these models to separately control for variation on school and student level characteristics (Cullen et. al, 2005), or they can use an interaction of school and student fixed effects, forming a "spell effect" for each unique student/school combination (Zimmer et. al, 2009). The limitation regarding the use of fixed effects models in this context is that they will not control for time-variant unobserved school level trends, potentially introducing bias in the estimation of competitive effects.

Difference in Difference Methodology

To avoid these limitations we employ a difference in difference (DND) estimation method, which allows us to measure the impact of charter competition on TPS while controlling for pre-existing differences between TPS that experience competition and those that don't. By distinguishing between students in schools that ever felt competition and those that did not, before the "treatment" of competition is applied, a DND model allows us to isolate the true impact of competitive pressure, controlling for pre-existing differences between these students:

$$\delta^{DND} = \beta_1^T - \beta_0^T - (\beta_1^C - \beta_0^C) = \beta_1^T - \beta_1^C - (\beta_0^T - \beta_0^C)$$

where δ^{DND} is the impact of competition, β_1^T is the treated student's record after their TPS faces competition, β_0^T is the treated student's record before their TPS faces competition, β_1^C is the untreated student's record after the treated student's TPS faces competition, and β_0^C is the untreated student's record before the treated student's TPS faces competition.

By rearranging the equation above we can see that DND estimation allows us to capture the impact of competition ($\beta_1^T - \beta_1^C$) while controlling for pre-existing differences between the treatment and control groups ($\beta_0^T - \beta_0^C$).

Our DND model includes a control variable, a treatment variable and an interaction variable. The simple DND model is presented below:

$$Y_{ijt} = \alpha + \beta_1(C_{jt}) + \beta_2(T_{jt}) + \beta_3(DND) + \beta_3(D_{ijt}) + \beta_4(M_{jt}) + \varepsilon_{ijt}$$

where

Y_{ijt} is the measured growth in test scores for each student *i* attending TPS *j* in year *t*,

C_{jt} is a variable that signifies the presence of competition at TPS *j* in year *t*,

T_{jt} is a measure of the competitive signal that is available to TPS *j* in year *t*,

DND_{jt} is the interaction of the control and treatment for TPS *j* in year *t*,

D_{ijt} is a vector of student demographic and program participation controls that apply to student *i* in TPS j in year *t*,

M_{jt} is a vector of market controls for TPS *j* in year *t*, and

ε_{ijt} is an error term for each student *i* in TPS *j* in year *t*.

Control Variables

The key to our DND model is to find a variable to control for the differences between those TPS that ever experience competition in our sample and those that don't. As discussed earlier, proximate location of a charter doesn't necessarily trigger a response in TPS. A variable that reflects both charter location and the strength of the competitive signal is required. The control also needs to be lagged at least one period to allow time for competitive signals to prompt a response from TPS.

We employ a pragmatic approach to differentiating TPS facing competition and those that do not. By testing a series of thresholds of student attrition deemed necessary to "feel" competitive pressure, it is possible to separate TPS into two groups: those that meet or exceed the student attrition threshold in a given year (and are therefore determined to be "feeling" charter competition), and those that do not. We use student attrition from TPS to charter schools to generate the control variable.[4] The rate of attrition is calculated by determining the number of TPS students eligible to stay at their school but who chose to leave for a charter, and then dividing this number by the total enrollment at their TPS in their last year of attendance. Each TPS's control variable is then coded "1" if the resulting attrition-to-charter rate is greater than or equal to the pre-determined threshold and "0" otherwise.

Choosing the level of attrition necessary to prompt a competitive response is arbitrary and could vary by state, district and school. For exploratory purposes, we devise four different *Competition Threshold* control variables, using attrition rates of 5, 8, 10 and 12 percent. TPS

[4] Initially, we also explored measures of quality to distinguish between TPS "feeling" competition and those that are not, based on the presumption that low TPS quality attracts charter competition. However, using average TPS performance as a control variable resulted in distributions of TPS between the "feeling competition" and "not feeling competition" categories that were uneven and fluctuated dramatically from year to year.

with student attrition rates lower than the threshold are deemed to not be "feeling" competition, a claim that we recognize becomes increasingly implausible as the threshold rises. Still, the range of values serves the useful purpose of defining a possible frontier for examining the impact of competition.

Treatment Variables

Our "treatment" variable is the specific measure of competitive pressure that a TPS faces in a given time period. The exploratory nature of the work prompted us to create both quality-based and attrition-based treatment variables. The aim was to develop different measures of the competition that TPS's face; not only to detect the existence of TPS reactions but also to discern whether particular types of charter competition prompted differential reactions. However, attempts to use student attrition to derive the treatment variable, given that student attrition is already used to derive the control variable, resulted in high degrees of multicollinearity. Therefore, we decided to reject a DND approach based solely on attrition. However, we were able to include attrition-based treatment variables in the fixed effects specification outlined later in this paper.

When constructing a measure of charter competition based on quality, a number of considerations arose. Several researchers elect to combine reading and math performance into a composite measure, however we chose to model them separately. Additionally, we chose to use absolute measures of achievement over value-added measures of school quality, even though the latter are superior reflections of quality. This is because during the period of study, school-level value added measures were under development but would not have been widely available to TPS educators and administrators as a signal of competitor charter quality.

For these estimations, we base the treatment variable on measures of the weighted average achievement levels in the competitor pool of charters that each TPS faces. The competitor pool is empirically determined by tracking students enrolled at each TPS into the following academic year -- the charter schools that receive transfers from a TPS (and have overlapping grades) are considered the competitor pool for that TPS. Treatment variables are lagged to allow time for TPS to receive signals of charter quality and subsequently react. Various measures of quality were investigated, including the mean standardized achievement of a TPS's charter competition and the difference in quality between a TPS and its' charter competition, but these measures of competition provided inconclusive and unstable estimates. The most consistent results were found using a simple binary treatment variable indicating whether a TPS's charter competition was above or below the TPS district average quality.

Difference in Difference Estimator

The final variable in our DND model is the actual "difference in difference" estimator, which is simply an interaction of the control and treatment variables. The coefficient on the DND estimator is interpreted as the impact of competitive pressure, measured by the quality of charter competitors on TPS performance, controlling for pre-existing differences between TPS facing competition and those that do not.

Additional Explanatory Variables

Each student's race, gender, free/reduced price lunch program participation, special education status and prior year test score are included in our models as additional explanatory variables.

Several other school-level variables are added to fully capture the market dynamics. To test whether the general enrollment trend at a TPS affects their response to competition, a variable capturing enrollment trends at each TPS is included in our models. This is an index of enrollment growth at each school, equal to 1 in the base year and increasing or decreasing in each subsequent year depending on whether total enrollment at that TPS rose or fell compared to the base year (e.g. a 5% rise in enrollment changes the value from 1 to 1.05).

Our model also includes a count of the total number of charter schools to whom each TPS lost students. It is possible that losing the same percentage of one's students to one charter school vs. ten could have differential impacts on TPS response. However, it should be noted that none of the fixed effects models include these additional school level control variables. Doing so would lead to "over-specification" of the fixed effects model at the school level by including a school fixed effect, a school level measure of the change in enrollment and a school level measure of the number of charter competitors.

Concerns about Endogeneity

Endogeneity occurs when one or more independent variables are correlated with the error term, which can bias the coefficients in an OLS regression. In research on the competitive impact of schools, the principle concern regarding endogeneity is that an omitted variable may bias the measured impact of competition downward. This is based on the hypothesis that low quality TPS attract charters to compete with them, creating a spurious negative correlation between achievement at a TPS and its proximity to a charter school (Betts, 2009). Thus, basing measures of competition on factors that relate to the propensity for charters to locate around poor TPS (such as the % market share of charters around a TPS, distance from a TPS to the closest charter, the number of charters within a defined radius around a TPS, or the attrition rate from TPS to charters) could lead to endogeneity between these measures of competition and the outcome variable.

Our modeling approach addresses the issue of endogeneity in two ways. First, the control variable that distinguishes whether a TPS ever experiences competition is a measure of student attrition to charters, thus making the potentially omitted factor (i.e., the propensity to attract competition) explicit. By controlling for the differences between TPS facing high levels of attrition and those that do not, unobserved factors potentially associated with lower quality at certain TPS are made explicit. The inverse relationship between attrition and TPS quality found in Table 2 below suggests that endogeneity is a legitimate concern if not controlled for and that high levels of attrition are a good proxy for low TPS quality in D.C.

The second way this model limits the impact of endogeneity is by using a measure of competition based on the quality of charter schools rather than a measure related to charter location around a TPS. For our treatment variable to raise endogeneity concerns, one would have to presume a relationship existed between TPS quality and charter competitor quality. For example, if we thought that poor quality TPS attracted disproportionately high quality charter competition, this could bias the measured impact of competition downward. There is little evidence suggesting that low quality TPS invite disproportionately high or low quality charter competition.

Dependent Variable

The outcome of interest is one-year student-level growth at a TPS. We use student scores on the District of Columbia Comprehensive Assessment System (DC-CAS) for four academic years starting in 2005-06 to create measures of academic growth for three periods. Test scores were obtained from the Office of the State Secretary of Education (OSSE), along with demographic information on each student, their eligibility for special/alternative programs and information on the school(s) they attended in each year of enrollment.

The adoption of the DC-CAS program in 2005-06 limits the available number of years with comparable test results. To create a growth measure requires two years of test results for each student, which further limits our study window.

V. Description of DC Public Schools

This research is based on the market experience in Washington, DC. The city has the second largest charter sector in the country and was especially dynamic during the period covered in this analysis. The share of public school students enrolled in charter schools grew from 27 percent in the 2005-06 school year to 41 percent by 2008-09. Given the dramatic growth in the charter sector, DC is a defined and clearly contested market for public schooling.

This study uses student level data from 135 elementary and middle schools in the Washington D.C. public school system over the four year period from 2005-06 to 2008-09. Data for future years could not be included, as the individual student i.d.'s used to track students over time were changed in 2009 in a manner that prevented CREDO from creating a crosswalk between the years 2009 and 2010. TPS and charter schools were included, but schools devoted exclusively to special education were not. We have test score data for math and reading assessments from grades 3 through 8 for 26,000 student records. Although we use the student level charter school data to develop measures of school quality, we restrict our impact analysis of charter competition to only those students enrolled at TPS. In other words, we are testing the impact of charter competition on TPS, not on other charter schools. Our subset of TPS students is representative of TPS students in the district as a whole, as can be seen in Table 1 below.

Table 1: Selected Demographics from Traditional Public Schools: 0506 to 0809 (%)

Demographics	Included in Study	In D.C. Traditional Public Schools
Female	50.1	49.9
Special Education	16.6	18.1
Eng Lang Learner	7	7
Free/Red Lunch	71.2	64.6
Black	82.3	82
White	5.6	4.7
Hispanic	10.2	11.0
Asian	1.4	1.4
Native American	0.5	0.38

Table 2 below shows the average test scores[5] of all TPS in D.C., stratified by the level of attrition a TPS experiences to charter schools each year.

Table 2: Average Prior-Year Test Score at TPS by Level of Student Attrition to Charter Schools and Year of Attrition
(Values are in standard deviation units)

Attrition Rate	2006-2007	2007-2008	2008-2009
1% or less	.38	.68	.53
2% or less	.50	.29	.55
3% or less	.19	.28	.44
4% or less	.07	.16	.34
5% or less	.04	.06	.17
6% or less	.02	.06	.12
7% or less	.01	.03	.08
8% or less	.01	.03	.07
9% or less	-.01	.02	.02
10% or less	-.02	.01	.02
11% or less	-.03	-.01	.01
12% or less	-.03	-.01	.01
13% or less	-.03	-.02	.01
14% or less	-.03	-.03	.01
15% or less	-.04	-.03	.00

[5] These averages are generated from student scores on the District of Columbia Comprehensive Assessment System (DC-CAS) and are standardized at each grade level. An average z score of 0 in Table 1 implies that a TPS attained math and reading scores placing them exactly at the mean of all public schools in Washington D.C.

Table 2 shows that parents are at least somewhat sensitive to quality, given that poorly performing TPS experienced higher levels of attrition. This suggests that one necessary criterion for competition to function in the education market in D.C. is present. However, even though we find an inverse pattern between attrition rates and TPS quality, we do not know the direction of causality at work. Do poorly performing schools lose students at higher rates due to their lack of quality, or are the schools themselves poorly performing because of their higher rates of attrition? The use of lagged attrition rates in our empirical models limits the impact of this uncertainty.

In addition to the inverse relationship between TPS quality and student attrition discussed above, we believe there are other characteristics inherent to the D.C. education market that make it a good environment to study the impact of charter competition on TPS. Both the quantity and quality of competition for TPS appears to be on the rise throughout the sample period. Table 3 illustrates that while some schools remain untouched by charter competition throughout the study period, the overall impact of charter schools on TPS attrition is growing. The average attrition rate from TPS to charters climbed over the sample period and the proportion of TPS students in the most affected schools grew as well.

Table 3: Rates of Student Attrition from TPS to Charter Schools by Year

Year	Weighted Average Attrition Rate	Lowest Attrition Rate	Highest Attrition Rate
0506 to 0607	5%	0%	29%
0607 to 0708	6%	0%	24%
0708 to 0809	7%	0%	41%

Tables 4 and 5 display the overall quality of the charter school sector in DC, measured by average math and reading scores over the study period. The variability tracks well with the dynamics of the charter community, with many new schools opening each year and entering the performance measures as they post their results.

Table 4: Average Math Performance of DC Public Charter Schools by Year

Year	Mean Z Score	Standard Deviation
0506 to 0607	.02	.23
0607 to 0708	.29	.20
0708 to 0809	.20	.27

Table 5: Average Reading Performance of DC Public Charter Schools by Year

Year	Mean Z Score	Standard Deviation
0506 to 0607	.05	.21
0607 to 0708	.24	.17
0708 to 0809	.15	.25

The increasing rate of competition can also be seen in the number of TPS meeting each threshold of competition, measured by student attrition, which increased significantly over the sample period. This is in line with the rapid expansion of the charter sector as a whole in Washington D.C. over the sample period.

Table 6: Number of Schools Meeting Thresholds of Competition Based on Attrition Rates

Attrition Rate Threshold*	0506-0607	0607-0708	0708-0809
5% or more	53 (44%)	72 (60%)	78 (65%)
8% or more	23 (19%)	39 (33%)	49 (31%)
10% or more	12 (10%)	28 (23%)	33 (28%)
12% or more	8 (7%)	10 (8%)	25 (21%)
14% or more	6 (5%)	7 (6%)	22 (18%)

*Each threshold includes schools with attrition rates greater than or equal to the base rate.

IV. Results from DND Estimation

We ran four specifications of each model, each with a different threshold of student attrition used to create the control variable (i.e. the rate of attrition above which TPS are considered to be "feeling competition."). We use threshold rates of attrition of 5 , 8 , 10 , and 12 percent. This results in a nested and increasingly strict set of control conditions. Employing various thresholds of competition ensures the range of potential response mechanisms (of TPS to charter quality) across the district is not artificially limited and that non-linear responses can be detected.

The basic model uses control, treatment and DND variables lagged one growth period. For example, a student's growth rate from 2007-08 to 2008-09 would be modeled using the attrition rate of their TPS from 2006-07 to 2007-08. This lag allows TPS one year to respond to signals of competition robustly enough to affect student growth. This approach also avoids potential simultaneity between high attrition and low quality TPS.

The basic model presented below uses lagged student attrition to create the binary control variable "Competition Threshold" and uses *Average Charter School Quality* as the treatment. The binary treatment variable signals that the TPS faces an environment of strong charter competitors (Equal to 1 if the average quality of charter competition is greater than the district average). The primary variable of interest is the DND estimator *Average Charter School Quality DND*. Results appear in the tables below.

MATH

Variable	(5% att)	(8% att)	(10% att)	(12% att)
Competition Threshold	-.07**	-.03**	-.04**	-.05**
Average Charter School Quality	.01	.05**	.04**	.04**
Average Charter School Quality DND	.08**	-.02	.04**	.03
Enrollment Trend Index	-.06**	-.05**	-.05**	-.05**
Number of Competing Charters	-.004**	-.005**	-.005**	-.005**
	* sig at 5%	** sig at 1%		

READING

Variable	(5% att)	(8% att)	(10% att)	(12% att)
Competition Threshold	-.11**	-.08**	-.08**	-.04**
Average Charter School Quality	-.009	.03*	.02	.04**
Average Charter School Quality DND	.12**	.07**	.15**	.06*
Enrollment Trend Index	-.03**	-.03**	-.03**	-.03**
Number of Competing Charters	-.007**	-.007**	-.008**	-.007**
	* sig at 5%	** sig at 1%		

The impact of charter competition on math growth rates in TPS is either positive or insignificant in the model above, while the impact of competition on reading growth is positive and significant in every specification. Facing above average charter competition is associated with an increase in math growth scores ranging from 0.04 to 0.08 standard deviations, where significant. The impact on reading growth ranges from 0.06 to 0.12 standard deviations. Units of standard deviation do not have much meaning for the average reader. Transforming these results into more accessible units is challenging and can be done only imprecisely. Therefore, the results from the adjacent figure should be interpreted cautiously (Hanushek E., and Rivkin, S., 2006).

Growth (in standard deviations)	Gain (in months of learning)
0.00	0.0
0.05	1.8
0.10	3.6
0.15	5.4
0.20	7.2
0.25	9.0
0.30	10.8
0.35	12.6

Using the results from the table above, we see that facing above average competition is associated with roughly 1.5 – 3 months more growth in math per year at a TPS. TPS facing higher than average quality charter schools see gains in reading roughly 2 - 4 months greater than TPS that do not.

The trend of student enrollment is found to have a consistently negative and significant impact on both math and reading growth scores, ranging from -0.03 for reading to -0.06 for math. The number of competitor charter schools is also negatively related to math and reading growth in all specifications, although the impact of one additional competitor charter school ranges between -0.004 and -0.008 standard deviations. Compared to the impact of both the quality signals of competition sent by charters to TPS and of the overall enrollment trend at a TPS, the impact of the presence of each additional charter competitor is relatively small. These findings suggest that charter competition will provoke the largest response when 1) charter competitor quality is above average and 2) TPS enrollment is stable or declining.

V. Results from Fixed Effects Estimations

Given the novelty of the DND model employed, and it's limitations regarding attrition-based measures of competition, a student/school fixed effects estimation was also employed. The use of a fixed effects model serves two functions. The first is to test whether the DND model does in fact control for endogenous charter location and can provide an accurate measure of the impact of charter competition (to the extent that results from fixed effects estimation are to be treated as the "real" impact"). The second is to allow the inclusion of separate measures of competition based on student attrition from TPS to charter and charter quality as well as interactions of the two, which the DND model did not.

The model used is of the following form:

$$Y_{ijt} = \alpha + \beta_1(X_i) + \beta_2(S_j) + \beta_3(D_t) + \beta_4(Comp_{jt}) + \varepsilon_{ijt}$$

where

Y_{ijt} is the measured growth in test scores for each student *i* attending TPS *j* in year *t*,

X_i is a student fixed effect,

S_j is a school fixed effect,

D_t represents controls for grade and year,

$Comp_{jt}$ is the measure of competition for TPS *j* in year *t*, and

ε_{ijt} is an error term for each student *i* in TPS *j* in year *t*.

The addition of a school fixed effect accounts for unobserved time-invariant TPS factors, controlling for the endogenous charter location around TPS. Including student fixed effects controls for unobserved time-invariant student characteristics. Many studies find that including both student and school fixed effects separately create data sets too large to analyze and therefore combine each student/school interaction to form a single “spell effect.” Recent literature suggests that these approaches provide similar results, albeit with the “spell effect” models providing slightly larger standard errors (Nisar, 2012). We did not face any computational limitations and therefore estimate student and school fixed effects separately.

The fixed effects model presented below uses the same measure of competition employed in the DND specification above, *Average Charter School Quality*. This binary variable signals that the TPS faces an environment of strong charter competitors (Equal to 1 if the average quality of charter competition is greater than the district average) and is the primary variable of interest. Results appear in the table below.

Student/School Fixed Effects with Charter School Quality as the Measure of Competition

Variable	Math	Reading
Grade	-.31**	-.23**
Year	.004**	.003**
Average Charter School Quality	.07**	.05*
	* sig at 5%	* *sig at 1%

The impact of charter competition on math and reading growth rates in TPS is positive and significant in the model above. Converting the results from standard deviations to "months of learning" as before, TPS facing above average charter competition experience roughly 2.5 months more growth in math and 2 months greater growth in reading. These results are generally consistent with range of estimates provided by the DND model. In fact, the estimated impact of competition found using the DND model average slightly higher than that found using the fixed effects method, strongly suggesting that the DND specification does sufficiently control for endogeneity (which would be expected to downwardly bias the measured impact of competition).

Concerns with multicollinearity prevented us from exploring the impact of competition based solely on market share/attrition using our DND method. The fixed effects model outlined above allows us to test the impact of charter competition measured without consideration of charter quality, similar to much of the previous literature. Various "market share" measures of charter competition were tested including: the number of charter schools competing with each TPS (*# Competing Charters*), the percentage of students each TPS lost to charter schools (*% Attrition to Charters)* and the percentage of students each TPS lost to new charter schools (*% Attrition to*

New Charters). Each of these measures of competition are lagged one year to allow time for TPS to respond. Results appear in the table below.

Student/School Fixed Effects with Charter Market Share as the Measure of Competition

Measure of Competition	Math	Read
# Competing Charters	-.004	-.01
% Attrition to Charters	.005	.005
% Attrition to New Charters	.000	-.002
	* sig at 5%	** sig at 1%

The results above suggest that the simple presence of charter schools is not sufficient to invoke a response from TPS. This is true for both math and reading, and whether competition is measured by the number of competing charter schools or by the specific proportion of TPS students lost to charter schools each year. However, given that results from the previous models suggest that charter quality is an important factor in provoking a competitive response, might the impact of attrition be diluted in these models by the implicit assumption that attrition to the best and worst charters provokes the same competitive response? To test this proposition, CREDO estimated models to determine if including measures of attrition and charter quality impact the findings when included either as separate independent variables or as interactions with one another.

The measures of competition used below include the percentage of students each TPS lost to charter schools (*% Attrition to Charters),* a binary variable signaling that the TPS faces an environment of strong charter competitors (*Average Charter School Quality)*, and the mean z score of all charter schools to whom a TPS loses students *(Mean of Charter Z Score).*

Student/School Fixed Effects with Attrition to Charters and Charter Quality as Measures of Competition

Measure of Competition	Math	Read
Average Charter School Quality	.06**	.05**
% Attrition to Charters	.004*	.002
	* sig at 5%	** sig at 1%

Measure of Competition	Math	Read
Mean of Charter Z Scores	.04*	.18**
% Attrition to Charters	.001	.002
	* sig at 5%	** sig at 1%

The inclusion of both attrition and a measure of charter quality in the same model do little to alter the results. In both models, attrition to charter schools is still insignificant, while the measures of charter quality are again found to have positive and significant impacts on student growth in TPS. Facing higher than average charter competition is found to provide nearly identical impacts to those found in the model above with *Average Charter School Quality* as the sole explanatory variable. Results found using the continuous measure of competition, *Mean of Charter Z Score,* suggest that a 1 s.d. improvement in the average quality of charter competition is associated with approximately 1.5 months of additional growth in math and 6.5 months of additional growth in reading for students in TPS.

Additional models were run to gauge the sensitivity of TPS to charter quality. Quartiles of both attrition and charter quality were created and then interacted, resulting in 16 separate measures of charter competition. For example, the dummy indicating maximum competition would be assigned to TPS facing charter competitors in the top quartile of quality and an attrition rate in the top quartile as well. Multiple versions of these models were run, all leading to the same basic conclusion; charter schools do not appear to be sensitive to relatively minor variations in charter quality, but quality does appear to be the primary driver of competition, not attrition rates. This is evidenced by the fact that the response to increasingly higher quality charter competition (moving "up" the chart) becomes more positive in most cases, while higher levels of attrition (moving "right" on the chart) does not. An example for both math and reading is shown below.

TPS Reading Growth by Attrition to Charters and Charter Achievement

Standard Deviations	Low Attrition High Charter Ach.	*25th Pctile*	*50th Pctile*	*75th Pctile* High Attrition High Charter Ach.	
	0.12**	0.03	0.05**	0.03	*75th Percentile*
	0.13**	-0.00	-0.00	-0.02	*50th Percentile*
	-0.21**	-0.08**	N/A	-0.14**	*25th Percentile*
	-0.15**	-0.12**	-0.11**	-0.13**	

TPS Math Growth by Attrition to Charters and Charter Achievement

Standard Deviations	Low Attrition High Charter Ach.	*25th Pctile*	*50th Pctile*	*75th Pctile* High Attrition High Charter Ach.	
	0.17**	0.06**	0.06**	0.11**	*75th Percentile*
	0.08**	0.08**	0.02	-0.04*	*50th Percentile*
	0.15**	0.03	N/A	-0.05**	*25th Percentile*
	-0.10**	-0.08**	0.02	-0.11**	

VI. Conclusions and Open Questions

This study explored the use of specific information about the competitive environments surrounding each TPS to examine the degree to which they react to the competition that charter schools provide. Despite the availability of fine-grain data on the schools and their experiences over time, this study brings into clear relief the challenges with creating robust models of competition in public education markets. The major impediment lies in the limited number of ways to tease out the cause and effect of competitive stimuli. The DND model is useful as a confirmation of the more common student/school fixed effects approach, as it employs both a different econometric strategy to control for the endogenous location of charter schools as well as a different identification strategy to tease out the causal relationship between charter competition and TPS student growth.

The findings from both the DND and fixed effects models suggest that TPS are sensitive to charter quality, though this is more obvious when the signal of quality is fairly blunt. Indeed, it is likely that by keeping the measure of competition simple, the quality signal is invoked under more limited conditions and is therefore clearer. Findings from the fixed effects models also suggest that simple competition from charters of varying quality does not promote a competitive response among TPS, or at least the noise introduced into this measure of competition by failing to control for variations in quality dilutes the positive competitive impact supplied by high quality charter schools. This may partially explain the mixed results found in previous literature, given that all prior attempts to capture the impact of charter competition do not consider the quality of the charter sector (to our knowledge). It is possible that studies which find a positive response to competition are simply evaluating environments with relatively higher quality charter competition.

It is also important to note the robustness of our findings across each specification of the basic DND model (using *Average Charter School Quality* as the treatment). Whether the threshold of student attrition used was 5%, 8%, 10%, or 12%, the measured magnitude and direction of competitive impacts were generally consistent, not only for our DND estimator but also for variables measuring the impact of both enrollment trends at each TPS and the number of competitor charter schools. Rapidly increasing enrollment at a school can put significant strain on financial and human capital resources, which may explain the negative and significant relationship between TPS enrollment trends and student growth.

A significant limitation of our analysis is the number of competition → response cycles we were able to observe. With only four years of testing data for DC, given the lagged nature of the models, we are only able to follow the experience of TPS for at most two iterations of the attrition → signal → reaction cycle. With additional years of data, it may be possible to discern more subtle behavior on the part of TPS. Additional years of data would also allow us to explore the cumulative impact of competition on TPS, as well as allowing expanded variable selection (e.g. 2 year lagged variables, etc.) In addition, exploration of the underlying relationship between attrition rates from TPS to their charter competitors and the relative quality of their competition is needed.

Expanding this analysis to other markets would allow us to determine if the underlying market structures necessary for competition to function exists in other educational landscapes, as it appears to in D.C. The development of our model to measure the impact of competition, and subsequent exploratory analysis, has led to some interesting observations. We have shown that it is possible to develop an empirical model that simultaneously controls for the potential endogeneity of charter location and TPS quality while avoiding the inherent limitations to fixed effects estimation and the challenge of finding a suitable instrument across many education markets, although this approach has its own limitations. It is also clear that the competition provided by charter schools is multi-faceted and acts across various channels that this paper has just begun to explore. Our results also suggest that the interests of the charter and TPS sector may in fact overlap; a focus on quality in the charter sector may lead to positive competitive impacts in the TPS sector as well, a result less likely if the local charter sector is of middling quality. Given the occasionally contentious relationship between TPS and charter schools, and the significance this issue will gain as the charter market continues to grow, identification of mutual interests between the two sectors should be treated as welcome news, particularly to advocates of quality in the charter sector.

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