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# Incentives and the Supply of Effective Charter Schools\*

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## Abstract

Charter school funding is typically set by formulas that provide the same amount for all students regardless of advantage or need. In this paper, I present evidence that this policy skews the distribution of students served by charters towards low-cost populations by influencing where charter schools decide to open and whether they survive. I develop and estimate an empirical model of charter school supply and competition to evaluate the effects of funding policies that aim to correct these incentives. To do this, I recover estimates of cost differentials across student populations by linking charter school effectiveness at raising student achievement with unique records of charter school expenditures gathered from Florida. I then leverage revealed preference with the exit and location choices of charter schools in an entry game to uncover how charter schools respond to competitive and financial incentives. The results indicate that a cost-adjusted funding formula would significantly increase the share of charter schools serving disadvantaged students with little reduction in the aggregate effectiveness of the sector.

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# 1 Introduction

School choice reforms aim to improve school quality while expanding educational opportunity. In the United States, charter schools have become the primary vehicle for school choice, with a number of recent papers finding compelling evidence that charter schools are effective at improving student outcomes (Hoxby and Murarka, 2009; Abdulkadiroğlu et al., 2011; Angrist et al., 2013a; Dobbie and Fryer, 2013). These findings have bolstered recent policy momentum behind charter schools, such as the Obama Administration’s Race to the Top, which is based in part on the belief that removing barriers to expansion will lead new, high-performing charter schools to serve underserved student populations.

Two common institutional features of the charter sector call this belief into question, however. First, charter schools, which are publicly funded but privately run, are typically funded by formulas that provide the same amount for all students regardless of advantage or need. Second, although charter schools are unable to screen students, they are differentiated by where they choose to locate and, due to travel costs, serve student compositions that closely reflect local demographics. Taken together, these features raise the question whether the current approach to funding skews the distribution of students served by charters towards low-cost student populations by influencing where charter schools decide to open and whether they survive.

To answer this question, I develop and estimate an empirical model of charter school supply and competition. The estimated model allows me to study counterfactual funding policies, in particular a formula that ties revenue to the characteristics of students, in terms of equilibrium sector outcomes. In the model, charter schools choose a location in a school district based at least partly on expected revenues, which depend on enrollment and the statutory per-pupil funding rate, and costs. As variable costs depend on the composition of students served, the flat formula potentially presents a strategic incentive for new charter schools to spatially “cream skim” and creates differential likelihood of survival of incumbents. At the same time, due to competition with public and other charter schools for students, the exit and location choices of charter schools are mutually dependent in the model. I thus adapt the structure of an incomplete information entry game.

This research design requires an institutional setting where the location choices of charter schools

reflect their competitive and financial incentives and where those incentives can be measured in order to apply revealed preference. In this regard, Florida, which is characterized by limited authorization discretion for districts and an accordingly high charter penetration rate, is especially well-suited. I assemble a unique dataset that links detailed financial records gathered from independent audits filed by all Florida charter schools with student performance on end-of-grade state exams and school characteristics. I estimate school value-added or effectiveness at raising student achievement from the panel of student test scores, while the financial statements of charter schools enable me to separate cost from demand-side determinants for a charter school's choice of location in the data.

I use the empirical model to evaluate the effects of funding policies on the composition of students served and the aggregate effectiveness of the charter sector. This latter outcome, which is sensitive to competitive incentives, is important for capturing a key policy tradeoff: funding policies that raise equity may do so by sustaining ineffective charter schools in the market. Three policy simulations are of interest: First, a cost-adjusted funding formula that ties revenue to student characteristics corrects the financial incentives to skim. I use this counterfactual to answer whether the current funding approach has unintended consequences. Second, targeted grants for entry into underserved markets may also incentivize charters to serve disadvantaged student populations. Lastly, a general increase in the per-pupil funding rate quantifies the elasticities of charter school supply and effectiveness with respect to funding. The predictions thus shed light on the value of expanded social investment in charter schooling.

Estimation of the model presents a number of empirical challenges. In a first step, I estimate the incentive structure of charter school operation, shaped by demand and variable costs, from the data. To do so, I apply a value-added production function to recover school effectiveness, which shifts household demand, from the test score panel. On the supply side, I link effectiveness with charter school expenditures, which I obtain from the financial audits, to estimate variable costs as a function of location and student characteristics. Finally, treating charter schools as not-for-profit maximizers, I leverage revealed preference with their exit and location choices in the entry game to uncover how charter schools respond to competitive and financial incentives and connect these choices to equilibrium aggregate outcomes. As the entry model contains a large state space due to

rich heterogeneity across charter schools and a large number of locations for entrants to choose from, I implement a computationally light, two-stage estimator that uses choice probabilities estimated semi-parametrically offline.

The policy simulations reveal evidence that the flat funding formula leads charter schools to underserve disadvantaged student populations. Implementing a cost-adjusted funding formula yields about a 4% increase in the share of subsidized lunch students and a 9% increase in the share of black students attending charter schools. In addition, because the charter schools sustained in the market by this policy change are not low effectiveness schools, this gain in equity is associated with little change in the aggregate effectiveness of the charter sector. By comparison, a location targeted start-up grant successfully shifts the location choices of new charter schools to underserved areas, but yields little net change in outcomes. Furthermore, though the total number of charter schools predictably increases, aggregate effectiveness responds only marginally due to an overall increase in charter school funding. This reinforces the general finding that gains in access to school choice do not appear costly in terms of the quality of charter schooling.

These findings are important as they are informative about school choice policy. In particular, a mismatch between funding and costs may generate significant inequities in access to and benefits from school choice. This point, which is largely unrecognized in both the existing literature on education markets and ongoing policy debate, has potentially broad implications for the design of school choice programs. The findings also underscore that funding policy, an element of both private school voucher and charter school programs, may provide an effective policy instrument for directing competition via supply-side incentives.

The remainder of this paper is organized as follows. In the next section, I situate the paper in the relevant literature. In Section 3, I describe the institutional setting of charter schooling in Florida and data sources in detail. I present the empirical model in Section 4. Section 5 then discusses estimation and identification of the model before I turn to the results, including estimates and counterfactual simulations, in Section 6. I conclude in Section 7.

## 2 Related Literature

School choice reforms embody two policy ambitions. The first is to enhance the quality of public education. Mechanisms supporting this include both direct access to better school alternatives for students and improvements in school quality stimulated by competition. The second ambition is to expand educational opportunities for underserved students. The growing empirical school choice literature, which combines evidence from international and domestic school choice programs (often private school vouchers and charter schools, respectively), can be viewed as attempts to assess the ability and conditions under which school choice policies may fulfill these ambitions.

A major strand of literature evaluates the effectiveness at improving student outcomes of school alternatives supported by school choice policies. Examples include evaluations of private schools and voucher programs, which in general find positive effects of private school attendance.<sup>1</sup> Evaluations of charter schools typically rely on either student-level administrative data or on admissions lotteries. Papers that estimate charter school effects from changes in exam performance for students who switch between sectors find largely mixed results overall (Sass, 2006; Hanushek et al., 2007; Booker et al., 2007).<sup>2</sup> On the other hand, lottery designs provide compelling evidence of improvement in student outcomes (Hoxby and Murarka, 2009; Abdulkadiroğlu et al., 2011; Angrist et al., 2013a; Dobbie and Fryer, 2013), and the benefits of charter school attendance appear highest for students from disadvantaged backgrounds (Angrist et al., 2012, 2013b).<sup>3</sup> These findings have partly motivated policy efforts to expand charter schooling.<sup>4</sup>

Charter expansion, though, raises questions about the role of competition in education markets. To the degree that households value school quality, school choice creates competitive incentives intended to enhance the quality of public education. This rationale, for instance, is explicitly written in to a number of charter laws, including Florida's. One mechanism for this may be that school choice induces government and public schools to improve. Neilson (2013), for example, studies an

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<sup>1</sup>In the U.S. context, a number of authors have examined the effectiveness of Catholic private schools (Neal, 1997; Altonji et al., 2005). International evidence, relying on lottery designs, finds largely positive impacts of attending private schools (Angrist et al., 2002, 2006; Muralidharan and Sundararaman, 2015).

<sup>2</sup>Similarly, CREDO (2009) uses matching techniques with student level-data from fifteen states and D.C., finding considerable heterogeneity in average charter quality.

<sup>3</sup>A major limitation of lottery designs, however, is that they can only be applied to evaluate oversubscribed charter schools.

<sup>4</sup>Beyond school outcomes, papers using both methods have also examined medium and longer term impacts, such as college completion and labor market returns. See Epple et al. (2015) for a recent review.

expansion of a private school voucher program in Chile, finding an increase in the quality of public schools in response. Papers examining the competitive effects of charters on public school quality, on the other hand, find ambiguous results.<sup>5</sup> Competition may nonetheless discipline the quality of school choice alternatives. Baude et al. (2014) present evidence of improvements in charter school quality in Texas over a ten-year period due to the exit and replacement of low-performing charter schools.

At the same time, scholars have long recognized the potential for school choice policies to generate inequities, compromising the second ambition. While households choosing schools based on characteristics other than school quality will tend to weaken competitive incentives, heterogeneity in preferences may also lead to stratification (Hastings et al., 2006; Bayer et al., 2007). Weiher and Tedin (2002) present evidence that racial composition predicts households' choice of charter school and Bifulco and Ladd (2007) attribute widening black-white achievement gaps to sorting along racial lines. Such patterns raise the question whether differences across households in the exercise of school choice enables the re-segregation of education.<sup>6</sup> Moreover, how households choose schools and the extent to which preferences for quality vary have supply-side implications that may cut against policy goals. Walters (2014) presents evidence from Boston that although disadvantaged students are most likely to benefit from charter schools, they are significantly less likely to apply and attend.

The role of costs in shaping outcomes remains largely neglected by both of these strands of literature, however. Costs, which influence the supply of school choice alternatives, are important for two reasons: First, fixed costs of entry may undermine competitive incentives by, for instance, leading to excessive or insufficient entry (Spence, 1976; Dixit and Stiglitz, 1977; Mankiw and Whinston, 1986). School choice is only effective if school alternatives are available and underperforming schools face competitive pressure. Second, costs may be an independent source of disparities in education outcomes by generating inequities in access to school choice.<sup>7</sup> With differences in the cost

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<sup>5</sup>For example, Sass (2006), Booker et al. (2008), and Winters (2012) report positive, if modest, effects, but Bettinger (2005), Bifulco and Ladd (2006), and Zimmer and Buddin (2009) find no competitive effects. Using an IV strategy to overcome endogenous charter location, Imberman (2011) finds mixed or even negative effects.

<sup>6</sup>More recently, Ladd et al. (2015) show that apparent improvements in charter school performance in North Carolina may be driven primarily by positive student selection.

<sup>7</sup>On this point, Denice and Gross (2016) find that apparent differences across demographics in preferences for academic performance are explained by differences in nearby supply.

of providing education to disadvantaged students (Duncombe and Yinger, 2005), such inequities may stem from program funding that provides the same amount for all students. In recognizing and quantifying the effects of this incentive, this paper thus has parallels with the literature on cost-based cream skimming in health care markets (Ma, 1994; Currie and Fahr, 2005) and advances the literature on estimation of education costs by linking cost differentials to school behavior and the design of school choice policy (Downes and Pogue, 1994).<sup>8</sup>

In this paper, I estimate the full cost structure of charter schools, which includes entry costs and operating cost differences across student populations. The empirical entry model I develop then allows me to connect education market equilibrium outcomes with funding policy through the strategic location choices of charter schools. In adapting these methods to my setting, the paper fits into the growing empirical literature using these methods to analyze policy questions (Berry and Reiss, 2007). Limited prior work has examined the determinants of charter school supply and location, such as Glomm et al. (2005) and Hoxby (2006), but these studies take a descriptive approach that is unable to separate demand from cost determinants and does not permit studying counterfactual policy changes. In work related to my approach, Ferreyra and Kosenok (2015) model demand for and entry of charter schools in Washington D.C., finding prospective welfare benefits of expansion, but do not model or consider the implications of strategic behavior by charter schools.<sup>9</sup> In addition, this paper differs in focusing on how policies affect the equilibrium quality of charter schooling, which I am able to measure in value-added terms from the panel of student test scores.

### 3 Background and Data

I describe the institutional background of charter schooling in Florida in this section to highlight the features that make it well-suited to studying charter school supply and competition. In particular, Florida, by limiting discretion of school districts when authorizing new charter schools, provides a setting in which charter schools' entry and location choices reflect their competitive and financial incentives and where those incentives can be measured.

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<sup>8</sup>Relatedly, targeted private school vouchers have been studied as a means of minimizing cream skimming due to peer-based externalities in education production (Nechyba, 2000; Epple and Romano, 2008).

<sup>9</sup>Also related, Mehta (2012) models competition between charters and public schools in North Carolina, but does not incorporate student heterogeneity nor consider its supply-side implications for policy.

The unique dataset I assemble combines detailed records gathered from financial audits filed by all Florida charter schools with student performance on end-of-grade exams and school characteristics. The merged panel facilitates estimating cost differentials across student populations from the relationship between expenditures, student composition, and gains in student achievement across charter schools. In addition, school locations are key as a choice variable for charters and for calculating the spatial distances between schools. After describing the institutional background and data sources for the panel, which tracks charter schools between the 2006-7 and 2012-13 school years, I also present summary statistics in this section.

### 3.1 Charter Schooling in Florida

Laws authorizing charter schools aim to strike a balance between operational autonomy and accountability. For instance, charter schools are generally granted considerable independence in terms of curricular design and focus, human resources, and choice of location. To ensure equity, however, charter schools may not screen students or apply any admissions criteria, such as tuition or entrance exams. If a charter school is oversubscribed, an admissions lottery must be held to randomly allocate places in the school. Further, charter schools are not exempt from state accountability and reporting requirements. Florida charter schools, for example, must participate in the School Grades program which assigns letter grades to schools based on student performance on end-of-grade exams.<sup>10</sup> While accountability provisions require intervention in cases of persistently poor performing charters, instances of forced shutdown are relatively rare. A Center for Education Reform report, for example, found that just 18% of charter closures nationally were attributable to academic reasons (Consoletti, 2011).

Although the level varies by state or district, charter school funding typically provides the same amount for all students served by a school. For example, Florida charter schools receive per-pupil disbursements through the Florida Education Finance Program (FEFP) according to a statutory formula. A base funding rate for each full-time equivalent student is multiplied by a district cost differential and totaled. While additional cost adjustments are made for disabled and English language learner students, charter school enrollment of these student populations is low.<sup>11</sup> This

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<sup>10</sup>The School Grades program accounts for both achievement and learning gains.

<sup>11</sup>The median charter school's student body is around 9% disabled and 3% English learners in my sample. This

funding source may be supplemented by federal programs, such as Title 1, other state sources, or private contributions, but the FEFP program provides the vast majority of operating support for charter schools.<sup>12</sup> The implication of this is that two charter schools serving student populations with different educational needs or advantages, but located in the same school district, will receive largely the same per-pupil support.

Charter schools are authorized by public school officials. In this regard, Florida’s distinctive institutional environment provides a number of advantages for studying charter school supply and competition. First, in contrast with a number of other settings such as Massachusetts and Washington D.C., caps on the number of schools are not and have never been in place. Second, school districts, which are coterminous with counties in Florida, retain sole authorization responsibility. This ensures that accountability standards are uniform for large, well-defined education markets that contain significant internal heterogeneity, such as both rural areas and urban centers.<sup>13</sup> Finally, Florida statutes spell out the criteria that school districts may apply in reviewing applications for new charter schools. A prospective charter school must outline its guiding principles and objectives, an “innovative” curriculum that meets state requirements for reading instruction, and a financial plan. This authorization process thus differs dramatically from other settings. A prospective new charter school in Massachusetts, for example, competes with a number of other applicants for authorization and is vetted based partly upon perceived need and expected success. In contrast, Florida provides a setting in which the entry and location choices of charter schools can be viewed as reflecting revealed preference.

The combined effect of Florida’s charter-friendly environment is a vital charter sector, characterized by both rapid growth and significant turnover. The first Florida charter schools opened for the 1996-7 school year. Since then, the sector has expanded into one of the largest nationwide in both enrollment terms and the number of charter schools. For the 2014-15 school year, 646 charter

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compares to 14% and 5% respectively for the median public school in Florida. Recent evidence indicates this enrollment gap is explained by the combination of a lower baseline probability to apply and a reduced likelihood of special education classification in charter schools (Setren, 2016; Winters et al., 2017; Winters, 2015).

<sup>12</sup>Charter schools are not considered separate Local Education Agencies in Florida and may receive capital funding or apply for state grants, but these account for little of operational revenues. Florida school districts are not required to share local revenues with charters and almost all do not. However, because Florida’s school finance system is largely centralized through FEFP, charters are less disadvantaged in funding relative to public schools than in many other states.

<sup>13</sup>In general, students may only attend in-district charters in Florida.

schools served over 8% of all Florida public school students, including more than 13% in Broward and Miami-Dade counties. In addition to the high penetration of charter schooling in Florida, there is a great deal of entry and exit. For instance, 75 new charter schools opened just for the 2013-14 school year, while 38 shut down and closed.

### 3.2 Data Sources

I combine newly collected financial records for Florida charter schools with existing data on all Florida public schools. Per Florida statute, all charter schools must file an independent financial audit with their district and the state for each year of operation. Containing revenue, itemized expenditures, assets, and capital investment, the audits richly characterize the spending patterns and financial health of each charter school. I gathered and digitized all audits on file with the Auditor General for the 2006-7 through 2012-13 schools years. As a source of financial data, the audits provide two added advantages (beyond their availability): (1) the audits correspond to an individual school year rather than a fiscal year; and (2) an audit must be filed for each individual school.

I use reported total expenditures to measure the variable costs of charter school operation in a given year.<sup>14</sup> These costs therefore include salaries paid to teachers, staff, and administrators, facility rent or mortgage payments, and any management fee paid, among other expenses incurred during a school year. In using expenditures to measure variable costs, two points of clarification are important: First, these expenditures represent variable costs in that they reflect annually adjustable input purchases and exclude the opportunity costs of entering the market and of operation (which inherently cannot appear on an accounting statement). As explained later, such sunk or fixed “costs” are identified from the entry and continuation decisions of charter schools. Second, the expenditures reported in the audits are not necessarily costs at the frontier (i.e. the costs that would be incurred were a charter school efficient in its input usage). Rather, the expenditures embed any allocative inefficiency, presenting a potential challenge for identification.

Three data sources provide information about the characteristics of Florida charter and public schools. First, I obtain enrollment, grade level, and student body characteristics for all schools

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<sup>14</sup>I subtract out large capital purchases, such as outlays for buildings or facilities.

from the National Center for Education Statistics' Common Core of Data for the 2006-7 through 2013-14 school years.<sup>15</sup> I define a school as open (i.e. operational) if enrollment in any primary grade (K through 5) is positive and calculate the number of years since opening for each charter school. Second, I merge these records with the Florida Department of Education's master school database. This database is used to identify schools as a charter school or not per state records and to obtain each school's exact address.<sup>16</sup> The last data source for school characteristics pertains to their locations and spatial relationship. I geocode the school addresses to 2000 Census tracts, for which I obtain American Community Survey estimates of the local demographics.<sup>17</sup> This is important as it allows me to relate the composition of each school's student body to the composition of the tract where it is located. The spatial distances between tracts also allow me to identify each school's set of competitors.

Finally, I obtain summaries of student achievement by school and grade on end-of-grade Florida Comprehensive Assessment Tests (FCAT) from the Florida Bureau of K-12 Assessment for years 2006-7 through 2013-14. Students attending charter and public elementary schools in grades 3 through 5 are examined in math and reading. For each tested grade in a given year, the data contain both the average current score and average prior year's score by grade and school for the set of students for whom records for both years are available.<sup>18</sup> Since testing begins in the third grade, I use only fourth and fifth grade performance to have a measure of prior learning for all grades. These score averages, which I normalize across schools within grade and year, allow me to estimate the value-added or effectiveness of each school at raising student achievement. I describe the specification and estimation of education production fully later.

My final merged panel tracks 341 charter elementary schools in Florida between the 2006-7 and 2012-13 school years. I restrict the sample to non-conversion and non-municipal charter schools, charter schools that are not a virtual school or laboratory school, and charter schools not specialized

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<sup>15</sup>For grade-level demographics, subsidized lunch, English language learner, and disabled status, I supplement these data with FCAT Demographic Reports.

<sup>16</sup>A limitation of this data source is that only the present address of charter schools is recorded, so I do not observe moves or model charter school location changes.

<sup>17</sup>I use 5-year Census tract estimates for 2005-9 through 2009-13, treating the middle year as corresponding to the spring of that school year. I impute data for 2012 and 2013. I then calculate location characteristics within a given distance of each Census tract using distances between centroids and population weights.

<sup>18</sup>Thus, students not in a Florida public or charter school the prior year are not included in the average. Importantly, the prior scores may have been obtained at another public or charter school if a student switched schools.

in serving disabled student populations. 193, or 57%, of the charter schools began operation during the seven year sample period, while 67 (20%) exit at some point. The median charter school is tracked for four school years.<sup>19</sup> Included in the sample are also all traditional public elementary schools in Florida.

### 3.3 Preliminary Evidence

In this subsection, I present preliminary evidence that suggests that cost differences not reflected in statutory funding formulas influence charter school supply. To begin with, I compare the location and student characteristics of charter schools in Florida with public schools in Table 1. Concerns that charter schools underserve disadvantaged students may be largely misplaced if, as the literature suggests (Epple et al., 2015), charter schools tend to serve more urban areas and minority student populations. However, such comparisons are typically made across education markets, rather than within them. In Florida, for example, many low population and rural school districts have no charter schools at all, potentially biasing the comparison. Florida charter schools As a result, I compare charter and public schools that are located in the same school district, which defines an education market in Florida.<sup>20</sup> The resulting comparisons in Table 1 reveal that, charter schools actually operate in less dense locations and serve a slightly larger share of students who are non-minority on average than public schools located in the same school district.<sup>21</sup>

A complementary approach to assessing the importance of cost differentials would potentially be to examine, similar to Glomm et al. (2005) and Hoxby (2006), the determinants of charter school presence in a market or location. The value of this exercise, however, is limited because many determinants, principally the demographic mix, simultaneously influence charter school presence through both demand and costs (variables and fixed). Instead, I propose a test based on whether an incumbent charter school continues or exits from the market: with a flat funding formula, cost differentials predict that, all else held equal, exit should be associated with the characteristics of the student population a charter school serves. This exercise thus leverages a charter school's

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<sup>19</sup>I am able to match expenditure data for 92% of charter school-year observations. The match rate is particularly low in the school year that a charter school closes, however.

<sup>20</sup>I regress each variable on district fixed effects, then use the residual (plus the constant for Palm Beach) for the comparisons. In the Appendix, I provide summaries for just charter schools in the 2012-13 school year.

<sup>21</sup>While charters also serve a lower share of students who are eligible for subsidized lunch, this likely reflects in part differences in participation and takeup across the two sectors.

enrollment (in combination with the funding formula) to implicitly condition on expected revenue, using the independent variation in enrolled student composition to proxy for cost differentials.

Before performing this test, I first present summary statistics in Table 2 that compare charter schools that ever exit during the sample with those that persist (i.e. are either open in 2007-8 or open at some point after, but do not exit by 2012-13).<sup>22</sup> Indicative of the importance of location and travel costs, the summaries show a close correspondence between the characteristics of charter schools' locations and the characteristics of students they serve. Additionally, the comparisons also reveal a number of striking differences between exiters and persisters. In particular, the locations of charter schools that exit are higher density and much lower income on average (about \$16,000 less mean household income). Accordingly, the average exiter charter school serves a 21 percentage point larger share subsidized lunch student composition. Exiters also serve a 37 percentage point larger share black student composition on average.

Table 3 compares exiter and persister charter schools in terms of expenditure per pupil and student performance on end-of-grade exams. The comparisons reveal that charter schools that exit spend nearly \$900 more per pupil (approximately 10% of total expenditure) per year than those that persist in the sample. In terms of achievement in math and reading performance, students attending exiter charter schools perform dramatically worse on average. The average math score for exiter charter schools, for example, is nearly 1 standard deviation on average below that of persister charter school. Nonetheless, these comparisons are ambiguous about the mechanisms structuring the education market. For instance, though exiters both serve more disadvantaged student populations and spend more per pupil on average, this association may be explained by where they locate rather than cost differences across student populations. Similarly, the large differences in student test performance may indicate differences in effectiveness at raising student achievement, consistent with market efficiency, or just reflect the differences in socioeconomic advantage between students attending exiter and persister charter schools

To get at the possible role of cost differentials, the proposed test thus examines how characteristics of the student population a charter school serves predict exit from the market. Such an association

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<sup>22</sup>To do this, I use the full panel to compute conditional averages for exiter and persister charter schools and test for statistical differences by regressing each variable on indicators for exiter, persister, and entrant, age, dummies for the year a school enters or exits, and year fixed effects.

would be consistent with cost differences across student populations not reflected in the statutory funding formula. To implement the test, I estimate linear probability models of the form:

$$Exit_{it} = \beta f(\mathbf{Z}_{it}) + \gamma X_{it} + \epsilon_{it} \quad (1)$$

In this equation,  $Exit_{it}$  is an indicator variable for whether charter school  $i$  exits the sample between period  $t$  and  $t + 1$  and  $\mathbf{Z}_{it}$  represents the characteristics of the student body at charter school  $j$ , including demographics and free or reduced price lunch status. These characteristics proxy for differences in socioeconomic status, household wealth, and other sources of advantage. I use  $f()$  to indicate that I allow for nonlinearities (interactions and quadratic terms) in the percentage of each student group in the specification.  $X_{it}$  is the set of control variables, including characteristics of the school’s location, the charter school’s age, measures of local competition, enrollment, and reading test scores. Importantly, expenditure per pupil is not included as a control because costs are the channel through which student characteristics are proposed to affect exit.  $\epsilon_{jt}$  represents a mean-independent error term. Table 4 presents the results.

The estimates in column (1) indicate that a 10 percentage point increase in the share of black students attending a charter school is associated with a 0.02 point increase in the probability of exit, all else held constant. This magnitude represents a nearly 50% increase in the exit probability from the baseline level. The share of Hispanic students is not statistically associated with exit, while the share of Asians student is negatively related. Reflecting significant collinearity with the demographic shares, the composition of free and reduced price lunch is not significantly related to exit.<sup>23</sup> By conditioning on enrollment, which proxies for expected revenues, column (2) implements the proposed test. The share of black students remains positively associated with exit and of similar magnitude, while the marginal effect of the share of Asian students does not differ from 0 at the 95% significance level. Finally, column (3) also controls for the reading achievement of students. While this control attenuates the estimate by around half, the the marginal effect of the share of black students on exit remains statistically and economically significant.

These results provide indirect evidence for the presence of cost differences across students that

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<sup>23</sup>While not reported, the shares of special education and English language learner students, which are also controlled for, do not predict exit. This is consistent with these being recognized categories of student need by the funding formula.

are not reflected in the funding formula. Nonetheless, these results are not able to rule out unobserved differences across schools that may influence survival, including differences in value-added or effectiveness. Moreover, applying this interpretation presumes that student characteristics shift costs and, further, that charter schools respond to those differences. The empirical model, which I describe in the next section, aims to directly quantify these mechanisms by, respectively, estimating variable costs across student populations from the expenditure data and applying revealed preference to exit and the location choices of new charter schools in an incomplete information entry game. These sources of evidence facilitate establishing the extent to which funding policy may skew the distribution of students served by charters towards low-cost student populations as well as evaluating counterfactual policies in terms of equilibrium sector outcomes.

## 4 Empirical Model

This section presents the empirical model of charter school supply and competition that I develop to study the effects of funding policy on equilibrium sector outcomes. Absent suitable empirical variation in funding policy, the model links the competitive and financial incentives of charter schools with their location and operation choices to apply revealed preference. For this purpose, there are two key elements of the model: First, I allow charter schools to differ in their effectiveness at raising student achievement (i.e. value-added), which is valued by households on the demand side. This allows for competition to drive ineffective charter schools from business and for assessing the effects of funding policy on the aggregate quality of the charter sector. Second, the variable costs of operating a charter school depend on the characteristics of students served. As a result, given the statutory funding formula, new charter schools may strategically locate to attract fewer costly-to-serve students and incumbents' survival may be linked to differences in the needs or advantages of the students they serve.

The basic building block of the model is an elementary education market, which I consider to be a school year and district combination. In each market, the following sequence occurs: First, incumbent charter schools – those in operation during the prior school year – decide whether or not to exit. Simultaneously, a pool of potential entrant charter schools decide whether to open for

the school year and, if so, on a location in the school district. These choices, predicated in part on expected revenues (which depend on the per-pupil funding rate) and costs, define the set of active schools from which households may choose. Households then choose a school to attend at the beginning of the school year. Given enrollments and the effectivenesses of schools in operation, variable costs and student achievement are realized at the end of the school year.

Charter schools' entry and exit choices are made in an incomplete information setting. Given the payoff-relevant information summarized by a commonly observed state vector, charter schools' choices constitute a Bayesian Nash equilibrium. The state vector then evolves between periods as a result of those choices. I adapt this basic entry game setup in a few ways for my setting. First, competition contains a spatial dimension and entering charter schools choose a location, which is characterized as a bundle of expected enrollments and costs. Second, I treat charter schools as not-for-profit maximizers that may behave as if they value output and effectiveness along with net income. Charter schools are characterized by their effectiveness at raising student achievement, profit status, age, and incumbency status in the model.

While the model endogenizes the composition of students served by charter schools (via location choices and demand) and the aggregate effectiveness of the charter sector (through differential survival), I abstract from other aspects of the education market. For instance, though they compete for students with charter schools, the locations and effectivenesses of public schools are treated as exogenous.<sup>24</sup> Additionally, while entry and exit dynamics may shift effectiveness in the aggregate, I do not model changes in effectiveness over time at the school level. Instead, effectiveness is an idiosyncratic characteristic drawn post-entry, and thereby an added source of uncertainty in the model, that evolves in a deterministic fashion.

This section is divided into three parts. In the first subsection, I define a school's effectiveness as its contribution to student learning in the context of a value-added education production function. In the second subsection, I detail the elements of the location choices of potential entrant charter schools and exit choices of incumbent charter schools, which are predicated on the "primitives" of demand and costs. I describe the equilibrium concept and evolution of states in the last subsection. Throughout, I suppress district-specific notation to simplify the exposition.

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<sup>24</sup>There is weak to mixed evidence for competitive effects of charter schools on public school students. See Epple et al. (2015) for a summary.

## 4.1 Education Production

In the model, both public and charter schools combine their inputs with those of households to produce education outcomes, measured by student performance on end-of-grade exams. Performance also depends on accumulated impacts of inputs up to the present, which I assume are fully summarized by exam performance the prior year. As a result, education is produced in a value-added fashion:

$$A_{nit}^k = \rho^k A_{nt-1}^k + \beta^k Z_{nt} + \mu_{it} + \nu_{nit}^k \quad (2)$$

In this equation,  $A_{nit}$  is student  $n$ 's achievement from attending school  $i$  during school year  $t$ , while  $A_{nt-1}$  represents prior learning. The  $k$  superscripts index subjects, e.g. math and reading. The contribution of household inputs to learning is represented by  $\beta^k Z_{nt}$ , while  $\nu_{nit}^k$  is a mean-zero measurement error.

I term the contribution or value-added of school  $i$  to student learning gains, represented by  $\mu_{it}$ , its effectiveness. This term summarizes the productive contribution of all of a school's inputs to student learning, including teacher quality, learning environment, infrastructure, management, etc., in a single index. In this way, effectiveness, which might equally be thought of as quality, vertically differentiates schools in the model.

## 4.2 Charter School Utility and Income

Based on their status in the prior period, charter schools in the model are either incumbents, who choose whether to exit, or potential entrants, who choose whether to enter and a location. While these choices are based in part on expected revenues and costs, I model charter schools as not-for-profit maximizers that potentially behave as if they value enrollment per se and their own effectiveness in addition to net income.

The latent utility for charter school  $i$  operating in location  $j$  at state  $s_t$  is given by:

$$U_{ij}(s_t) = U_i(\Pi_{ij}(s_t), D_{ij}(s_t), \mu_{it}) \quad (3)$$

where  $\Pi_{ij}(s_t)$  is net income and  $D_{ij}(s_t)$  is the total enrollment of  $i$  in location  $j$ . This formula-

tion of not-for-profit utility, which shares commonalities with numerous health sector applications (Lakdawalla and Philipson, 2006), is intended to capture charter school operation for altruistic or mission-oriented reasons (Malani et al., 2003). An implication of this utility is that the degree to which charter schools respond to financial incentives, such as a counterfactual change to the funding formula, is an empirical question. In the estimation, I allow the parameters of the utility function (3) to be heterogeneous by whether a charter school is managed by a for-profit organization.<sup>25</sup>

Represented by  $\Pi_{ij}(s_t)$ , net income is determined by revenue, variable costs, and fixed costs of operation,  $FC_{jt}$ :

$$\Pi_{ij}(s_t) = \tau_t D_{ij}(s_t) - VC_{ij}(s_t) - FC_{jt} \quad (4)$$

The product of the funding rate,  $\tau_t$ , and enrollment yields revenue. Each location in a school district,  $j$ , is associated with an enrollment level,  $D_{ij}(s_t)$ , and variable costs of operation,  $VC_{ij}(s_t)$ . Charter schools' choices of where to locate or whether to exit therefore depend on these "primitives." I describe the structure I place on these objects, from which competitive and strategic incentives derive, in turn next.

#### 4.2.1 Demand

Households' school choice determines charter school enrollment in the model. Households weigh characteristics, including effectiveness, which may be imperfectly observed, travel distance, and the enrollment of peers, in selecting a school to attend from among the available alternatives in their district. As a result, the locations and effectiveness of public and other charter schools have competitive implications for charter schools' enrollment.

For parsimony, I abstract from the household-level choice problem to model the enrollment of a given household type  $z$  at each charter school as a function of its effectiveness, the enrollment of other household types, location, and competition. Household types include demographic and

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<sup>25</sup>Charter schools must be legally organized as non-profits in Florida, though many contract with a for-profit management organization for services. I examine for-profit management of charter schools in Florida in other work (Singleton, 2016).

socioeconomic groups. The total enrollment of student group  $z$  in school  $i$  in location  $j$  is given by:

$$D_{ij}^z(s_t) = D^z(\mu_{it}, \mathbf{D}_{ij}^{-z}(s_t), x_{jt}^z, a_{-it}, \mu_{-it}) \quad (5)$$

In this expression, demand depends in part on the effectiveness,  $\mu_{it}$ , of a charter school as well as the size of the market in location  $j$  for type  $z$ , denoted  $x_{jt}^z$ . Additionally, enrollment of student group  $z$  depends on the enrollment of other types of students, represented by vector  $\mathbf{D}_{ij}^{-z}(s_t)$ , in equation (5). This is consistent with the evidence on school sorting that indicates preferences for peer groups influence households' school choice (Rothstein, 2006). Note that such preferences over peers may be direct or induced by, for example, preferences over test score levels, which households may use to imperfectly infer effectiveness. Finally, reflecting local competition,  $a_{-it}$  and  $\mu_{-it}$  represent the locations and effectivenesses, respectively, of competing charter and public schools schools.

This formulation of demand captures a number of important features of education markets: First, the demand function incorporates competitive effects of nearby public and competing charter schools, which may be magnified by closer proximity. In this way, competition between schools is spatial, reflecting the imperfectly competitive nature of the education market. Second, effectiveness, to the degree that is valued by households, will also differentiates schools in that, all things being equal, greater own effectiveness increases enrollment. These features are important for modeling the horizontal and vertical aspects of school competition. Finally, the formulation allows for heterogeneity in how households, characterized by type, evaluate school alternatives, such as how they weight effectiveness and peers in their choice.

From (5), the total enrollment for a charter school  $i$  in location  $j$  is given by summing demand over mutually-exclusive household types:

$$D_{ij}(s_t) = \sum_z D_{ij}^z(s_t) \quad (6)$$

Similarly, the vector of household type shares of students attending each charter school, which I denote by  $\mathbf{Z}_{ij}(s_t)$ , is endogenized in the model by (5) and (6).

### 4.2.2 Variable Costs

Operating a charter school incurs costs that can be conceptually separated into variable and fixed. Variable costs represent the minimum expenditure for a charter school in a given state. Unlike fixed costs, variable costs therefore depend on input prices, which may vary across locations and with student composition, and a charter school’s outputs. These relationships are summarized by charter schools’ variable cost function:

$$VC_{ij}(s_t) = VC(D_{ij}(s_t), \mu_{it}, \mathbf{Z}_{ij}(s_t), x_{jt}^C) \quad (7)$$

Expressed in this way, each charter school is a “firm” that produces effectiveness  $\mu_{it}$  for a given enrollment,  $D_{ij}(s_t)$ , and composition of students,  $\mathbf{Z}_{ij}(s_t)$ .<sup>26</sup> As effectiveness represents a combination of inputs, this formulation recognizes it as potentially costly to supply.

Since student composition is tied to a charter school’s location through demand, a strategic incentive to “cream skim” potentially derives from the dependence of costs on the student composition served in equation (7). While I do not model the mechanism through which they arise, such cost differentials may in general stem from two sources: the production surface or input prices. For instance, teaching assistants or non-classroom school inputs, such as social services, may be especially important for effectively serving disadvantaged students. This is consistent with recent evidence from school finance reforms that spending improves later life outcomes of low socioeconomic status students in part by increasing support services and staff (Jackson et al., 2015).<sup>27</sup> As a result, the optimal mix of inputs may vary with the composition of students. To input prices, evidence from teacher sorting suggests that teachers view concentrations of disadvantaged students as a disamenity, necessitating compensating differentials (Lankford et al., 2002; Jackson, 2009; Clotfelter et al., 2011).<sup>28</sup> I assume that input prices are fully captured by the combination of a charter school’s student composition and location-specific characteristics,  $x_{jt}^C$ .

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<sup>26</sup>The variable cost function is derived from a cost-minimization problem over inputs conditional on effectiveness and enrollments.

<sup>27</sup>Relatedly, students in schools with concentrated low-income populations disproportionately benefit from non-instructional spending (Sorensen, 2016).

<sup>28</sup>Note that charter schools are not constrained by teacher salary schedules. Evidence indicates that hiring practices in charter schools are more market-based than traditional public schools (Podgursky, 2006). Differences across households in terms of parental involvement in the school may also translate to cost differences.

### 4.3 Entry Location and Exit

Charter schools decide where to locate (if a potential entrant) and whether to exit (if an incumbent) in the model. These choices are made simultaneously in an incomplete information setting.<sup>29</sup> In other words, while state variables such as market characteristics and the effectivenesses of public schools and incumbents are commonly observed, the actions of competitor schools are stochastic from the point of view of a given charter school. In addition, the effectiveness of potential entrants is only revealed (to them and to rivals) post-entry, so charter schools also take expectations over this vector to evaluate the choice alternatives in expected utility terms.

For describing charter schools' choice problems in the game, it is useful to divide the state vector,  $s_t$ , into four sub-components. First,  $a_{-it}$  represents the actions of other charter schools, which may be either a location in the market or decision to exit/remain out, and the locations of public schools. Second,  $s_{it}$  lists the characteristics of charter school  $i$ , which include its effectiveness, its profit status, its age and incumbency (i.e. whether in operation the prior period). Vector  $s_{-it}$ , on the other hand, lists the characteristics of charter schools other than  $i$  and of public schools, while  $x_t$  summarizes the exogenous characteristics of all market locations that shift demand and variable costs and also contains the per-pupil funding rate  $\tau_t$ . Unlike potential entrants' effectiveness, the profit status of all charter schools in the market is commonly known.

Incumbent charter schools in state  $s_t$  make the choice of remaining in operation in their present location  $j$  or exiting the market. Operation yields expected utility  $E[U_{ij}(s_t)] = E[U_j(a_{-it}, s_{it}, s_{-it}, x_t)]$ , while I normalize the value of exiting to 0. Each choice alternative is associated with a corresponding private information draw that is known to the charter school, but unobserved to competitors and to the econometrician. Thus, incumbent  $i$ 's choice problem can be expressed as to remain in operation (in location  $j$ ) if:

$$E[U_j(a_{-it}, s_{it}, s_{-it}, x_t)] + \epsilon_{ijt} \geq \epsilon_{i0t} \tag{8}$$

and to close otherwise.  $\epsilon_{ijt}$  and  $\epsilon_{i0t}$  represent  $i$ 's private information regarding the utility of continuing operation and exiting, respectively. The expectation in (8) is taken over competing charter

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<sup>29</sup>This information structure allows for the realistic scenario that charter schools' make ex-post "mistakes."

schools' simultaneous entry location and exit decisions and the effectivenesses of potential entrants.

For a charter school deciding to enter the market, the choice problem also contains a location choice. An entering charter school weighs the alternative locations in a school district, indexed by  $j$ , by computing the expected utility of each alternative. Entering the market incurs entry costs that are denoted  $EC_t$ , which represent both monetary and non-monetary costs associated with the application, authorization, and opening process, including organizing a board, curriculum, staffing, and securing facilities. The choice problem facing potential entrants can be written as:

$$\max\{E[U_j(a_{-it}, s_{it}, s_{-it}, x_t)] - EC_t + \epsilon_{ijt}, \dots, E[U_J(a_{-it}, s_{it}, s_{-it}, x_t)] - EC_t + \epsilon_{iJt}, \epsilon_{i0t}\} \quad (9)$$

Recall that, in addition to the entry and exit choices of competitors, potential entrants take expectations over their own (and all other potential entrants') effectiveness, which is revealed post-entry. Importantly, this uncertainty over their own effectiveness generates, via heterogeneity in how households value quality on the demand side, uncertainty for potential entrants in the composition of students they will serve when selecting a given location. Potential entrants may choose to remain out of the market, which yields only the associated private information draw, in addition to the set of locations in the school district.

#### 4.4 Equilibrium and State Evolution

Equations (8) and (9) map charter schools' expected utility, given their beliefs about the choices of other charter schools, into ex ante choice probabilities. Since the choice shocks are private information, each charter school's decision rule is a function of the common state variables and its private information, but not the private information of other charter schools. I denote by  $\mathbf{P}_t$  the set of all charter schools' choice probabilities to re-express the expected utility for charter school  $i$  of location  $j$  as:

$$E[U_j(a_{-it}, s_{it}, s_{-it}, x_t)] = \tilde{u}_{ij}(s_t, \mathbf{P}_t) \quad (10)$$

Given this expected utility, (8) and (9) represent a system of best response probability functions that define the Bayesian Nash equilibrium of the game wherein strategies and beliefs are consistent.<sup>30</sup>

<sup>30</sup>I focus on pure-strategy equilibria, with anonymous and symmetric strategies. Existence of equilibrium follows from Brouwer's fixed point theorem, but is not guaranteed to be unique. The two-step estimator I use conditions on

Charter schools’ choices determine the equilibrium outcomes in the current period and the state vector evolves as a result of those choices.

The vector of charter schools’ effectivenesses,  $\mu_t$ , is a state that influences choices and thereby outcomes. While competitive entry and exit dynamics endogenize the aggregate effectiveness of the charter sector in the model, I specify a deterministic law of motion for the evolution of a given school’s effectiveness between periods:

$$\mu_{it} = \mu_{1i} + \mu_2 \log(a_{it} + 1) \tag{11}$$

In this process,  $\mu_{1i}$  represents an idiosyncratic and permanent component of effectiveness that is drawn upon entry, while  $\mu_2$  scales the rate at which effectiveness accumulates with age,  $a_{it}$ , of a charter school. This process, which is similar to returns to teacher quality with experience, captures improvement over time within charter schools.

## 5 Estimation and Identification

Estimation of the empirical model broadly consists of three steps: (1) recovering effectiveness of schools from the panel of test score data; (2) estimating the demand and variable cost functions, which shape the incentive structure of charter school operation; and (3) plugging-in the “offline” estimates to leverage revealed preference with the entry game to uncover how charter schools respond to the incentive structure. In this section, I detail each step and the identification assumptions made to recover the model parameters.

### 5.1 Offline Elements

#### 5.1.1 Effectiveness

I use the panel of end-of-grade exam scores by school and grade to estimate the effectiveness of each school at raising student achievement. Averaging (2) to the grade level and substituting in the equilibrium in the data.

charter schools’ law of motion for effectiveness (11) yields the equation that I take to the data:

$$A_{igt}^k = \rho_g^k A_{igt-1}^k + \beta^k \mathbf{Z}_{igt} + \mu_{1i} + \mu_2 \log(a_{it} + 1) + \delta_{gt}^k + \nu_{igt}^k \quad (12)$$

The dependent variable,  $A_{igt}^k$ , is the normalized average subject  $k$  score of grade  $g$  students in school  $j$  at time  $t$ , while  $A_{igt-1}^k$  is their average score the prior year.<sup>31</sup> Net of subject-grade-year intercepts,  $\delta_{gt}^k$ , effectiveness at raising student achievement is constant across subjects and grades.

The primary identification challenge in recovering estimates of school effectiveness stems from potential household sorting on unobservables across schools. As a result, the control for prior year’s achievement in (12), assumed to capture unobserved inputs into student learning prior to  $t$ , is key to guard against this. Recent evidence regarding teachers’ value-added, for example, indicates that controlling for prior student test scores is most important for obtaining unbiased estimates (Chetty et al., 2014). In addition to the prior scores, however, I also control for all observed grade-level student characteristics, including demographics, subsidized lunch, special education, English language learner, and gifted student status in  $\mathbf{Z}_{igt}$ .<sup>32</sup> To allow for differential sorting across public and charter schools, I also interact the household variables with a charter indicator.

I estimate (12) by school fixed effects pooling charter and public schools, while allowing  $\rho$  to vary by grade and subject and  $\beta$  to vary by subject. In the estimation, I weight each observation in the data by the number of students going into calculation of the achievement score averages. The fixed effects for charters schools are taken as estimates of  $\mu_{1i}$ , while the effectivenesses of public schools are assumed to be fixed over time. Residual average growth in student performance across grades and years therefore identifies the effectiveness of each school.

### 5.1.2 Demand

To estimate charter school demand, I pool the elementary enrollment of household types across charter schools and years. I use Asian, black, Hispanic, white, other demographic, and subsidized

<sup>31</sup>Note that the averaging in both years is over the same students, although the prior score may have been received at a different Florida public or charter school if the student switched schools. I normalize current and prior scores separately.

<sup>32</sup>Since I do not observe the characteristics of just the matched sample of students (those for whom current and prior scores are available), I assume that the overall grade-level demographics are representative. I also control for the share of grade-level enrollment that the matched test score sample accounts for in the estimation.

lunch status, a proxy for household income, as the types of households. To take equation (5) to the data, I first collect the endogenous enrollments on the left hand side:

$$D_{it}^z = \tilde{D}^z(\mu_{it}, \mathbf{x}_{j(i)t}^{-z}, x_{j(i)t}^z, a_{-it}, \mu_{-it}) \quad (13)$$

In re-writing the equation this way, peer spillovers are captured by dependence of a given household type’s enrollment on the market size for other type households, contained in vector  $\mathbf{x}_{j(i)t}^{-z}$  where the subscript  $j(i)$  indicates that charter  $i$  is located in  $j$ . This dependence is in addition to the market size of the “own” type (e.g. the enrollment of Hispanic students depends on the population of Hispanics and the Asian population), represented by  $x_{j(i)t}^z$ .

To capture spatial competition, I then bin counts of nearby charter and public schools into mutually-exclusive distance bands centered around each school’s location, while conditioning on charter school effectiveness and location characteristics. The equation I estimate is given by:

$$\log(D_{it}^z + 1) = \alpha^Z(\mu_{it} - \bar{\mu}_{j(i)t}^P) + \varrho^z x_{j(i)t}^z + \varrho^{-z} \mathbf{x}_{j(i)t}^{-z} + \sum_d \gamma_c^d NC_{j(i)t}^d + \sum_d \gamma_p^d NP_{j(i)t}^d + \pi_{j(i)t}^z + \epsilon_{it}^z \quad (14)$$

$NC_{j(i)t}^d$  and  $NP_{j(i)t}^d$  represent the number of charter and public schools, respectively, in distance band  $d$  from charter school  $i$ ’s location at time  $t$ . The  $\gamma$  parameters are thus interpretable as semi-elasticities of enrollment with respect to an additional competitor (public or charter) in a given distance band. I use three distance bands in the estimation: within one mile, between one and three miles, and between three and five miles. For the sizes of the local market by household type, which enter  $x_{j(i)t}^z$  or  $\mathbf{x}_{j(i)t}^{-z}$ , I similarly include the logged school aged population of each demographic group within the one, three, and five mile distance bands.

Demand also depends on charter school  $i$ ’s effectiveness relative to effectiveness of public schools nearby location  $j$ , given by  $\mu_{it} - \bar{\mu}_{j(i)t}^P$  in equation (14). For the latter term, I compute the average effectiveness of public schools within five miles. As a result,  $\alpha_z$ , which I allow to be heterogeneous across household types, governs the return to effectiveness at raising student achievement and embeds incentives to locate in areas underserved by public schools. Note that this heterogeneity may capture differences in preferences for school quality across households, but also may reflect differences in information about the quality of schools.

There are two major identification concerns in estimating equation (14). First, the number of competing charter schools nearby, which enters on the right hand side, is a function of school  $i$ 's supply decision, potentially leading to simultaneity bias. The spatial nature of competition, however, provides sources of exogenous variation in competitors' supply choices. To take an illustrative example, while the influence of market characteristics on charter school  $i$ 's enrollment is bounded at five miles, the choice of an incumbent competitor located five miles away from  $i$  will be influenced by the presence of public schools (and cost conditions) beyond five miles from  $i$ . More generally, the location choices of potential entrants will be influenced by the presence of public schools (and incumbent charters) and cost conditions across the entire school district, while only local characteristics directly affect  $i$ 's enrollment. In addition, it is instructive to consider the implications of any simultaneity bias for the estimates. Simultaneity would lead to overestimates of the competitive effects (i.e. more negative  $\gamma$ s). In terms of recovering how charter schools choose among locations, if profits are increasing in enrollment, such bias would then translate into underestimates of charter schools' responsiveness to financial incentives. This in turn implies that the results reported for the impact of the flat funding formula on inequity would be a lower bound.

The second identification concern stems from market characteristics that may be unobserved. This omitted variable bias, such as unobserved characteristics of locations that may reduce fixed costs and thereby produce agglomeration of schools, is likely to attenuate the estimates of  $\gamma$  towards zero (or even make them positive). As a result, in estimating (14), I include income quintile-by-urban-by-household type, district-by-type, and year-by-type fixed effects, represented by  $\pi_{j(i)t}^z$ , in addition to the observed market characteristics in  $x_{j(i)t}^z$  and  $\mathbf{x}_{j(i)t}^{-z}$ . Intuitively, this identifies the competitive effects by comparing the enrollment of a given household type between similar schools in (observably) similar locations, but exposed to different competitive environments. Given the attenuation associated with this kind of bias, an available validity check of this identifying assumption is that the estimated competitive effects are negative (and decline in magnitude with distance).

### 5.1.3 Variable Costs

To estimate the variable costs of charter school operation, I combine the recovered estimates of charter school effectiveness with the panel of expenditures, student compositions, and location characteristics. As described earlier, the variable cost function embeds cost differences across student populations.

The specification I estimate is given by:

$$\log VC_{it} = \kappa T(\log D_{it}, \mu_{it}) + \lambda \mathbf{Z}_{it} + \eta x_{j(i)t}^C + \epsilon_{it} \quad (15)$$

The dependent variable in this equation is the reported total expenditure of charter school  $i$  during school year  $t$ , which depends on enrollment, effectiveness, student composition  $\mathbf{Z}_{it}$ , and characteristics of the location,  $x_{j(i)t}^C$ .<sup>33</sup> The location characteristics I include in the estimation include income quintile-urban and district-year intercepts. To allow for possible nonlinearities, such as a quantity-quality tradeoff, I specify  $T(\log D_{it}, \mu_{it})$  by a quadratic polynomial (akin to a translog) in log enrollment and effectiveness.

Cost estimation in education settings is subject to a number of endogeneity concerns (Costrell et al., 2008; Duncombe and Yinger, 2011; Gronberg et al., 2011). For example, effectiveness or quality of education is often poorly measured due to non-random sorting of students across schools. By estimating the education production (12) in a first stage, however, I obtain a measure of effectiveness identified by residual student achievement growth. As a result, the cost estimates obtained from equation (15) implicitly condition on students' unobserved prior inputs into education.<sup>34</sup>

Nonetheless, unobserved differences across schools in allocative efficiency may confound naive regressions of expenditure on measures of outcomes and student characteristics. In this case, the error term in (15) can be decomposed into an efficiency term and measurement error:

$$\epsilon_{it} = u_{it} + \zeta_{it}$$

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<sup>33</sup>In addition to the student compositions endogenized by the model (demographics and subsidized lunch status), I also control for the share of gifted, special education, and English language learner students in the cost estimation.

<sup>34</sup>Another traditional endogeneity concern is market power of public school districts in setting teacher wages. As charter schools are small players in the labor market, this is not a salient issue in this setting.

If efficiency in input usage, represented by  $u_{it}$ , is correlated with effectiveness or enrollment, then ordinary least squares estimates will be subject to omitted variable bias.<sup>35</sup> Teacher salary schedules, bureaucracy, and rent-seeking are likely sources of allocative inefficiency in public school districts. While the more competitive charter school market may lessen some of this worry, I also assume that any allocative inefficiency across charter schools is fully captured by the age and profit status of a charter school. I therefore include these as additional controls when estimating equation (15).

## 5.2 Entry Game

Estimating how charter schools respond to incentives relies on pairing the offline estimates of demand and variable costs with the logic of revealed preference in the entry game. This requires placing a functional form on the latent utility function of charter schools and a distributional assumption on the choice shocks. In this subsection, I also discuss the sources of identifying variation of the entry game parameters in the presence of unobserved market heterogeneity. Given the computational burden required to solve the game, I implement a modified two-step approach for estimation, described below.

I specify charter schools' utility as quasi-linear in net income per pupil:

$$U_{ij}(s_t) = \theta_i \Pi_{ij}(s_t) / D_{ij}(s_t) + g_i(D_{ij}(s_t), \mu_{it}) \quad (16)$$

$\theta_i$  therefore represents the marginal utility of net income per pupil and governs how charter schools respond to financial incentives. On the other hand,  $g_i$  represents how, whether for altruistic or other reasons, charter schools may value enrollment and effectiveness independently. Using the equation for profit, I re-write (16) as follows:

$$\begin{aligned} U_{ij}(s_t) &= \theta_i(\tau_t D_{ij}(s_t) - VC_{ij}(s_t) - FC_{jt}) / D_{ij}(s_t) + g_i(D_{ij}(s_t), \mu_{it}) \\ &= \theta_i(\tau_t - VC_{ij}(s_t) / D_{ij}(s_t) - FC_{jt} / D_{ij}(s_t)) + g_i(D_{ij}(s_t), \mu_{it}) \\ &= \theta_i(\tau_t - VC_{ij}(s_t) / D_{ij}(s_t)) + \tilde{g}_i(FC_{jt}, D_{ij}(s_t), \mu_{it}) \end{aligned} \quad (17)$$

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<sup>35</sup>The cost estimation literature typically models unobserved  $u_{it}$  using parametric distributional assumptions. See chapter 3 of Davis and Garcés (2009) and Greene (2008) for overviews. Gronberg et al. (2012) is an application to charter schools.

This expression is useful for considering the potential sources of variation in the data that identify  $\theta_i$ , the key parameter of interest for the purpose of conducting counterfactuals. For instance, the rearrangement in the last equation reflects that if fixed costs,  $FC_{jt}$ , are parameterized by a linear index of location characteristics (including at least a constant), those parameters are just scaled by  $\theta_i$ . Moreover, variation in demand will only help identify  $\theta_i$  to the extent it shifts variable costs per pupil due to any scale economies.

Instead, consider the difference in expected utility for a potential entrant  $i$  choosing between locations  $j$  and  $j'$ :

$$\begin{aligned}
E[U_{ij}(s_t)] - E[U_{ij'}(s_t)] &= \theta_i(\tau_t - E[VC_{ij}(s_t)/D_{ij}(s_t)]) + E[\tilde{g}_i(FC_{jt}, D_{ij}(s_t), \mu_{it})] \\
&\quad - \theta_i(\tau_t - E[VC_{ij'}(s_t)/D_{ij'}(s_t)]) + E[\tilde{g}_i(FC_{j't}, D_{ij'}(s_t), \mu_{it})] \\
&= \theta_i(-E[VC_{ij}(s_t)/D_{ij}(s_t)] + E[VC_{ij'}(s_t)/D_{ij'}(s_t)]) \\
&\quad + E[\tilde{g}_i(FC_{jt}, D_{ij}(s_t), \mu_{it})] - E[\tilde{g}_i(FC_{j't}, D_{ij'}(s_t), \mu_{it})]
\end{aligned}$$

Across the locations, the above reveals that the per-pupil funding rate  $\tau_t$  is constant and thus drops out of the comparison. As a result,  $\theta_i$  is informed by revealed preference over locations: the sensitivity of charter schools' location choices to expected variable cost differences (all else held equal). Potentially, however, the per-pupil funding rate  $\tau_t$  can inform the identification of  $\theta_i$  from the decision of a potential entrant to enter (vs. staying out of the market altogether) or of an incumbent to continue in operation. Consider the latter choice in expected utility terms:

$$E[U_{ij}(s_t)] - E[U_{i0}(s_t)] = \theta_i(\tau_t - E[VC_{ij}(s_t)/D_{ij}(s_t)]) + E[\tilde{g}_i(FC_{jt}, D_{ij}(s_t), \mu_{it})] \quad (18)$$

The expected utility of exiting, denoted as alternative 0, is normalized to 0, so the comparison resolves to evaluating whether the expected utility of remaining in operation in location  $j$  is positive. As can be seen, the statutory funding rate,  $\tau_t$ , like expected costs per pupil, therefore informs the identification of  $\theta_i$  through revealed preference by shifting the expected profits of continued operation.

As described earlier, these expected utility comparisons are accompanied by idiosyncratic private information draws that are assumed to be independent across charter schools and over time. How-

ever, it is important to consider the presence of unobserved heterogeneity, which can create omitted variable bias and is a principal focus in the empirical games literature (Seim, 2006). In this context, market-level unobservables, which I denote by  $\xi_t$ , also limit the variation for identifying  $\theta_i$ . To see this, consider again the incumbent decision, but now incorporating unobserved heterogeneity:

$$E[U_{ij}(s_t)] - E[U_{i0}(s_t)] = \theta_i(\tau_t - E[VC_{ij}(s_t)/D_{ij}(s_t)]) + E[\tilde{g}_i(FC_{jt}, D_{ij}(s_t), \mu_{it})] + \xi_t$$

The expression makes clear that  $\xi_t$  is collinear with the statutory funding rate,  $\tau_t$ . As a result, taking unobserved heterogeneity seriously in the estimation absorbs this potential source of variation in the data, leaving only expected variable costs per pupil to identify  $\theta_i$ . This highlights the importance of the expenditure data used to estimate variable costs offline.

As I observe multiple school districts for each time period, I capture the unobserved market-level heterogeneity in the estimation by including year and district fixed effects. Because the parameters that enter  $\tilde{g}$  are not of direct interest in the analysis, I flexibly specify this function with a quadratic polynomial in enrollment and the urban and income quintile intercepts and demographic shares of the one mile radius surrounding each location. As mentioned earlier, I also allow  $\theta_i$  and  $\tilde{g}_i$  to vary by whether a charter is for-profit managed, allowing for the sensitivity to expected costs per pupil (versus other determinants) to depend on a charter school's profit status. Entry costs are similarly allowed to vary with profit status.

I assume that the private information draws in (8) and (9) are distributed i.i.d. type I extreme value. This assumption produces familiar closed-form expressions for the probability of continuing for incumbents (which I superscript by  $I$ ) and for choosing a location for potential entrants (superscripted  $E$ ). These are given by

$$P_{ij}^I(s_t) = \frac{\exp(\tilde{u}_{ij}(s_t, \mathbf{P}_t))}{1 + \exp(\tilde{u}_{ij}(s_t, \mathbf{P}_t))} \quad (19)$$

$$P_{ij}^E(s_t) = \frac{\exp(-EC_{it} + \tilde{u}_{ij}(s_t, \mathbf{P}_t))}{1 + \sum_j \exp(-EC_{it} + \tilde{u}_{ij}(s_t, \mathbf{P}_t))} \quad (20)$$

where the expected utility expressions are now written to reflect the equilibrium structure of the choice environment. These choice probability expressions form the basis for the likelihood.

There are two primary approaches for dealing with the equilibrium structure of this system of equations. The nested fixed point approach, adapted from Rust (1987), requires solving the game for all equilibria for every parameter guess to evaluate the likelihood. Due to heterogeneity across charter schools and the large set of locations (for example, there are nearly 350 Census tracts in Miami-Dade), this approach is computationally prohibitive. For this reason, I adopt a two-step approach based on insights from Hotz and Miller (1993) that semi-parametrically recovers conditional choice probabilities of entry location and exit,  $\hat{\mathbf{P}}_t$ , in a first step. The second step then uses the choice probabilities as estimates of charter schools' beliefs to calculate  $\tilde{u}_{ij}(s_t, \hat{\mathbf{P}}_t)$  offline using simulation. This two-step approach, which conditions estimation on the equilibrium played in the data, is also more robust to possible multiplicity of equilibria.<sup>36</sup>

I estimate the model by pooling the 26 school districts in Florida with at least 3 total charter school entries during the sample. A potential entrant's choice set consists of all Census tracts in their assigned school district.<sup>37</sup> As the demand model (5) overdetermines total enrollment, I use the predicted enrollment of the five mutually exclusive demographic groups (Asian, black, Hispanic, other, white) to predict total enrollment in each location and require predicted enrollment to be at least one while capping the subsidized lunch share at one. For the first stage, I estimate a multinomial logit with a flexible polynomial in the state variables that includes district and year fixed effects. Finally, an entrant's initial effectiveness is drawn from the empirical distribution of  $\mu_{1i}$ , which I discretize.

## 6 Results

This section presents the estimates of the empirical model and results of the counterfactual exercises. In the first subsection, I present the parameter estimates of the offline functions and from the entry game. As successive estimation steps use estimates obtained from prior ones, I compute standard errors using a block bootstrap that samples markets (district-years) with replacement. To assess goodness-of-fit, I then simulate the empirical model. Finally, I examine three counterfactual policy

<sup>36</sup>Bajari et al. (2010) apply the two-step estimator to a static game. Two-step estimators have been extended to the estimation of dynamic games (Aguirregabiria and Mira, 2007; Bajari et al., 2007; Pakes et al., 2007).

<sup>37</sup>I populate the pool of potential entrants for each school district by setting the total to actual entrants plus the minimum of two times a third the amount of observed entries (rounded up to the next integer) and 2. I assign for-profit status to half of the created potential entrants.

changes in the last subsection: (1) a cost-adjusted funding formula based on the estimated cost differentials; (2) start-up grants targeted by household income of the location; (3) and a general increase in the per-pupil funding rate for charter schools. I compare these simulations in terms of aggregate effectiveness and the demographic composition of students served by the charter sector.

## 6.1 Estimates

### 6.1.1 Effectiveness

Figure 1 summarizes the school effectiveness estimates recovered from equation (12) by comparing public and charter schools operating in Florida in the 2012-13 school year. I demean the effectiveness estimates over the entire sample to facilitate the comparisons and plot kernel densities for both school types. The figure illustrates that the average charter school was around 0.07 standard deviations (on the student achievement distribution) worse than average, with public schools ever so slightly better than average. Notably, the difference compares favorably with recent estimates of the relative quality of charter schools in Florida based on student-level data. For instance, CREDO (2009) reports charter school effects in the range of -0.03 to -0.02 standard deviations using matching. Similarly, Davis and Raymond (2012) obtain estimates in the range of -0.04 to -0.02 standard deviations from student fixed effects models. Figure 1 also reveals a wider dispersion in estimated effectiveness across charter schools than across public schools. These distributions are summarized numerically in the upper panel of Table 5.

In Figure 2, I compare charter schools that exit the sample with charter schools that persist in terms of effectiveness.<sup>38</sup> In contrast with the level test score difference of nearly 1 standard deviation on average (summarized earlier in Table 3), the density plots reveal a considerably smaller average gap in effectiveness, as measured by value-added. As reported in the middle panel of Table 5, the average exiter charter school raises learning 0.49 standard deviations less than the average school. Moreover, the figure also shows considerable overlaps in the effectiveness distributions, such that some exiter charter schools are very effective in absolute terms. For instance, the 75th percentile charter school that closes and exits the sample would be nearly as effective as the average charter

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<sup>38</sup>For purposes of this comparison, I construct effectiveness from the estimated school fixed effects from equation (12) and plug in the average charter school age in 2012-13.

school in 2012-13 (if it survived to the same age). Conversely, the 25th percentile charter school that survives during the sample actually lowers student performance by about 0.27 standard deviations relative to the average school.

The bottom panel of Table 5 presents a final comparison of persisting and exiting charter schools. Using the estimates of public school effectiveness recovered from equation (12), I compute the average effectiveness of public schools within 5 miles of each charter school and average over the sample period. This comparison produces the additional finding that exiters are located in relatively more underserved areas, as measured by the quality of nearby public schools. This suggests that some charter schools that close and exit the sample are better relative to local public school alternatives. Together, the estimated effectiveness distributions provide suggestive evidence that funding policies which exiter sustain charter schools may not necessarily imply “costs” in terms of aggregate effectiveness.

### 6.1.2 Primitives

Demand estimates are presented in Tables 6 and 7. Estimates of competitive effects, shown in Table 6, indicate that charter school competition is highly localized. For instance, an additional competitor charter school within one mile is associated with around an 11% drop in enrollment, but at further distances the competitive effect of other charter schools is not statistically different from zero. On the other hand, an additional public school within one mile is associated with around a 10% drop in enrollment, publics between one and three miles reduce enrollment around 4%, and publics 3 to 5 miles away reduce enrollment by 2%. These negative effects of competition that attenuate with distance provide a useful validity check of the estimates against economic theory.

Table 7 presents the estimates of the return to effectiveness, how demand depends on market size, and peer spillovers in equation (14). As expected, the estimates indicate that greater relative effectiveness is associated with larger charter school enrollment for most household types. For example, a one standard deviation increase in charter school effectiveness, all things being equal, is associated with around a 68% increase in the enrollment of Hispanic students. For black households, on the other hand, the estimate is not statistically different from zero. Further, as relative effectiveness is with respect to local public schools (within 5 miles), these estimates also influence charter schools’

incentives to locate in underserved areas. Table 6 additionally displays how demand depends on school-aged populations within 1 mile. For example, a 10% increase in the size of the local Hispanic population is predicted to raise Hispanic enrollment in a charter school by 2%. Reflecting peer spillovers, a larger school-aged Asian population is predicted to raise the enrollment of not only Asians, but also Hispanic and white students. Conversely, a larger black population in a given location is associated with lower enrollment of other household demographics. These sorting dynamics due to preferences over peers thus influence the equilibrium concentration of students across charter schools.

Table 8 presents estimates of the charter school variable cost function. The results indicate modest returns to scale of charter school operation. For a charter school of average size and effectiveness, a 10% increase in enrollment is associated with about an 8.9% increase in costs, all things being equal. While a one standard deviation increase in effectiveness does not appreciably change the costs of an average sized charter school, the cost of providing effectiveness increases with additional effectiveness. For example, costs are 6% higher for a one standard deviation above average effectiveness (average sized) charter school. The estimates also indicate the the costliness of effectiveness diminishes with scale, though this effect is small in magnitude. For-profit managed schools are estimated to be more efficient, as represented by around 5% lower variable costs.

The results in Table 8 also indicate cost differentials across student populations. In particular, holding effectiveness and enrollment constant, a 10 percentage point increase in the share of black students is associated with about a 2% increase in variables costs. For the share of Hispanic students, a 10 percentage point increase is associated with around a 1% increase, all else constant. As these characteristics proxy for differences in socioeconomic status, household wealth, and other sources of advantage, they are highly collinear with subsidized lunch status.<sup>39</sup> I use these estimated cost differences to implement the counterfactual cost-adjusted funding formula, as described later.

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<sup>39</sup>Though not presented in Table 8, the estimates also imply that costs increase 3% for a 10 percentage point increase in the share of English language learner students, a recognized category of student need in the state funding formula.

### 6.1.3 Utility

The results from estimating the entry game are presented in Table 9. These parameters correspond to the utility function of charter schools in deciding whether and where to open or to close. From the negative point estimate on variable costs per pupil, the estimates reveal that charter schools respond positively to additional net income per pupil. Although the estimates indicate somewhat counterintuitively that for-profits managed charters respond less to variable costs per pupil, this difference is not statistically significant. While the utility specification, in relaxing the assumption of profit maximization, flexibly allows charters to value enrollment and effectiveness (which would be reflected in differential exit rates) in their choices, the estimates on these variables are not statistically different from zero for either non- or for-profits.

Table 9 also presents estimates of entry costs. To facilitate interpretation, the point estimates can be put in willingness-to-pay terms based on how charters value net income. The results indicate that the disutility of setting up a new charter school is worth on the order of \$20,000 per pupil in willingness to pay (about \$5 million dollars for the average sized charter school).<sup>40</sup> This is indicative that barriers to entry into the market are considerable in magnitude. Entry costs are perhaps lower for for-profit managed charter schools, but the difference is not statistically significant.

## 6.2 Goodness-of-Fit

To assess the ability of the empirical model to fit the data, I compare selected moments to those generated by simulating the model. To perform the simulations, I begin with the data that characterizes the state of the education market in Florida in the very first year of the sample, the 2006-7 school year. Using the estimated parameters, I then simulate a number of paths forward to compare the average model predictions for the 2012-13 school year to the 2012-13 data. Simulation requires solving the incomplete information entry game (i.e. finding a fixed point), so this exercise simplifies that requirement somewhat by only finding an equilibrium for states along each path.<sup>41</sup>

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<sup>40</sup>This reflects the entry cost for the 2012-13 school year. The estimates of the entry by year fixed effects, not presented here, show entry costs declining slightly over time.

<sup>41</sup>Although the equilibrium found is not guaranteed to be unique, I initialize the contraction mapping using the first stage conditional choice probability estimates, which represent the equilibrium played in the data, so the counterfactual equilibrium arrived at is “local” in that sense.

The moments I examine are those of most interest in the counterfactual exercises, including the equilibrium number of charter schools, the composition of charter school enrollment, and aggregate effectiveness. Note that for the model to match these moments with this exercise, it must accurately fit the spatial configuration of the charter sector over time (in addition to fitting enrollments).

Table 10 presents the comparisons. 274 elementary charter schools were in operation in Florida in the 2012-13 school year for the estimation sample. Matching this moment closely, the model predicts an average of 273 charter schools across the 50 simulated paths. Further, the predicted composition of students attending charter schools is close to the data: 50% of students in elementary charter schools participated in subsidized lunch, 28% were black and 33% were Hispanic in 2012-13. The model predicts 55%, 28% and 34% on average, respectively. Finally, aggregate charter school effectiveness, measured by the average of effectiveness across all charter schools in operation, is -0.09 in the data, as compared with 0.13 standard deviations below the mean predicted by the model. In sum, although the model mildly underpredicts the aggregate effectiveness of the charter sector, these comparisons indicate that the model is able to reproduce important features of the data well.

### 6.3 Policy Counterfactuals

In this section, I study counterfactual changes to funding policy in terms of equilibrium sector outcomes. Using the estimates of cost differences across students, I examine a cost-adjusted funding formula designed to correct the strategic incentive to cream skim. These results thereby answer whether current funding policy has the perverse effect of skewing the distribution of students served by charters towards low-cost student populations by influencing where charter schools locate.

To implement this policy, I consider a funding formula that attaches weights to the enrollment of each household type and denote this policy by  $\hat{\tau}(\mathbf{D})$  where  $\mathbf{D}$  represents the vector of enrollments by household type. I choose the weights to satisfy two intuitive conditions: First, that the marginal revenue of enrolling an additional student of a given type approximately equals the marginal cost. This is where the variable cost estimates enter the calculation. The second condition is that the formula provides approximately the same amount of total revenue as the status quo funding formula:  $\hat{\tau}(\mathbf{D}) \approx \tau D$ . In other words, the counterfactual is intended to only reallocate funding

across household types.<sup>42</sup> I use the average expenditure and student compositions in the data to calibrate the formula.

I also consider two additional policy counterfactuals. First, I study the effects of a targeted start-up grant that provides \$1,000 of additional support per pupil – on the order of existing federal and state grants – for charter schools locating in areas with average household income in the first quintile (below about \$45,000). This policy aims to capture the allocative benefits of the cost-adjusted funding formula in a practicable fashion. Finally, to quantify the elasticities of charter school supply and aggregate effectiveness, I examine a general per-pupil funding increase.

I compare the counterfactuals in terms of two primary outcomes: the composition of students attending charter schools and the aggregate effectiveness of the charter sector. The first outcome is determined by demand and where charter schools decide to locate in equilibrium. As the first counterfactual removes the financial motive to cream skim, those results provide a benchmark for comparison. Aggregate effectiveness depends on the effectivenesses of charter schools operating in the market. By influencing entry and exit via competition, this outcome is sensitive to a change in funding policy.

Table 11 presents the results of the counterfactual simulations, which are implemented by the same procedure used to assess model fit. I report the equilibrium outcomes in terms of percentage changes from the base model predictions, reported in Table 10. Column (1) presents the predictions of a cost-adjusted funding formula. The cost-adjustment leads to a significant shift in the composition of students attending charter schools. In the counterfactual, the share of students attending charters that participate in subsidized lunch increases by nearly 4% and the share of black students attending charters increases by 9%. This provides positive evidence of cost-based cream skimming in the charter sector. At the same time, however, the cost-adjusted funding formula predicts a drop in aggregate effectiveness of the charter sector of 0.01 standard deviation. As a result, the cost-adjusted formula increases the share of charter schools serving underserved populations with little reduction in aggregate effectiveness. As suggested earlier by Table 5, this is in large part due to the fact that a number of the charter schools sustained in the market by this policy change serve disadvantaged students and are not ineffective schools.

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<sup>42</sup>To provide a sense of the magnitudes, the difference in funding for a fully Hispanic charter school and a fully white charter school is \$1,040 per pupil in the implemented counterfactual.

The second counterfactual I study, presented in column (2), is a targeted start-up grant for charter schools that locate in areas with average household income in the 1st quintile. This policy moves the dial towards the cost-adjusted policy outcomes (e.g. the share of students attending charters who participate in subsidized lunch and who are black increase by 1% and about 3%, respectively), though the magnitudes of the change are lower. To see why this is, I examine the characteristics of entrant and exiting charter schools in the counterfactuals, presented in Table 12. The top panel shows that, in terms of the student composition of entrants, policies (1) and (2) are comparable: the targeted start-up grant is effective at shifting where new charter schools locate and the composition of students they serve. However, the bottom panel reveals that the start-up grant fails to support charter schools as incumbents. In fact, Table 12 shows that exiters' shares of subsidized lunch and black students actually increase somewhat in counterfactual (2) because the policy *increases* the exit rate of the reallocated charter schools. The continuation margin is thus important for the net impact of the cost-adjusted funding formula. In sum, the targeted start-up grant captures limited benefits of cost-adjusting.

The final counterfactual I study is an increase of \$1,000 per pupil in annual revenue for charter schools. This counterfactual is interesting given its two likely effects. First, the additional funding should expand the charter sector by attracting new schools into the market. Second, if the new entrants intensify competition, this effect may imply changes in the aggregate effectiveness of the sector through differential exit. This is countervailed against the possibility that, due to the imperfect nature of spatial competition, the additional funding subsidizes low-effectiveness schools. The results in column (3) of Tables 11 and 12 present the results. The additional funding significantly increases the number of charter schools by about 17%. Aggregate effectiveness of the charter sector, however, does not change appreciably. This reinforces the general finding of weak competitive incentives, such that gains in access to school choice do not appear costly in terms of quality of charter schooling.

## 7 Conclusion

This paper uses unique data from Florida to study the effects of charter school funding policy on the equilibrium composition of students served by charter schools and aggregate effectiveness. This is motivated by the possibility that, due to the flat statutory funding formula, charter schools face strategic incentives to underserve disadvantaged student populations through their choice of location. The data assembled present a number of suggestive differences between charter schools that exit and those that survive in the sample: Exiters serve 21 percentage point higher subsidized lunch and 37 percentage point higher black student bodies. At the same time, those that exit also spend over \$900 more per student per year and display much lower student achievement levels on end-of-grade exams on average.

To understand the mechanisms behind these patterns, I develop an empirical model of charter school supply and competition that enables me to study the effects of counterfactual funding policies on equilibrium sector outcomes. In the model, charters consider competition and the cost of educating the expected student body composition in choosing where to locate. As a result, charter sector outcomes depend on whether and how charter schools strategically respond to the policy environment. To estimate the model, I first recover estimates of school effectiveness, demand, and variable costs, which embed cost differences across student populations, to plug these primitives into an incomplete information entry game. I then leverage revealed preference to uncover how charter schools, which I treat as not-for-profit maximizers, respond to incentives.

I use the estimated model to study three policy changes in detail. First, I consider a cost-adjusted funding formula that aims to correct the strategic incentive to cream skim. The results indicate a significant increase in the share of charter schools serving students of disadvantaged backgrounds with little change in aggregate effectiveness. This result provides evidence that the current flat funding formula unintentionally skews the distribution of students served by charters towards low-cost populations. Second, I consider a location targeted start-up grant that provides support for charter schools serving lower income areas. While this policy shifts the location choices of new schools, it fails to support schools serving disadvantaged students and yields a modest overall change in outcomes. Finally, I examine the effect of a general funding rate increase for charters.

This policy increases the size of the sector, but generates no considerable change in the aggregate effectiveness of the sector.

These findings are important as they are informative about school choice policy. In particular, a mismatch between funding and costs may generate significant disparities in access to and benefits from school choice. This point, while relevant to ongoing debates over the expansion of charter and voucher programs, is largely unrecognized in the existing literature on education markets. Further, the counterfactuals I study underscore that funding policy, an element common to both private school voucher and charter school programs, may provide an effective policy instrument for directing competition via supply-side incentives. This has implications for the design of school choice programs broadly.

The empirical model I develop makes several important simplifying assumptions that motivate future work. For instance, I abstract from incomplete information in modeling how households choose schools. While these features influence how students sort across schools, they also have supply-side implications that remain unexamined and which I do not develop here. In addition, I do not analyze the sources of within-school changes in effectiveness over time. While on the one hand this may underestimate some quality effects of competition, it also suggests another margin which may inform the design of school choice policy, particularly school accountability regimes. Lastly, as the charter sector continues to mature, the roles of charter school networks and management organizations, which are beyond the scope of this work, are likely to take on added importance.

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Figure 1: Effectiveness of Public and Charter Schools, 2012-2013

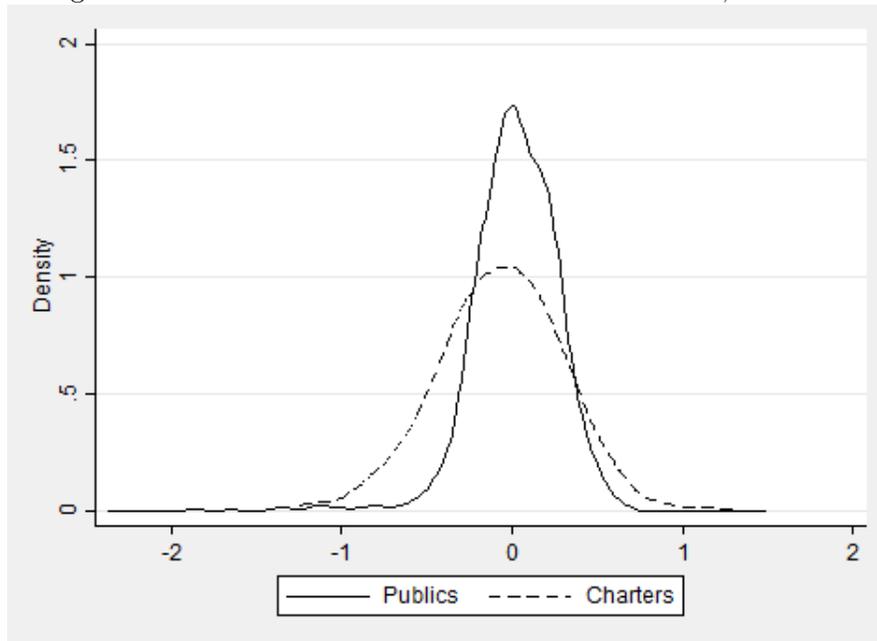


Figure 2: Effectiveness of Exiters and Persisters, 2006-2013

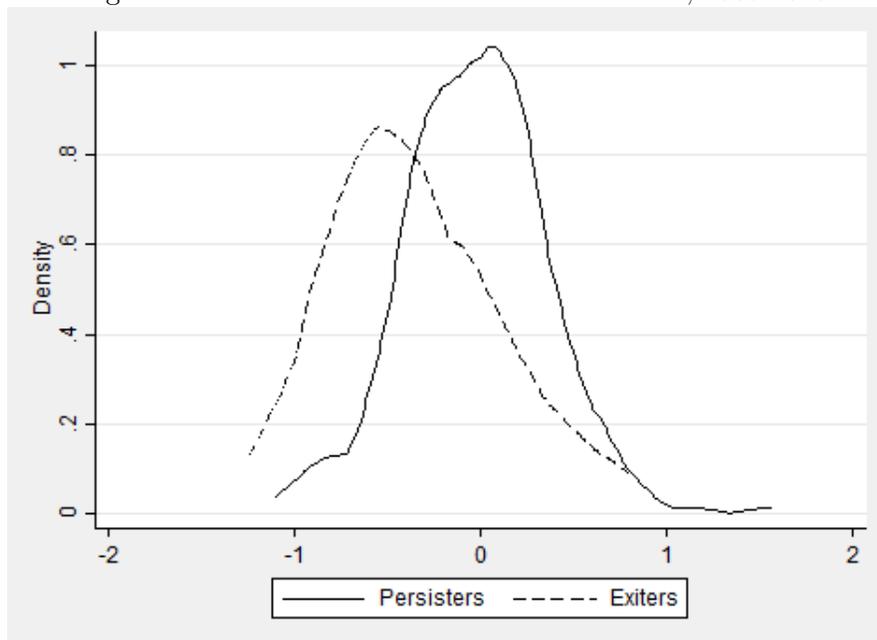


Table 1: Within-District Comparison of Public and Charter School Characteristics, 2012-13

	Publics	Charters
Location Characteristics		
Density	3,092	2,613
Household Income	68,775	66,453
% White	47.01	45.62
% Black	27.13	25.63
% Hispanic	22.31	25.36
% Asian	2.10	2.10
Student Characteristics		
Enrollment	616.95	352.90
% FRP Lunch	64.22	46.91
% White	30.42	31.75
% Black	33.53	31.74
% Hispanic	29.32	29.80
% Asian	2.51	2.32

*Notes:* 288 schools and 1,933 public schools. Values computed after conditioning on school district using Palm Beach as reference group. Note that location characteristics represent area within one mile of a school's Census tract.

Table 2: Student and Location Characteristics of Exiters and Persisters, 2006-13

	Exiters	Persisters	Difference
Location Characteristics			
Density	4,468	4,039	429
Household Income	46,366	62,713	-16,347***
% White	37.46	47.56	-10.10***
% Black	24.87	12.18	12.69***
% Hispanic	34.06	36.54	-2.47
% Asian	1.65	2.11	-0.46*
Student Characteristics			
Enrollment	287.71	408.78	-121.10***
% FRP Lunch	66.23	45.27	20.97***
% White	15.93	39.00	-23.07***
% Black	53.86	17.08	36.78***
% Hispanic	28.52	39.93	-11.40***
% Asian	1.43	2.75	-1.32***

*Notes:* \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Note that location characteristics represent area within one mile of a school's Census tract.

Table 3: Expenditure and Student Performance of Exiters and Persisters, 2006-13

	Exiters	Persisters	Difference
Expenditure / Pupil	7,988	7,086	902***
Math $z$	-0.90	0.05	-0.96***
Reading $z$	-0.62	0.17	-0.79***

*Notes:* \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Math and reading scores represent averages of within grade and year normalized 4th and 5th grade exam performance.

Table 4: Marginal Effects on Probability of Charter School Exit

	(2)	(3)	(4)
% FRP Lunch	0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
% Black	0.002*** (0.001)	0.002*** (0.001)	0.001** (0.001)
% Hispanic	-0.000 (0.001)	-0.000 (0.001)	-0.000 (0.001)
% Asian	-0.011** (0.005)	-0.010* (0.005)	-0.009* (0.005)
Log Age+1	-0.034*** (0.013)	-0.031** (0.013)	-0.024* (0.013)
Log Enrollment		-0.027** (0.011)	-0.024** (0.011)
Reading $z$			-0.024* (0.013)
Baseline $P(Exit)$		0.044	
District and Year FE	Y	Y	Y
Observations		1,369	
R <sup>2</sup>	0.127	0.131	0.137

*Notes:* Robust standard errors in parentheses. \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Specification also controls for the percentages of ELL and ESE students, the number of charters and publics within 1, 1 to 3, and 3 to 5 miles each, grade levels served, an indicator for year of entry, an indicator for missing reading scores, and income quintile and urban indicators.

Table 5: Estimates of School Effectiveness

	Mean	SD	p5	p25	Median	p75	p95
All Schools, 2012-13							
Publics	0.02	0.27	-0.36	-0.12	0.03	0.19	0.39
Charters	-0.07	0.38	-0.71	-0.31	-0.07	0.20	0.52
Charter Schools, 2006-13							
Persisters	-0.03	0.38	-0.64	-0.27	-0.04	0.20	0.57
Exiters	-0.49	0.76	-1.25	-0.67	-0.47	-0.09	0.46
Nearby Public Schools, 2006-13							
Persisters	0.02	0.14	-0.22	-0.07	0.03	0.13	0.22
Exiters	0.00	0.10	-0.23	-0.06	0.00	0.07	0.14

*Notes:* Top panel represents just 2012-13 school year. In the middle panel, I use the fixed effect estimates of  $\mu_{1i}$  from (12) and predict effectiveness if each school were the average age of charter schools in 2012-13. In the bottom panel, mean effectiveness is calculated over all public schools within 5 miles of each charter and averaged over the sample.

Table 6: Estimates of Demand Function: Competitive Effects

	Log Enrollment
N Charters < 1 Mi	-0.109*** (0.038)
1 Mi $\leq$ N Charters < 3 Mi	0.012 (0.016)
3 Mi $\leq$ N Charters < 5 Mi	-0.001 (0.018)
N Publics < 1 Mi	-0.101*** (0.026)
1 Mi $\leq$ N Publics < 3 Mi	-0.041*** (0.007)
3 Mi $\leq$ N Publics < 5 Mi	-0.021*** (0.006)
Income Quintile x Urban x Type FE	Y
District x Type FE	Y
Year x Type FE	Y
Observations	8,590
R <sup>2</sup>	0.767

*Notes:* Standard errors obtained by block bootstrap that samples markets (50 draws). \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Specification also controls for relative effectiveness, log school-aged populations by household demographic in 1, 1 to 3, and 3 to 5 mile distance bands, and dummies for year of entry and exit. Estimates of the return to effectiveness, market size, and spillovers presented in Table 7.

Table 7: Estimates of Demand Function: Effectiveness, Market Size, and Spillovers

	Asian	Black	Log Enrollment		Other	FRP Lunch
			Hispanic	White		
Relative Effectiveness	0.545*** (0.136)	-0.207 (0.140)	0.680*** (0.162)	0.606** (0.249)	0.219* (0.114)	0.216* (0.119)
Within 1 Mile:						
Log Population	0.112*** (0.038)	0.143*** (0.033)	0.218*** (0.074)	0.181** (0.090)	-0.004 (0.032)	
Log Asian Population		-0.067* (0.035)	0.145*** (0.041)	0.117** (0.051)	0.106*** (0.034)	0.031 (0.034)
Log Black Population	-0.066** (0.028)		-0.201*** (0.028)	-0.265*** (0.047)	-0.094*** (0.029)	-0.002 (0.034)
Log Hispanic Population	-0.132** (0.051)	-0.169* (0.091)		-0.033 (0.083)	-0.072 (0.051)	0.031 (0.063)
Log White Population	0.034 (0.074)	0.016 (0.089)	-0.053 (0.078)		-0.022 (0.053)	-0.123** (0.049)
Income Quintile x Urban x Type FE				Y		
District x Type FE				Y		
Year x Type FE				Y		
Observations				8,590		
R <sup>2</sup>				0.767		

*Notes:* Standard errors obtained by block bootstrap that samples markets (50 draws). \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Relative effectiveness refers to charter school's effectiveness less the average effectiveness of public schools within 5 miles. Specification also controls for number of charter and public schools by distance band, log school-aged populations by household demographic in the 1 to 3 and 3 to 5 mile distance bands, and dummies for year of entry and exit. Estimates of the competitive effects are presented in Table 6.

Table 8: Estimates of Variable Cost Function

	Log Expenditure
Log Enrollment	0.808*** (0.081)
Log Enrollment <sup>2</sup>	0.015** (0.007)
Effectiveness	0.306** (0.133)
Effectiveness <sup>2</sup>	0.057* (0.031)
Effectiveness * Log Enrollment	-0.053** (0.023)
% FRP Lunch	-0.001* (0.000)
% Black	0.002*** (0.000)
% Hispanic	0.001 (0.000)
% Asian	-0.009** (0.004)
% Other	0.003 (0.002)
For-Profit	-0.048** (0.021)
Log Age+1	0.006 (0.013)
Income Quintile x Urban FE	Y
District x Year FE	Y
Observations	1,319
R <sup>2</sup>	0.942

*Notes:* Standard errors obtained by block bootstrap that samples markets (50 draws). \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. Specification also controls for the percentages of ESE, ELL, and gifted students, grade levels offered, the percentage of enrollment above grade 5, and dummies for year of charter entry or exit.

Table 9: Estimates of Utility Function

	Utility
Variable Costs / Pupil	-3.80*** (1.16)
Variable Costs / Pupil * For-Profit	0.624 (1.86)
Enrollment	-0.080 (0.107)
Enrollment * For-Profit	0.168 (0.167)
Enrollment <sup>2</sup>	0.002 (0.007)
Enrollment <sup>2</sup> * For-Profit	-0.012 (0.017)
Effectiveness	0.628 (0.405)
Effectiveness * For-Profit	2.85 (1.85)
Entrant	-8.88*** (0.402)
Entrant * For-Profit	-1.27 (0.828)
Entrant * Year FE	Y
Year and District FE	Y
Observations	409,558

*Notes:* Standard errors obtained by block bootstrap that samples markets (50 draws). \*, \*\*, and \*\*\* indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The excluded entrant by year fixed effect is 2012-13. Variable costs per pupil are in tens of thousands of dollars. Specification also controls for urban and income quintile intercepts and demographic shares corresponding to each location.

Table 10: Model Fit, 2012-13

	Data	Model
Number of Charters	274	272.70
Enrollment	328.72	323.83
% FRP Lunch	50.31	54.72
% Black	28.16	28.44
% Hispanic	32.81	33.53
% Asian	2.08	2.09
Effectiveness	-0.09	-0.13

*Note:* 2012-13 averages over 50 simulated paths. Values represent average charter school (except for number of charters).

Table 11: Counterfactual Results, 2012-13

	(1)	(2)	(3)
Number of Charters	1.05	1.95	16.58
Enrollment	-3.98	0.25	-1.76
% FRP Lunch	3.58	1.06	-0.42
% Black	9.28	2.60	-0.60
% Hispanic	-0.18	-1.01	-0.27
% Asian	-13.40	5.74	3.83
Effectiveness	-0.01	0.00	0.00

*Notes:* Average percentage change from baseline predictions over 50 simulated paths, 2012-13 school year. Effectiveness reported as difference in average. (1) corresponds to cost-adjusted funding formula using estimates of variable cost differences calibrated to leave average revenue unchanged; (2) corresponds to star-up grant for locations with mean household income in the 1st quintile (less than approx. \$45,000) of \$1,000 per pupil; (3) corresponds to additional \$1,000 per pupil in operating revenue for all charters.

Table 12: Entrants and Exiters in Counterfactuals

	Model	(1)	(2)	(3)
Entrants				
% FRP Lunch	50.09	52.32	51.15	49.46
% Black	32.41	35.69	33.53	31.76
% Hispanic	32.34	32.37	31.99	32.22
% Asian	2.11	1.68	2.20	2.15
Exiters				
% FRP Lunch	49.10	49.13	51.16	50.52
% Black	35.40	32.92	35.69	35.60
% Hispanic	24.81	25.25	25.51	26.38
% Asian	1.73	2.06	1.79	1.70

*Notes:* Averages over 50 simulated paths. (1) corresponds to cost-adjusted funding formula using estimates of variable cost differences calibrated to leave average revenue unchanged; (2) corresponds to start-up grant for locations with mean household income in the 1st quintile (less than approx. \$45,000) of \$1,000 per pupil; (3) corresponds to additional \$1,000 per pupil in operating revenue for all charters.

## Appendix

Table 13: Location and Student Summary Statistics for Charter Schools, 2012-13

	Mean	SD	p10	Median	p90
Location Characteristics					
Density	3,722	3,752	209	2,983	7,507
Household Income	59,206	21,536	37,554	53,836	89,680
% White	20.84	23.58	0.60	11.75	54.97
% Black	45.59	29.85	2.82	47.61	85.03
% Hispanic	29.84	27.21	3.67	20.27	72.30
% Asian	2.23	2.27	0.05	1.62	4.74
Student Characteristics					
Enrollment	324.76	263.57	72	234	687
% FRP Lunch	50.05	27.16	13.64	49.77	87.52
% White	34.86	29.59	1.20	30.19	78.05
% Black	27.49	30.73	1.06	13.26	87.76
% Hispanic	31.91	29.03	3.85	21.50	84.38
% Asian	2.07	2.85	0	1.32	4.76

*Notes:* 288 charter schools. Note that location characteristics represent area within one mile of a school's Census tract.

Table 14: School Summary Statistics for Charter Schools, 2012-13

	Mean	SD	p10	Median	p90
Expenditure / Pupil	7,398	1,932	6,034	7,051	9,407
Math $z$	-0.05	1.11	-1.49	0.00	1.38
Reading $z$	0.14	1.05	-1.30	0.18	1.36
For-Profit	0.47	0.50	0	0	1

*Notes:* 288 charter schools. Expenditure missing for 13 schools.