Open enrolment and student achievement

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Abstract

Critics have long argued that traditional school enrolment mechanisms that assign students to schools on the basis of attendance zones confer substantial monopoly power on neighborhood schools, weakening both opportunities for choice among students and incentives for effort by school managers. We study the effect of an education reform that directly weakened this monopoly power, by eliminating the authority of principals to prevent attendance zone students from opting out to other neighborhood schools, and by requiring that schools accept out-of-zone students so long as they have space available. We find that this simple, low-cost reform resulted in small, precisely estimated improvements in fourth grade math and reading scores. As predicted by our simple partial equilibrium model, these estimated improvements are greatest among students whose own attendance zone school initially scored lowest among nearby neighborhood schools. When these students live in areas where the density of neighborhood schools is high, the effect size is large enough to be of policy significance. In contrast, among students whose attendance zone school initially scored highest among nearby neighborhood schools, our estimates allow us to rule out all but negligible effects.

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1 INTRODUCTION

Economists argue that expanding the scope for parents to choose among competing schools can lead to improvements in the quality of education, by allowing students to enroll in better schools or in schools that better suit their individual needs, and, more fundamentally, by leveraging market pressures to motivate school leaders to deliver effective programs. In traditional education systems where students are assigned to public schools based on geographic enrolment zones, authorities can expand school choice opportunities within the public system simply by eliminating schools' local monopoly power and allowing students to enroll in any public school that has space available. This type of reform has been adopted over the last several decades in most U.S. states (Education Commission of the States 2015), as well as in jurisdictions as diverse as England, Tel Aviv, Sweden, the Netherlands, New Zealand, Beijing and British Columbia, Canada.

Yet, despite the significant advances made by a large and rapidly growing literature on the effects of a wide variety of school choice policies, evidence of the overall effects of this simple, low-cost school reform on student outcomes is extremely limited. Lavy (2010) estimates the effects on high school outcomes of replacing a complex bussing system aimed at school integration in Tel Aviv with a form of public school open enrolment. While highly credible, his results yield little insight into the likely consequences of introducing open enrolment in more general contexts. Gibbons et al. (2008) use distance from school district boundaries to create instruments for local school density measures in cross-sectional data under England's open enrolment system, but their estimates are too imprecise to rule out either moderately sized positive or negative effects on primary school test scores.[4] While a number of credible studies estimate the effects of open enrolment on those who opt out to a choice school (with mixed results, e.g. Betts et al. 2006; Cullen et al. 2005, 2006; Deming et al. 2014; Hastings et al. 2006, 2009, 2012; Ozek 2009), this approach doesn't capture effects that come about via

[4] Early cross-sectional studies that exploit geographic variation in the local density of public schools to estimate the overall effects of open enrolment failed to address the issue of non-random selection into residential neighborhoods (see Belfield and Levin (2002) for a review).

increased competition among schools or changes in the distribution of peer characteristics.[5]

This paper aims to fill this gap in the literature by studying the effects on achievement of a policy reform introduced in British Columbia (B.C.), Canada in 2002. Before the reform, children were guaranteed access to a single neighborhood public school based on geographically defined attendance zones, and enrolment in a different neighborhood school required the permission of both the principal of the preferred school and the principal of the guaranteed school. Under the new open enrolment rules, principals of neighborhood schools that have space available cannot refuse to accept students from outside their attendance zone. Most importantly, principals can no longer veto applications from students in their attendance zone who want to opt out to a different neighborhood school.

Several aspects of the B.C. reform make it a compelling candidate for evaluation. Open enrolment was introduced in B.C. as a stand-alone initiative, rather than as part of a broad suite of educational reforms. This feature distinguishes it from cases including the Netherlands, New Zealand and Sweden, where the introduction of open enrolment in tandem with universal private school vouchers makes it challenging to separately identify the effects of the two policies.[6] A combination of other factors provides textbook conditions for encouraging the kind of behavioural responses that school choice advocates argue will lead to widespread improvements in the quality of public education. Information about school-level test scores was publicly available and widely disseminated at the time of B.C.'s reform, and this information has been shown to influence school choice decisions in this specific context (Friesen et al. 2011). B.C.'s

[5] A broader empirical literature finds mixed and typically small effects of a broad array of choice programs on public school performance, including Tiebout choice (Hoxby 2000; Rothstein 2007), private school vouchers (e.g. Böhlmark and Lindahl 2015; Chiang 2009; Hoxby 1994; Hsieh and Urquiola 2006; Rockoff et al. 2010; Rouse et al. 2007), publicly funded Catholic schools (Card et al. 2010), autonomous schools (e.g. Clark 2009), private school tax credits (Figlio and Hart 2014) and charter schools (see Epple et al. 2015 for a review)

[6] Wondratschek et al. (2013) study the effect of increased competition from Sweden's 1992 reforms that introduced both public school open enrolment and universal private school vouchers, making no attempt to separately identify their effects. They find small positive effects of increased competition on marks in the final year of compulsory schooling, but no effect on longer-term outcomes.

education funding system is directly tied to district enrolment numbers, and money tends to follow students to schools within districts. Finally, the new policy was implemented during a period of ongoing decline in neighborhood school enrolment due to the growing popularity of private schools and magnet programs, leaving many neighborhood schools with excess capacity.

Our empirical analysis is informed by a simple partial equilibrium model of school choice and competition in which we model the introduction of open enrolment as an expansion in the number of local school choice options available to families. We introduce an important source of heterogeneity by allowing schools to differ in initial quality relative to nearby alternatives,[7] and by requiring both that schools maintain a minimum enrolment level in order to avoid closure and that they do not exceed maximum capacity constraints. In the case of students living in the attendance zones of locally low-quality schools, our model generates the standard prediction that their achievement will improve as they gain access to higher quality schools located nearby, and as school managers increase effort to stave off threatened closure caused by shrinking enrolment. In the case of students living in the attendance zones of locally high-quality schools, our model generates the novel insight that their achievement may improve little or not at all, and may even decline. Nearby schools that these students gain access to may be no better or lower quality than the guaranteed school and, if the school attracts excess demand under open enrolment, managerial effort will fall.

Our empirical strategy is motivated by a further implication of our theoretical model: regardless of its sign, the predicted effect of open enrolment on student achievement is increasing in the number of additional choice schools that students gain access to. We use this variation to identify the effect of open enrolment in using student-level administrative and test score data for multiple cohorts of fourth grade students that span the introduction of open enrolment. Intuitively, our estimator compares the difference in fourth grade test scores of pre- and post-treatment cohorts of students who reside in

[7] This assumption is supported by evidence that differences in perceived school quality are capitalized into housing prices, including one study that demonstrates this in the very jurisdiction and time period that we study (Ries and Somerville 2010).

attendance zones where they gain access to a larger number of nearby neighborhood schools, to the difference in test scores of pre- and post-treatment cohorts who reside in attendance zones where they gain access to fewer. We exploit the detailed geographic information in our data to identify schools that are initially high- or low-achieving relative to other nearby neighborhood schools, and use this local ranking to create two subsamples of students: those who gain access to relatively high quality local alternatives and whose guaranteed school is likely to lose enrolment, and those who gain access to relatively low quality local alternatives and whose guaranteed school is likely to attract excess demand.

We find that average test scores increased as a result of this reform. Across the full sample, the effect size is about 0.04 standard deviations in reading and 0.03 standard deviations in numeracy in a typical attendance zone, and 0.10 standard deviations in reading and 0.08 standard deviations in numeracy in a high density attendance zone (i.e. where families gain access to a large number of nearby neighborhood schools). As predicted, we find that this effect is largest among students living in the attendance zones of locally bottom-ranked schools. When these schools are located in high-density neighborhoods, the effect size is 0.13 standard deviations in reading and 0.14 standard deviations in numeracy. In contrast, precisely estimated effects for students living in the attendance zones of locally top-ranked schools allow us to rule out all but very small changes in test scores.

Our interpretation of these relationships as causal rests on the key assumption that the distribution of characteristics across attendance zones among test-writers did not change before and after open enrolment in ways that are systematically related to the number of nearby neighborhood schools. Three types of behavioral responses to open enrolment could violate this identifying assumption: managers who face greater enrolment pressures may discourage or exclude marginal students from the tests; students who gain access to a greater number of nearby neighborhood schools may be more likely to substitute from private to public schools; and families may be more likely to locate in the attendance zones of low-achieving schools when they doing so provides them with access to a larger number of nearby schools that are of relatively high quality (e.g. Epple and Romano 2003; see Brunner et al. 2012 for empirical evidence).

We evaluate these threats to identification in three ways. First, we estimate the effect of open enrolment on the probability that a student writes the tests and that she attends a private school, and on the number of fourth grade students residing in an attendance zone. We find no evidence of behavior that would undermine our identification strategy. Second, we estimate regressions that summarize the relationship between open enrolment and the characteristics of students living in an attendance zone. Again, these estimates provide no evidence against our identifying assumption. Finally, we assess the degree of selection on unobservable characteristics that would be required to fully account for our estimates. We conclude that selection bias is an unlikely explanation for our findings.

2 INSTITUTIONAL CONTEXT

2.1 School choice and funding

All students in B.C. are guaranteed access to the single neighborhood school that is associated with their residential address via the school's attendance zone. The provincial Ministry of Education changed the rules governing students' access to neighborhood schools outside their attendance zone in July 2002. In prior years, enrolment in a neighborhood school associated with a different attendance zone required permission from both the student's guaranteed school and the preferred neighborhood school. Under the new rules, students are free to enroll in any neighborhood school in the province that has space and facilities available after students who reside in the attendance zone have enrolled. Transportation out of attendance zones is not provided. When a neighborhood school faces excess demand from students from outside its attendance zone, provincial legislation requires that priority be given to students who reside within the same school district. District boards may elect to give priority to siblings of children who are already enrolled in the preferred school. Within these enrolment categories, school principals have discretion over which students to accept.

Parents in B.C. may also choose to enroll their children in "independent" schools that charge tuition (commonly referred to as private schools) or in a public magnet program.

The most popular magnet program is French Immersion, which enrolls about 10 percent of Kindergarten students in the province (B.C. Ministry of Education 2011). Entry into French Immersion programs is restricted to students entering Kindergarten or first grade, and is often allocated by lottery.

The B.C. Ministry of Education provides operating and capital funding directly to districts. Operating funds are allocated in proportion to total district enrolment, with supplementary funding for each student who is Aboriginal, gifted or disabled, or who qualifies for English as a Second Language (ESL) support. Districts and schools are not authorized to raise any additional revenue. Private schools that conform to provincial curriculum standards and meet various administrative requirements are entitled to provincial operating grants that range from 35 to 50 percent of the public school grant depending on their operating costs (B.C. Ministry of Education 2005).

2.2 Standardized testing

The Foundation Skills Assessment (FSA) tests are administered each year to students in Grades 4 and 7 in all public and provincially funded independent schools in British Columbia (British Columbia Ministry of Education 2005b).[8] Our analysis is based on the Grade 4 reading and numeracy scores. These tests are based on a variety of questions, both multiple-choice and open ended, and are graded centrally by accredited B.C. teachers. All students are expected to participate in the FSA tests, with the exception of ESL students who have not yet developed sufficient English skills to respond to the test, and some special needs students.

The FSA tests are "low-stakes" - they do not contribute to students' academic records and play no role in grade completion, and there are no financial incentives for teachers or schools related to student performance. Following the introduction of standardized testing in 1999, B.C. slowly began to release information about test scores to the public. In the 2000/01 school year, the provincial Ministry of Education provided information about individual, provincial, district and school-level test results to schools, and instructed them

[8] FSA tests were also administered to Grade 10 students between 2000 and 2004; these low-stakes Grade 10 assessments were replaced by high-stakes Provincial examinations beginning in 2005.

to share the information with parents upon request (B.C. Ministry of Education 2000). Beginning in 2003, schools were required to share individual students' exam results with parents before September 30 of each school year. An independent organization (the Fraser Institute) began issuing annual "school report cards" based on these results in June 2003 (Cowley and Easton 2003), which are widely reported in the local media.[9]

3 DATA

Our estimates are based on extracts from two administrative databases collected and maintained by the B.C. Ministry of Education. The enrolment database records the school at which each student is enrolled on September 30 of each year. Our extract from this database includes records for all students enrolled in Kindergarten or Grade 4 at any public or private school in fourteen school districts in the Lower Mainland of B.C between 1999/2000 and 2006/2007.[10] It includes indicators for the language spoken in the student's home (English, Chinese, Punjabi, and other), whether the student self-identified as Aboriginal in any year, whether the student was registered in ESL or special education (i.e., a gifted or disabled program), whether the student was enrolled in French Immersion, whether the school is public or private, and the student's sex. In addition, the extract provides the student's residential postal code and unique student, school, and district identifiers. The second database provides student-level data on participation and scores on the FSA tests. We merge students' FSA scores with the enrolment database via the unique student identifier provided in both files. We normalize valid FSA scores in reading and numeracy to have a mean of zero and standard deviation of one in each year. We also attach average family income in the student's Census neighborhood, based on a postal code match.[11]

4 OPEN ENROLMENT AND SCHOOL QUALITY

[9] None of the authors is affiliated with the Fraser Institute.

[10] The Lower Mainland consists of the city of Vancouver and its suburbs. It is geographically isolated by the Canada/U.S. border to the south, rugged mountains to the east and north, and the Salish Sea to the west.

[11] We measure neighborhood characteristics at the enumeration/dissemination area level, which is the smallest geographic area for which public-use Census data are produced, and typically comprises several hundred households. See the Data Appendix for a detailed description of our procedures for locating residential postal codes within Census enumeration/dissemination and school attendance zone boundaries.

Our goal in this section is to set up a simple partial equilibrium model that captures key features of the choice environment in British Columbia, generates testable predictions that we can bring to our data and provides a framework for interpreting our empirical results. Since school finance is determined at the provincial level in B.C., we are not concerned with the implications of open enrolment for tax and expenditure policy that would arise in a decentralized fiscal environment.[12] We abstract from residential choice decisions; evidence presented in Section 6.4 supports this modeling choice in the B.C. context.

Formally, we assume that student i's academic achievement, y_i, depends on the quality of the school she attends, $q_{s(i)}$, and on her ability, a_i, according to:

$$y_i = f(q_{s(i)}, a_i) \tag{1}$$

where $f(\cdot)$ is increasing in both arguments. Open enrolment may affect the quality of the school that a student attends by affecting her choice of school, $s(i)$. It may also affect the quality of the school she enrolls in, $q_{s(i)}$, by inducing a different effort level from the school manager or by changing the composition of peers. We discuss each of these channels in turn.

4.1 School choice decisions

Parents value school quality but cannot observe it directly. Instead they base their assessments of school quality on available information about school-average test scores. Parents of student *i* have preferences over schools represented by the utility function:

$$U_{is} = \beta \bar{y}_s - \gamma d_s + \varepsilon_{is} \tag{2}$$

[12] Epple and Romano (2003) examine the implications of open enrolment in a general equilibrium model of school and residential choice in a multi-district metropolitan area with district-level tax and expenditure policies. Parents are assumed to care about peer composition and school quality, and school quality is determined by peer characteristics and district-level expenditure. Schools in their model are passive. Barseghyan et al. (2015) study open enrolment in a dynamic general equilibrium model where parents value both school quality and peer characteristics, school quality depends on both managerial effort and peer composition, and schools differ with respect to initial peer composition.

where $\bar{y}_s$ is the average test score at school s (observed by parents before they make their school choice), d_s is the travel distance to school s, $\beta > 0$ and $\gamma > 0$ are utility parameters, and ε_{is} is a random preference parameter.[13]

Before open enrolment, parents who reside in neighborhood *k* located in the attendance zone of neighborhood school *s* are both guaranteed access to *s* and required to enroll their child there. Under open enrolment, they may choose from among a set of schools, S_k, which includes n_k alternatives along with their guaranteed school. Parents evaluate the utility of all schools in the choice set and choose school s if and only if:

$$\beta\Delta\bar{y}_{sr} - \gamma\Delta d_{sr} \geq \varepsilon_{ir} - \varepsilon_{is} \tag{3}$$

for all *r* = 1, 2, 3, …, n_k, where $\Delta\bar{y}_{sr} \equiv \bar{y}_s - \bar{y}_r$ and $\Delta d_{sr} \equiv d_s - d_r$. The probability that family *i* in neighborhood *k* chooses to enroll their child in school *s* under open enrolment is:

$$\prod_{r=1}^{n_k} F(\beta\Delta\bar{y}_{sr} - \gamma\Delta d_{sr}) \tag{4}$$

where $F[\cdot]$ is the distribution function of the random variable $(\varepsilon_{ir} - \varepsilon_{is})$, normalized to have mean zero. Differentiating (4) with respect to $\Delta\bar{y}_{sr}$ gives us:

$$\sum_{r=1}^{n_k} \beta f(\beta\Delta\bar{y}_{sr} - \gamma\Delta d_{sr}) \prod_{m\sim r}^{n_k} F(\beta\Delta\bar{y}_{sm} - \gamma\Delta d_{sm}) > 0 \tag{5}$$

where f is the density of $(\varepsilon_{ir} - \varepsilon_{is})$. Differentiating (4) with respect to Δd_{sr} gives us:

$$\sum_{r=1}^{n_k} [-\gamma f(\beta\Delta\bar{y}_{sr} - \gamma\Delta d_{sr}) \prod_{m\sim r}^{n_k} F(\beta\Delta\bar{y}_{sm} - \gamma\Delta d_{sm})] < 0 \tag{6}$$

These conditions tell us that, all else equal, the probability that the family chooses school *s* under open enrolment is increasing in its perceived quality and decreasing in its travel distance, and it is decreasing in the perceived quality of each of the alternative choice schools and increasing in their travel distances.

4.2 Competition and managerial effort

[13] Empirical evidence suggests that parents value specific peer characteristics, independently of their effect on student achievement (e.g. Hastings et al. 2009; Burgess et al. 2014). Incorporating such preferences would weaken the predicted effects of open enrolment on student achievement in our model (see Hastings et al. 2006; Ladd 2002; Rothstein 2006).

We now consider how the expansion of school choice opportunities affects the quality of schools. We begin by abstracting from peer effects, so that school quality depends only on the level of effort exerted by school managers, e_s, via an increasing concave function:

$$q_s = q(e_s) \tag{7}$$

The preferences of school managers depend on the number of students who enroll in their school, E_s, and on the effort they expend on managing the school:

$$V(E_s, e_s) = \theta E_s - e_s \tag{8}$$

where $\theta > 0$ reflects the relative weight on enrolment.

Let K_s^0 denote the set of neighborhoods that lie in the attendance zone of school *s* and K_s^1 denote the set of neighborhoods where school *s* is an element of families' choice sets under open enrolment. The school-age population in each neighborhood is given by N_k. Before open enrolment, when families must enroll their children in their guaranteed school, the market share of enrolment demand for school *s* is one among parents residing in neighborhood $k \in K_s^0$ and zero otherwise, and the total demand for school *s* is:

$$\textstyle\sum_{k \in K_s^0} N_k \tag{9}$$

School managers choose effort levels to maximize their utility in (8). Before open enrolment, enrolment demand does not depend on the effort of managers. The optimal choice of effort, e_s^{*0}, therefore equals zero.

Under open enrolment, the market share of enrolment demand for school *s* among parents residing in neighborhood $k \in K_s^1$ depends on the school mean test score and travel distance to school *s* relative to all other schools in their choice set:

$$m_{sk} = m\left(\Delta\bar{\mathrm{y}}_{s1}, \dots, \Delta\bar{\mathrm{y}}_{sn_k}, \Delta\mathrm{d}_{s1}, \dots, \Delta d_{sn_k}\right) \tag{10}$$

The market share of school *s* in other neighborhoods is zero. The total demand for school *s* is:

$$\textstyle\sum_{k \in K_s^1} N_k m_{sk} \tag{11}$$

Again, school managers choose effort levels to maximize their utility in (8), but now enrollment depends on effort, via (11). The optimal choice of effort, e_s^{*1}, satisfies the first-order condition:

$$\theta \sum_{k \in K_s^1} N_k \frac{\partial m_{sk}}{\partial \bar{y}_s} \frac{\partial \bar{y}_s}{\partial q_s} \frac{\partial q_s}{\partial e_s} - 1 = 0 \qquad (12)$$

Assuming that enrolment demand is an increasing non-linear function of managerial effort, optimal effort under open enrolment is positive. School quality improves as effort increases.

4.2.1 School capacity constraints and minimum enrolment requirements

We now consider the implications of hard caps on the number of students that schools can enroll. We begin by noting that, holding effort constant, open enrolment will change the demand for each school as families optimize over their expanded choice sets. Enrolment demand for a given school may increase or decrease, depending on the number of students who opt out from within its attendance zone relative to the number of students from other neighborhoods who opt in.[14]

In very popular schools, enrolment demand at the level of effort that satisfies (12) may exceed the physical capacity of the school, E_s^{max}. In this case, the level of effort chosen under open enrolment satisfies:

$$\sum_{k \in K_s^1} N_k m_{sk}(e_s) = E_s^{max} \qquad (13)$$

This optimal effort level is less than the unconstrained choice of effort, e_s^{1*}, and may be zero. As a result, binding capacity constraints will attenuate or annul potential improvements in school quality under open enrolment.

In very unpopular schools, the level of effort that satisfies (12) may fail to attract the minimum number of students required to avoid closure, E_s^{min}. In this case, effort is chosen to satisfy:

$$\sum_{k \in K_s^1} N_k m_{sk}(e_s) = E_s^{min} \qquad (14)$$

[14] We assume in this section that the distribution of student ability a_i across schools is unchanged under open enrolment. We explore the potential effects of relaxing this assumption below.

so long as this choice generates more utility than that which the manager receives if the school closes. This effort level is greater than the unconstrained choice of effort, e_s^{1*}. Effort under open enrolment will be higher when schools face binding minimum enrolment requirements relative to the unconstrained case, resulting in even greater improvements in school quality under open enrolment.

4.2.2 More than one school in the initial choice set

We now consider modifying our model to allow parents to have a limited amount of school choice *before* open enrolment. This scenario more closely resembles the actual environment that we study, where parents had some access to other neighborhood schools before open enrolment, and could also choose a private school or public magnet. When parents are initially constrained to enroll their child in their guaranteed school, enrolment demand is unresponsive to effort and managers choose zero effort. Since effort cannot be negative, the effect of open enrolment on effort is non-negative. However, the availability of choice before open enrolment means that enrolment demand is responsive to managerial effort and managers initially choose a positive level of effort. In this case, open enrolment can cause effort to fall, even in the absence of capacity constraints.

This can occur when some students who attend non-guaranteed schools *before* open enrolment choose different schools under open enrolment. If these alternative choice schools are relatively weak substitutes for the guaranteed school, the responsiveness of enrolment demand to the perceived quality of the guaranteed school declines among students living within its attendance zone. This effect offsets the increase in the responsiveness of enrolment demand to managerial effort that comes about via the expansion of the number of neighborhoods the school can draw from under open enrolment in (12), attenuating the predicted improvement in school quality or even causing it to decline.

4.3 Composition and peer effects

We now allow the distribution of student ability across schools to change as students re-sort under open enrolment. A change in school mean student ability affects school quality directly via peer effects.[15] It may also affect school quality indirectly, via its effect on managerial effort. The change in school mean test scores caused by the change in mean student ability, amplified by peer effects, alters parents' perceptions of school quality, causing enrolment demand to shift further. If this change in demand causes enrolment constraints to bind, managers respond by choosing effort as described in Section 4.2.2. Specifically, a decline (rise) in school average student ability resulting from choice behavior under open enrolment causes the perceived quality of the school to decrease (increase), all else equal. At unpopular schools that lose enrolment, this change reinforces (offsets) the initial enrolment losses, raising (reducing) the likelihood of the threat of closure. At popular schools that gain enrolment, this change offsets (reinforces) the initial enrolment gains, reducing (raising) the likelihood of excess enrolment demand.

4.4 Geographic density

In this section, we argue that the intensity of the effects of open enrolment on student achievement will vary with the number of neighborhood schools that are located nearby. From inspection of (4), we know that the probability that a student opts out to a non-guaranteed school under open enrolment is non-decreasing in the number of nearby schools that she gains access to. If these schools are relatively high quality, this raises the probability that she enrolls in a higher quality school that raises her achievement. The number of nearby schools also affects the optimal level of managerial effort in (12), via two avenues. First, the increase in the responsiveness of enrolment demand to the perceived quality of school *s* under open enrolment is increasing in the number of nearby neighborhoods in which students gain access to school *s* (i.e. when the change in the number of terms in the weighted sum, $K_s^1 - K_s^0$, is greater), since all terms in the sum are non-negative and some are likely positive (demand for school *s* in neighborhood k is a non-decreasing function of its perceived quality). Second, the increase in the responsiveness of enrolment demand to the perceived quality of school *s* within each neighborhood, $\frac{\partial m_{sk}}{\partial \bar{y}_s}$, is increasing in the number of nearby school choices that students gain access to (given the non-negativity of (4)). For schools that are not constrained by

[15] See Epple and Romano (2011) for a review of empirical evidence on the effects of peers at school.

minimum or maximum enrolment requirements, the increase in optimal effort therefore is increasing in the number of nearby neighborhood schools, with analogous implications for school quality and therefore for student achievement.

5 EMPIRICAL MODEL

Our empirical strategy exploits the predicted variation in treatment intensity under open enrolment that arises from variation across neighborhoods in the geographic density of neighborhood schools. Rather than trying to distinguish the separate effects that come about via choice, competition and peer effects, we aim to identify the overall effect of open enrolment on achievement.[16] We therefore construct a single variable, $Density_{g(i),t(i)}$, which reflects the scope for choice, competition, and sorting in year $t(i)$ and attendance zone $g(i)$. To construct this variable, we first count the number of "nearby" neighborhood schools, which are located within a circle centered on a postal code, with radius equal to the 75th percentile of distance travelled to neighborhood schools in the year preceding open enrolment. We then identify a travel zone (different from an attendance zone) for each neighborhood school, defined as the set of all postal codes for which that school is "nearby." We calculate the student-weighted average number of nearby neighborhood schools over all postal codes within a school's travel zone, and assign to each student the value associated with their guaranteed neighborhood school.

Our key treatment variable interacts this density measure with a binary variable that indicates whether open enrolment is in effect in a given year, $OE_{t(i)}$. When open enrolment became law in July 2002, registration for the 2002/03 school year was effectively complete. Parents who wished to enroll their child in a non-guaranteed neighborhood school in that school year would have had to contact the school's principal

[16] Gibbons et al. (2008) include separate measures of school choice and school competition in their spatial model of the effects of open enrolment on primary school achievement. They measure choice as the number of schools that are available to families living a given location, and competition as the average number of choices that are available to students attending a given school. This approach does not address the endogeneity of school choice decisions, nor can it distinguish between the effects on school mean achievement that come about via effects on school quality versus changes in student composition. We avoid these problems by constructing a single treatment variable that does not vary with school choice, conditional on residential choice.

in early September 2002 to inquire about space. We therefore code our open enrolment variable as an indicator that the school year is 2003/04 or later. This assumption is supported by aggregate patterns in enrolment behavior presented in Section 6.1.

Our empirical model is:

$$y_i = \beta_1 X_i + \beta_2 X_{c(i)} + \beta_3 \bar{X}_{\sim i,z(g(i)),t(i)} + \beta_4 nPrivSchools_{p(i),t(i)} + \beta_5 nFrenchSchools_{f(i),t(i)} + \phi_1 Density_{g(i),t(i)} + \phi_2 OE_{t(i)} Density_{g(i),t(i)} + \tau_{t(i)} + \kappa_{g(i)} + \varepsilon_i \quad (16)$$

where y_i is student *i*'s test score, X_i is a vector of student characteristics, $X_{c(i)}$ is a vector of socioeconomic characteristics measured at the Census neighborhood level, $\bar{X}_{\sim i,z(g(i)),t(i)}$ is a vector of mean characteristics of same-grade students living in the travel zone, *z,* of student *i*'s guaranteed neighborhood school, in the year that *i* is observed, $nPrivSchools_{p(i),t(i)}$ and $nFrenchSchools_{f(i),t(i)}$ are the numbers of private and public French Immersion public schools that are "nearby" to student *i*'s postal code in that year, and $\tau_{t(i)}$ and $\kappa_{g(i)}$ are fixed year and attendance zone effects respectively. The scalars ϕ_1, ϕ_2, β_4 and β_5 and the vectors β_1, β_2 and β_3 are parameters to be estimated, and ε_i is a stochastic error. We define nearby private and French Immersion public schools as those schools that are located within circles centered on a student's postal code with radius equal to the 75th percentile of distance travelled to that type of school in our sample in the year before open enrolment was introduced.

Our key treatment variable, $OE_{t(i)} Density_{g(i),t(i)}$, varies across attendance zones and over time. We include attendance zone fixed effects to control for any time-invariant factors at the attendance zone level that influence achievement and are correlated with the local density of neighborhood schools, and we control for gender, home language and Aboriginal identity (measured at the student level), number of nearby French Immersion and private schools (measured at the postal code level), mean family income (measured at the Census neighborhood level) and the proportion of same-grade peers who speak Chinese, Punjabi or another non-English language at home, who are Aboriginal, and who are female (measured at the guaranteed school travel zone level). Our estimator of ϕ_2 is identified from variation across attendance zones in the average number of nearby neighborhood schools that students gain access to under open enrolment. Our key identifying assumption is that there are no time-varying unobserved factors at the attendance zone level that affect student achievement before versus after open enrolment and that are correlated with the geographic density of neighborhood schools.

6 RESULTS

6.1 School enrolment trends

Although standardized tests are not administered to Kindergarten students, enrolment choices at the time of school entry are likely to be most malleable and therefore the clearest indicator of changes in enrolment pressures facing school managers under open enrolment. Figure 1 shows that, after being flat over the previous five years, the share of Kindergarten students attending a non-guaranteed neighborhood school increased by 5.5 percentage points between 2003 and 2006, to 27 percent. The corresponding increase among fourth grade students was slightly lower, at 4.4 percentage points.[17]

The scope for other forms of school choice was also increasing during this period. While the fourth grade population increased by 11 percent between 1996 and 2006, the number of private schools increased by 21 percent to 104 and the number of French Immersion schools increased by 14 percent to 41. At the same time, the number of neighborhood schools grew by only 5 percent to 449. Returning to Figure 1, we see that the private school share of Kindergarten enrolment grew by 3.6 percentage points to 14.1 percent of students over the period, while the French Immersion share of Kindergarten enrolment grew by 4.3 percentage points to 10.1 percent. The share of Kindergarten students attending their guaranteed neighborhood schools fell by 13.3 percentage points to 54.2 percent. Again, fourth grade enrolment shows similar patterns that are slightly less pronounced.

[17] The magnitude of this increase is strikingly similar to the 5 percentage point increase in out-of-zone public school enrolment in "non-transition" grades following the introduction of open enrolment in Pinnelas County, Florida (Ozek 2009) and the 6.6% participation rate in San Diego's open enrolment program (Betts et al. 2006).

6.2 Sample restrictions and characteristics

Our main estimation sample includes all students who have non-missing values for all relevant variables and attend a public neighborhood school or public magnet school that enrolls at least five Grade 4 students.[18] We exclude students enrolled in private schools because we expect that non-guaranteed neighborhood schools may be weaker substitutes for private schools than for guaranteed schools, and that the effect of open enrolment on schools therefore may differ across sectors. From the perspective of public policy, the effect of open enrolment on public school quality is of primary interest.

The model described in Section 4 predicts that the treatment effect is likely to be heterogeneous across schools. Students who live in the attendance zones of schools that are relatively unpopular compared to nearby alternatives may experience substantial improvements in school quality both via the direct effects of choice and via increased effort from school managers concerned about falling enrolment. Students who live in the attendance zones of schools that are relatively popular compared to nearby alternatives may experience little if any improvements in school quality and may even see school quality decline if school managers respond to excess demand by reducing effort. In order to investigate these hypotheses, we rank each student's guaranteed neighborhood school relative to nearby neighborhood schools according to school mean test scores in the first year of our sample (i.e. 1999). We then create two sub-samples, consisting of students whose guaranteed neighborhood school is locally top- or bottom-ranked, respectively.

The variation in the local density of neighborhood schools among fourth grade students in our estimation sample is illustrated in Figure 2. Overall, 17 percent of students lived in a postal code with only one nearby neighborhood school (their guaranteed school) and 20 percent lived in a postal code with only two nearby neighborhood schools, i.e. their guaranteed school and one other. The maximum number of nearby neighborhood schools is sixteen.

[18] A small number of public schools provide instruction in French to students whose mother tongue is French. These francophone schools are distinct from French Immersion magnet schools. We exclude students attending these schools from our estimation sample and do not include them in students' school choice sets.

Table 1 reports mean characteristics for our main sample. The two largest non-English language groups are Chinese-speakers (12 percent of our sample) and Punjabi-speakers (7 percent of our sample); other non-English languages are spoken by 15 percent of students. Aboriginal students, most of whom are English speakers, make up 6 percent of the sample. The average student lives in a postal code that has 1.2 nearby French Immersion schools, and 9.7 nearby private schools. The relatively large number of nearby private schools reflects the relatively large travel zones that private schools draw students from in our sample. Students living in the travel zone of the average student's guaranteed school on average have 3.6 nearby neighborhood schools (including their guaranteed school). Table 2 shows that students who attend non-guaranteed neighborhood schools on average are drawn from attendance zones of schools where mean test scores are slightly below average, and enroll in schools where mean test scores are 0.06-0.09 standard deviations higher.

6.3 Changes in test scores over time

Our theoretical framework predicts that the effects of expanding school choice will depend on the popularity of a student's guaranteed school, and this effect will be greater when the scope for choice expands to include a larger number of alternatives. In order to provide simple visual evidence related to these hypotheses, we calculate the average test score in each year among students whose catchment school ranked highest (lowest) among fewer than two public competitors, and those whose catchment school ranked highest (lowest) among six or more public competitors. The top panel of Figure 3 plots these averages for reading, and the bottom panel for numeracy. Mean test scores among students whose guaranteed school faced little new competition under open enrolment changed little between 1999 and 2004. In contrast, mean test scores among students whose guaranteed school faced substantial new competition under open enrolment show clear trends. As predicted, mean test scores fell among students whose guaranteed school was locally top-ranked, and increased among those whose guaranteed school was locally bottom-ranked. In the case of reading, this convergence of mean test scores among top- and bottom-ranked schools appears to coincide with the introduction of open enrolment in 2002. In the case of numeracy, the improvement in test scores among students with guaranteed access to low-ranked schools after 2002 follows on an improvement in the previous year.

6.4 Main regression results

We present our main regression results in Table 3. Standard errors are clustered at the attendance zone-by-year level. The first two columns report results for the full sample. We find that average Grade 4 reading and numeracy test scores improve modestly after the introduction of open enrolment. For the average student, whose guaranteed neighborhood school has a neighborhood school density value of 3.6, the point estimates imply that reading and numeracy scores increase by 0.04 and 0.03 standard deviations respectively after the introduction of open enrolment. Among those whose guaranteed schools are at the 90th percentile of neighborhood school density (8.5 neighborhood schools), the estimated effects for reading and numeracy are 0.10 and 0.08 standard deviations respectively.

The results for our two sub-samples, shown in the remaining columns of Table 3, reveal substantial heterogeneity. Among students whose guaranteed school is the lowest-ranked among nearby neighborhood schools, open enrolment has a positive and statistically significant effect on test scores in both reading and numeracy. The implied effect size for students with guaranteed schools at the 90th percentile of neighborhood school density is 0.13 standard deviations in reading and 0.14 standard deviations in numeracy. However, among students whose guaranteed school is the highest-ranked among nearby neighborhood schools, open enrolment has virtually no effect on test scores, regardless of neighborhood school density.

6.5 Assessing selection bias

We consider three potential sources of selection bias. First, if school managers respond to increased competition by excluding low-achieving students from standardized tests, this behavior would bias upwards our estimates for students whose guaranteed neighborhood schools face potential enrolment losses under open enrolment. While we don't observe the potential test scores of students who are excluded from a test, we can estimate the effect of open enrolment on the frequency of such exclusions. While the share of missing reading and numeracy test scores increased throughout the period, the results reported in Table 4 show that this increase was *smaller* among students whose guaranteed neighborhood school faced a larger number of new competitors under open enrolment. The point estimates are negative even among locally bottom-ranked schools that arguably faced the biggest threats from enrolment losses. If anything, therefore, this source of bias is likely to result in our underestimating the true positive effect of open enrolment on test scores. While we can't rule out the possibility that schools are engaging in other practices in order to manipulate test scores, we are not aware of any anecdotal or empirical evidence of such behavior in the B.C. context.

The second potential source of selection bias arises from our exclusive focus on public school students. According to our model, a greater share of private school students will switch to the public sector when they gain access to a larger number of nearby neighborhood school choices under open enrolment, all else equal. To the extent that these families differ from the average public school family in unobservable ways that affect achievement, this behavior could bias our estimates. Our data allow us to directly estimate the effect of open enrolment on substitution between private and public schools. The results in Table 5 provide no evidence that increased public school choice opportunities under open enrolment affect private school enrolment.

The third potential source of selection bias arises if open enrolment affects residential choice. For example, parents may be more willing to reside in the attendance zones of low-quality neighborhood schools when they have easier access to non-guaranteed public schools. This behavior will bias our estimates if residential selection into attendance zones changes under open enrolment in ways that change the relationship between students' unobservable characteristics and the local density of neighborhood schools. In order to investigate this potential threat, we aggregate our data to the attendance zone and year level, and estimate the effect of open enrolment on the number and characteristics of fourth grade students residing in an attendance zone. The results in the last three columns of Table 5 show no systematic relationship between neighborhood school density and the change in the size of the fourth grade population following the introduction of open enrolment. Table 6 shows the relationship between our treatment variable and the percentage of students in an attendance zone whose families report speaking English at home and who are Aboriginal. None of these estimates is statistically significant, and most are small enough to allow us to rule out any meaningful relationship.

While none of our results indicates any substantial risk of bias, we undertake an additional exercise to assess the degree of selection that would be required to fully account for our main results. Consider the case of a bottom-ranked neighborhood school, where the estimated effect size in numeracy in neighborhoods at the 90^{th} percentile of neighborhood school density is 0.14 standard deviations (see Table 3). This estimated effect can be accounted for by selection bias if, for example, 5% of the public school test-writers living in the attendance zone of this school under open enrolment would otherwise have lived elsewhere or attended a private school, and if these responders on average scored 2.72 standard deviations higher in both reading and numeracy than non-responders residing in the same attendance zone, conditional on observed characteristics. Table 7 presents results for this and other selection scenarios, which demonstrate that it would require extreme degrees of selection to fully account for the estimated effects of open enrolment in high-density neighborhoods.

6.6 Robustness checks

Mean reversion. Our local ranking of neighborhood schools may reflect idiosyncratic shocks to test scores in the year of ranking, and the magnitude of these shocks will tend to be larger among schools that score highest relative to a larger number of alternatives. Subsequent changes in mean test scores resulting from mean reversion therefore may be correlated with the treatment variable in our subsamples of top- and bottom-ranked schools. We address this concern by dropping data from the 1999 cohort (the year on which the ranking is based) and re-estimating our main specification. If attendance zone-level shocks are not serially correlated, this approach will eliminate any systematic bias introduced by our method of defining sub-samples based on past achievement. The results presented in Table 8 show that our conclusions are robust to the exclusion of these data.

Other robustness checks. We estimate several versions of our model that differ in minor ways from our main specification. First, we allow for a gradual response to the policy change by interacting our school density measure with a linear function of years since its introduction, rather than a simple open enrolment indicator. The results for this specification, presented in Appendix Table A1, are not substantially different from our baseline estimates. Second, we investigate the sensitivity of results to the treatment of information about school mean test scores on our results. As described earlier, an independent think tank began issuing annual "school report cards" based on FSA test scores in June 2003. In order to control for the potential effects of this information shock, we include one- and two-year lags of the guaranteed school's mean test scores in our specification, interacting the first lag with an indicator that the year is 2003 or later (the first year it could affect managerial effort) and interacting the second lag with an indicator that the year is 2004 or later (the first year it could affect school choice).[19] This lag structure requires that we drop the first two years of data, leaving us with only two years of data before open enrolment was introduced. While somewhat smaller, the estimates nevertheless continue to provide strong evidence that open enrolment led to improvements in test scores, particularly in reading. When we restrict our sample to students living in attendance zones of locally top- and bottom-ranked schools, the point estimates are mixed and statistically insignificant. We are more inclined to conclude that these weaker results reflect challenges in separately identifying the effects of information and open enrolment in this much richer specification and shorter panel, rather than evidence against our baseline results. These results are reported in Appendix Table A2.

7 CONCLUSION

Before B.C.'s open enrolment reform, students were assigned to public schools according to a traditional enrolment mechanism based on neighborhood attendance zones. Critics point out that this type of system confers substantial monopoly power on neighborhood schools with respect to the provision of public education. Open enrolment weakened this

[19] Foundation Skills Assessment Tests written in spring of school year t are released in the fall of $t+1$; their influence on managerial effort therefore may be reflected in the test scores of students who write the FSA exams in spring of $t+1$. Information from year t test scores released in fall of $t+1$may influence school choice decisions recorded in the enrolment data recorded on September 30 of year $t+2$.

monopoly power by eliminating the authority of principals to prevent attendance zone students from opting out to other neighborhood schools, while at the same time requiring that schools accept out-of-zone students so long as they have space available. We find that this simple, low-cost reform resulted in small, precisely estimated improvements in fourth grade math and reading scores for students living in neighborhoods where the geographic density of neighborhood schools produced a substantial expansion in school choice opportunities. As predicted, these estimated improvements are greatest among students whose guaranteed school is relatively weak compared to nearby neighborhood schools. When these students live in areas where the density of neighborhood schools is high, the effect size is large enough to be of policy significance. In contrast, among students whose guaranteed school scored highest among nearby neighborhood schools before open enrolment, our estimates allow us to rule out all but negligible effects.

Our methodology does not allow us to identify the various mechanisms that may be driving our results. In the case of students living in the attendance zones of bottom-ranked schools, the estimated increase in average test scores under open enrolment may reflect moderate gains that are experienced broadly as a result of improvements in school quality that create a "rising tide that lifts all boats," or larger gains that are concentrated among those who opt out of their guaranteed school, while those who remain behind could even be worse off as a result of declining peer quality. In order for the latter scenario to be plausible, given the magnitude of our point estimates, either a very large percentage of students would have to opt out and/or those who opt out would have to gain a substantial advantage from doing so. Direct evidence of the effects of opting out under open enrolment in other environments does not suggest that the gains would be large enough to account for our estimates. It seems likely, therefore, that at least some of the gains we measure come about via improvements in school quality.

Acknowledgements

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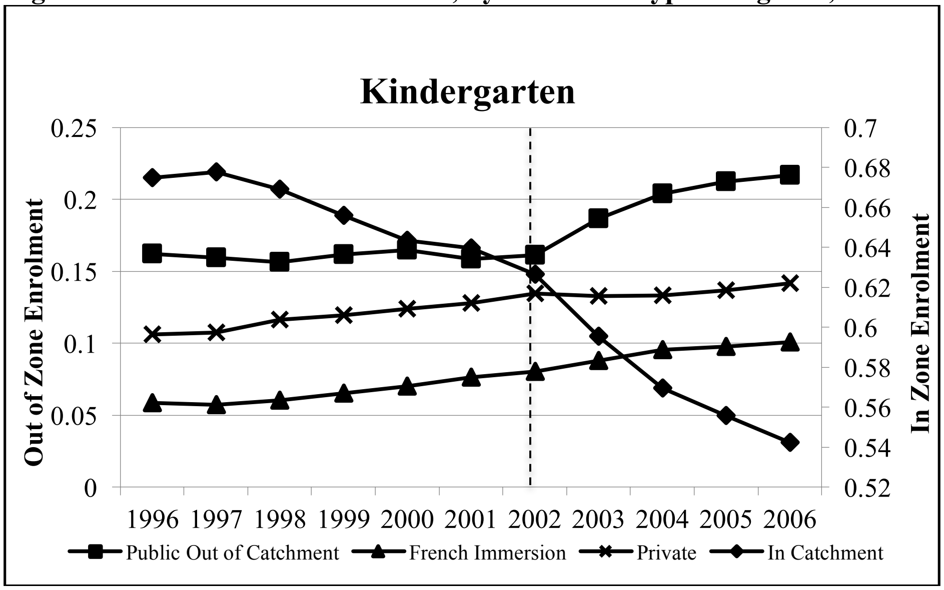
FIGURES

Figure 1. Enrolment in B.C. schools, by enrolment type and grade, 1996-2006



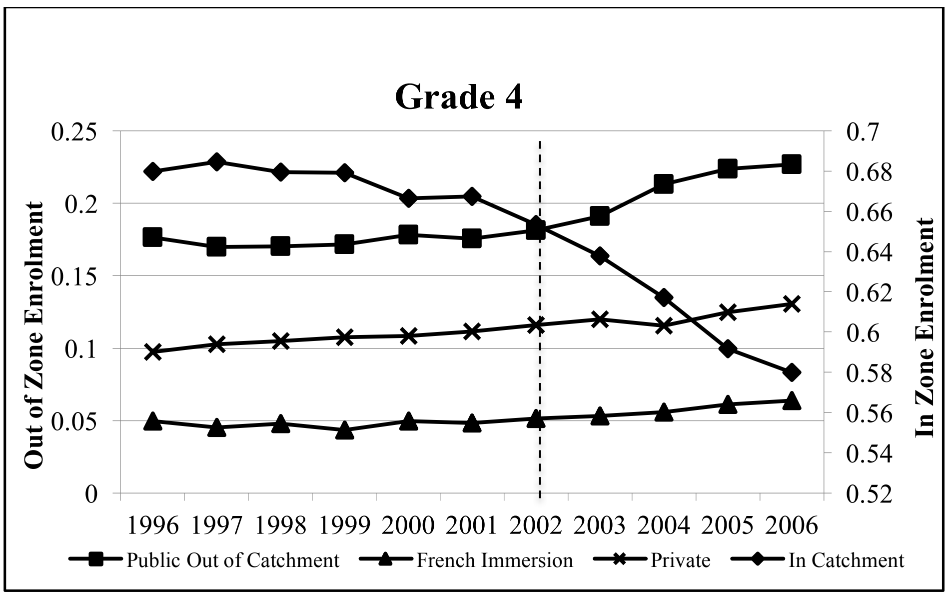
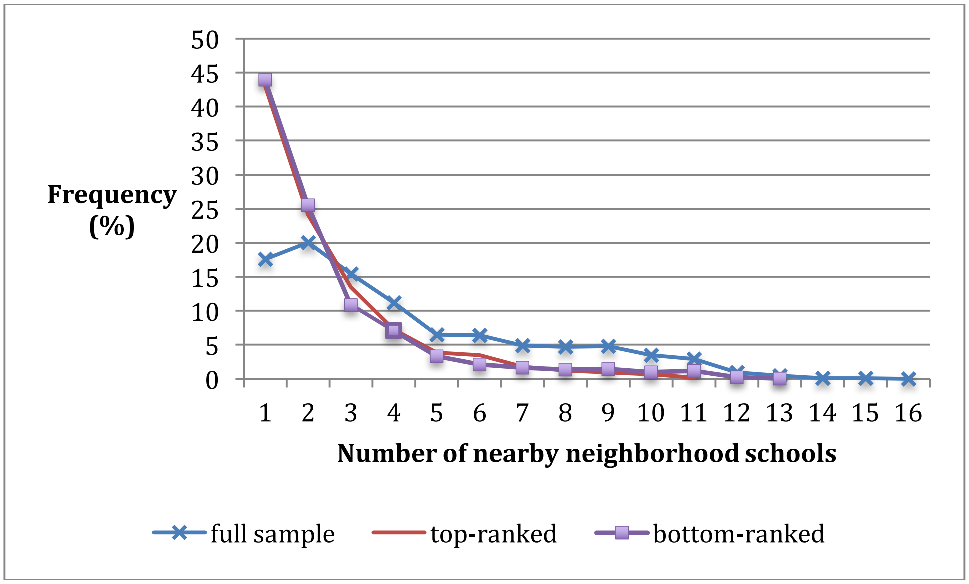
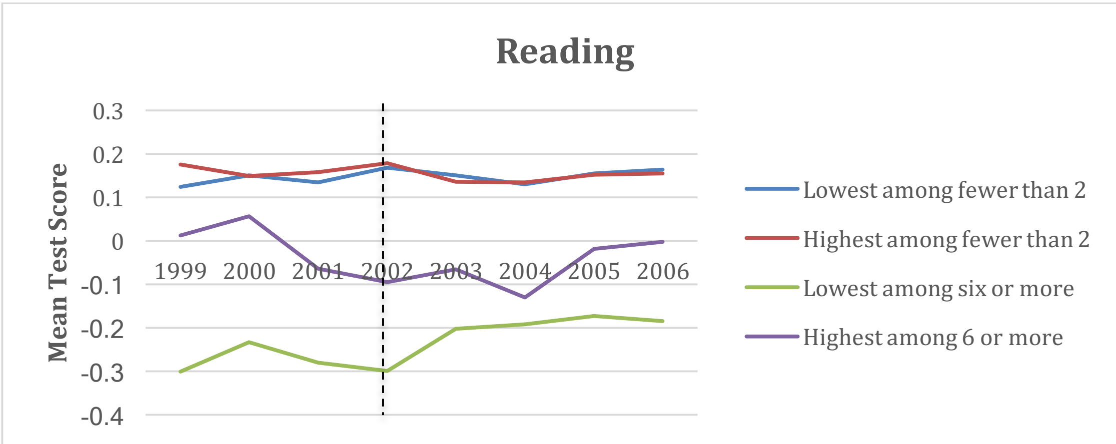


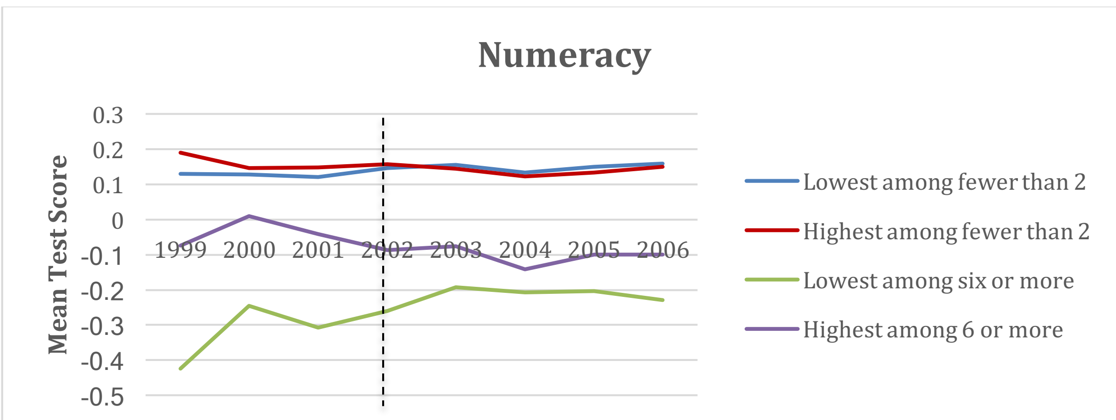
Figure 2. Number of nearby neighborhood schools, by local ranking of guaranteed school, 1996-2006



Notes: Sub-samples are defined according to the ranking of student's guaranteed school with respect to school mean test scores in 1999, relative to other nearby neighborhood schools. The number of nearby neighborhood schools includes the student's guaranteed school. When there are no nearby alternatives to this school (number of nearby neighborhood schools = 1), the observation is included in both the top-ranked and bottom-ranked sub-samples.

3. Mean test scores among students whose guaranteed school ranked highest/lowest relative to fewer than two or more than six local competitors





TABLES

Table 1: Sample characteristics

	Mean	Std. Dev.
Student characteristics		
Chinese home language	0.12	0.33
Punjabi home language	0.07	0.26
Other non-English home language	0.15	0.36
Aboriginal	0.06	0.24
Female	0.48	0.50
FSA Reading Score	-0.05	0.99
FSA Numeracy Score	-0.04	0.99
Missing FSA Reading Score	0.11	0.31
Missing FSA Numeracy Score	0.12	0.32
Neighborhood characteristics		
Neighborhood family income	$68,000	$28,000
Number of nearby French Immersion schools	1.22	0.98
Number of nearby private schools	9.71	5.57
Guaranteed school characteristics		
Number of competing public schools	3.62	2.82

Notes: see text and Data Appendix for details of sample selection and construction, and for variable definitions.

Table 2: School mean test scores, students attending neighborhood school that is not their guaranteed school

	Reading		Numeracy	
	Guaranteed School	School attended	Guaranteed School	School attended
Before Open Enrolment	-0.11	-0.04	-0.09	-0.03
After Open Enrolment	-0.12	-0.03	-0.11	-0.03

Table 3: Regression results, effect of open enrolment on Grade 4 student test scores, public school students

	(1)	(2)	(3)	(4)	(5)	(6)
	All attendance zones		Top-ranked		Bottom-ranked	
KEY VARIABLES	Reading	Numeracy	Reading	Numeracy	Reading	Numeracy
Density	-0.018	-0.005	-0.008	-0.018	0.027	0.049**
	(0.011)	(0.013)	(0.023)	(0.026)	(0.020)	(0.023)
OE*Density	0.012***	0.009***	0.004	-0.003	0.015***	0.016***
	(0.002)	(0.003)	(0.005)	(0.006)	(0.004)	(0.005)
Constant	-0.087	-0.014	0.021	0.114	-0.174**	-0.115
	(0.057)	(0.064)	(0.072)	(0.082)	(0.075)	(0.082)
# of observations	148469	147617	58516	58227	56562	56212
R-squared	0.031	0.032	0.031	0.033	0.031	0.032
# of attendance zones	455	455	330	330	356	356

Notes: a. Dependent variable is the student's FSA test score. b. Standard errors clustered by attendance zone and year. Additional control variables in all specifications include indicators for gender, home language (Chinese, Punjabi, other non-English), and Aboriginal identity; the proportion of peers in the guaranteed school's travel zone who speak Chinese, Punjabi, or another non-English language at home, who are Aboriginal and who are female; mean family income in the student's neighborhood, the number of nearby private and French Immersion schools and year and attendance zone fixed effects.

Table 4: Regression results, effect of open enrolment on missing Grade 4 test scores, public school students

	(1)	(2)	(3)	(4)	(5)	(6)
	All attendance zones		Top-ranked		Bottom-ranked	
KEY VARIABLES	Reading	Numeracy	Reading	Numeracy	Reading	Numeracy
Density	0.010***	0.016***	0.001	0.001	0.004	0.012*
	(0.004)	(0.004)	(0.007)	(0.007)	(0.006)	(0.006)
OE*Density	-0.004***	-0.005***	-0.005***	-0.005***	-0.002	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	0.080***	0.068***	0.122***	0.115***	0.085***	0.075***
	(0.019)	(0.019)	(0.023)	(0.024)	(0.025)	(0.025)
# of observations	166564	166564	65685	65685	63869	63869
R-squared	0.018	0.016	0.020	0.019	0.022	0.020
# of attendance zones	455	455	331	331	359	359

Notes: a. Dependent variable is a binary indicator for whether the student participated in the FSA test. b. See note b in Table 3.
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Regression results, effect of open enrolment on private school enrolment and on attendance zone student population size, public and private school students

	(1)	(2)	(3)	(4)	(5)	(6)
	Private school enrolment			Grade 4 population size		
KEY VARIABLES	All	Top-ranked	Bottom-ranked	All	Top-ranked	Bottom-ranked
Density	-0.004	-0.004	0.001	-1.54	-2.84**	-2.17*
	(0.003)	(0.006)	(0.005)	(0.95)	(1.178)	(0.927)
OE*Density	0.000	0.000	-0.001	-0.050	0.099	-0.084
	(0.001)	(0.001)	(0.001)	(0.10)	(0.144)	(0.118)
Constant	0.103***	0.136***	0.111***	57.16***	56.92***	56.42***
	(0.014)	(0.020)	(0.020)	(3.93)	(3.52)	(2.62)
# of observations	188646	76268	73637	3485	2348	2489
R-squared	0.015	0.019	0.017	0.019	0.021	0.022
# of attendance zones	455	333	363	455	334	364

Notes: a. Dependent variable in columns (1-3) is a binary indicator for whether the student attended a private school in Grade 4. Standard errors clustered by attendance zone and year. b. For details of specification, see note b in Table 3. c. Additional control variables in these specifications include the number of nearby private and French Immersion schools and attendance zone and year fixed effects. d. The unit of observation in columns (4-6) is the attendance zone-year, and the dependent variable is the number of fourth grade (public and private school) students residing in the attendance zone. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Regression results, effect of open enrolment on characteristics of attendance zone population, public and private school students

	(1)	(2)	(3)	(4)	(5)	(6)
	English home language			Aboriginal		
KEY VARIABLES	All	Top-ranked	Bottom-ranked	All	Top-ranked	Bottom-ranked
Density	-0.032	-0.010	-0.071	-0.001	0.012	0.001
	(0.050)	(0.057)	(0.050)	(0.017)	(0.021)	(0.023)
OE*Density	-0.007	-0.014	0.005	0.004	0.002	-0.004
	(0.008)	(0.012)	(0.004)	(0.004)	(0.005)	(0.004)
Constant	0.774***	0.615***	0.752***	0.028	0.034	0.073
	(0.217)	(0.137)	(0.188)	(0.058)	(0.079)	(0.055)
# of observations	3485	2348	2489	3485	2348	2489
R-squared	0.006	0.009	0.005	0.002	0.003	0.004
# of attendance zones	455	334	364	455	334	364

Notes: a. The unit of observation in all columns is the attendance zone-year. b. Dependent variable in columns (1-3) is the proportion of students who reported speaking English at home. c. Dependent variable in columns (4-6) is the proportion of students who reported Aboriginal identity. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Mean test scores of movers required to fully account for estimated effects of open enrolment on test scores via composition effect, by percentage of students who move

	(1)	(2)	(3)	(4)
	Top-ranked		Bottom-ranked	
	Reading	Numeracy	Reading	Numeracy
Estimate (see Table 3)	0.004	-0.003	0.015***	0.016***
Implied effect size				
High-density neighborhoods	0.03	-0.03	0.13	0.14
Average neighborhoods	0.01	-0.01	0.05	0.06
Mean score to fully account for effect size in				
High-density neighborhoods where…				
5% of students move	0.68	-0.51	2.55	2.72
10% of students move	0.34	-0.26	1.28	1.36
15% of students move	0.23	-0.17	0.85	0.91
Average neighborhoods where…				
5% of students move	0.29	-0.22	1.08	1.15
10% of students move	0.14	-0.11	0.54	0.58
15% of students move	0.10	-0.07	0.36	0.38

Notes: In high-density neighborhoods (at the 90th percentile of neighborhood school density), 8.5 public schools compete with one another; in average neighborhoods (50th percentile) this number is 3.6. *** p<0.01, ** p<0.05, * p<0.1

Table 8: Regression results, student achievement in Reading and Numeracy, with 1999 omitted to control for mean reversion, public school students

	(1)	(2)	(3)	(4)
	Top-ranked		Bottom-ranked	
KEY VARIABLES	Reading	Numeracy	Reading	Numeracy
Density	-0.008	-0.018	0.027	0.049**
	(0.023)	(0.026)	(0.020)	(0.023)
OE*Density	0.004	-0.003	0.015***	0.016***
	(0.005)	(0.006)	(0.004)	(0.005)
Constant	0.021	0.114	-0.174**	-0.115
	(0.072)	(0.082)	(0.075)	(0.082)
Observations	58516	58227	56562	56212
R-squared	0.031	0.033	0.031	0.032
# of attendance zones	330	330	356	356

Notes: See notes to Table 3.
*** p<0.01, ** p<0.05, * p<0.1

Data Appendix

Control variables

Controls for individual characteristics include indicators for sex, Aboriginal identity and language spoken at home (English, Chinese, Punjabi or other). We also control for mean household income in the Census Enumeration or Dissemination Area (EA or DA, respectively) in which the student resides, as a proxy for unobserved student background characteristics. Postal code level controls include the number of nearby French Immersion schools and number of nearby private schools. Details of the construction of these variables are provided below. Guaranteed school level controls include the proportion of peers who reside in the guaranteed school's travel zone who speak Chinese, Punjabi or other non-English home languages, who are Aboriginal and who are female. Details of the construction of these variables are provided below.

Coding of Neighborhood Family Income

To proxy for the student's socioeconomic status, we match their residential postal code to the most recent public-use estimates of neighborhood average income from the 1996, 2001, and 2006 Census long-form. Statistics Canada publishes average income at the Enumeration Area (EA) or the Dissemination Area (DA) level, depending on Census year. 1996 Census estimates were published at the EA level, where an Enumeration Areas typically included 125 to 440 dwellings (in rural and urban areas, respectively). Since the 2001 Census, Statistics Canada has replaced EA-level estimates with estimates at the DA level. A Dissemination Area comprises 400 to 700 persons, so EAs and DAs are comparable in size.

We link postal codes are to an EA/DA using Statistics Canada's Postal Code Conversion File (PCCF), which contains the longitudinal history of each postal code (postal codes are routinely retired and reused elsewhere). Postal codes are smaller than EAs/DAs, although they sometimes straddle multiple EAs or DAs. In these cases, we link the postal code to the best EA/DA using Statistics Canada's single link indicator, which identifies the EA/DA with the majority of dwellings assigned to that postal code. The PCCF also includes the latitude and longitude of the postal code's centroid, which we use to compute the great circle distance between each student's residence and nearby schools. We use these distances to define and code our measures of nearby schools; see below.

Assignment of Postal Codes to School Attendance Zones

We identify students' guaranteed school by locating residential postal codes within school attendance zone boundaries as defined in 2007. Historical information about attendance zone boundaries prior to 2007 was not available. To minimize measurement error associated with changes in attendance zone boundaries between 1999 and 2007, we use detailed information about school openings and closings to identify all students in our sample whose attendance zone may have been affected by such an event. All such cases were assigned a missing value for their guaranteed school in the relevant years.

Coding of Nearby Schools

We obtained postal codes from public sources (most notably, school and district websites) for all schools attended by grade 4 students who met our sample restrictions. We used the PCCF to assign a latitude and longitude to each postal code in each year, and calculated the great circle distance (in km) between the student's residence and all schools in our data set. For each residential postal code in each year, we then calculated the number of active neighborhood, French Immersion and private schools within a circle centered on the residential postal code and with radius equal to the 75th percentile of in-sample travel distance neighborhood, French Immersion and private schools, respectively, in the year preceding the introduction of open enrolment.

Coding Neighborhood School Density

We measure neighborhood school density associated with a guaranteed school by first identifying all students who reside within the 75th percentile of the relevant in-sample travel distance to that school. We then compute the average number of nearby neighborhood schools for those students.

APPENDIX TABLES

Table A1: Robustness checks, student achievement in Reading and Numeracy, public school students

	(1)[a]	(2)[b]	(3)[a]	(4)[b]
KEY VARIABLES	Reading		Numeracy	
Density	-0.022*	-0.017	-0.008	-0.005
	(0.011)	(0.012)	(0.013)	(0.013)
OE*Density	0.012***		0.009***	
	(0.002)		(0.003)	
Years since OE*Density		0.004***		0.003***
		(0.001)		(0.001)
Observations	148485	148469	147626	147617
R-squared	0.031	0.031	0.032	0.032
# of attendance zones	455	455	455	455

Notes: [a] Baseline specification (from Table 3). [b] With 'years since open enrolment' instead of open enrolment indicator. Dependent variable is the student's Grade 4 FSA test score. Additional control variables in all specifications include indicators for gender, home language (Chinese, Punjabi, other non-English), and Aboriginal identity; the proportion of peers in the guaranteed school's travel zone who speak Chinese, Punjabi, or another non-English language at home, who are Aboriginal and who are female; mean family income in the student's neighborhood, the number of nearby private and French Immersion schools and year and attendance zone fixed effects.

*** p<0.01, ** p<0.05, * p<0.1

Table A2: Regression results, student achievement in Reading and Numeracy, full sample, with controls for public information about school mean test scores, public school students

	(1)	(2)	(3)	(4)	(5)	(6)
	All attendance zones		Top-ranked		Bottom-ranked	
KEY VARIABLES	Reading	Numeracy	Reading	Numeracy	Reading	Numeracy
Density	-0.022	-0.019	-0.017	-0.014	0.029	0.024
	(0.015)	(0.017)	(0.027)	(0.032)	(0.024)	(0.026)
OE*Density	0.010***	0.006*	0.004	0.000	0.004	-0.002
	(0.003)	(0.003)	(0.006)	(0.007)	(0.006)	(0.006)
Constant	-0.046	0.065	0.026	0.063	-0.116	-0.027
	(0.071)	(0.080)	(0.088)	(0.100)	(0.093)	(0.099)
Observations	111475	110896	43561	43354	42217	41992
R-squared	0.032	0.032	0.032	0.034	0.031	0.033
# of attendance zones	455	455	323	323	347	347

Notes: a. Dependent variable is the student's FSA test score. b. Standard errors clustered by attendance zone and year. Additional control variables in all specifications include indicators for gender, home language (Chinese, Punjabi, other non-English), and Aboriginal identity; the proportion of peers in the guaranteed school's travel zone who speak Chinese, Punjabi, or another non-English language at home, who are Aboriginal, and who are female; mean family income in the student's neighborhood, the number of nearby private and French Immersion schools; one- and two-year lags of the guaranteed school's mean test score, first lag of mean test score interacted with an indicator for 2003 or later, second lag of mean test score interacted with an indicator for 2004 or later, and year and attendance zone fixed effects.
*** p<0.01, ** p<0.05, * p<0.1