Disabled peers and academic achievement[1]

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Abstract

We use data on students in grades 4 through 7 in the Canadian province of British Columbia (B.C.) to investigate the effect of having disabled peers on value-added exam outcomes. Longitudinal data for multiple cohorts of students are used together with school-by-grade fixed effects to account for endogenous selection into schools. Our estimates suggest that same-grade peers with learning and behavioral disabilities have an adverse effect on the test score gains of non-disabled students in B.C. However, these effects are statistically insignificant, and sufficiently small that they are unlikely to raise concerns with respect to the placement of this group of disabled students. The effect of peers with other disabilities is also small and statistically insignificant, but varies in sign.

JEL codes: I12, I21
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1 Introduction

Since the 1970's, special education has taken on an increasingly important role in North American public schools. This period has seen substantial growth both in the proportion of students with assessed disabilities and in the resources allocated to special education. Recent research addresses issues such as the effect of special education on student outcomes (Hanushek et al. 2002; Cohen 2006) and the incentives to place students in special education (Figlio and Getzler 2002; Cullen 2003; Jacob 2005; Kwak 2007; Dhuey and Lipscomb 2008). The consequences of placement outcomes – where and with whom special education students attend school – are less well-understood, but may be as important as the program effects and their fiscal implications. Several trends in North American public education make these peer effects potentially important, particularly increased emphasis on "inclusion" of disabled students in classrooms with regular-education students (Dworet and Bennet 2002) and growth in private schooling and in public school choice policies (Cullen and Rivkin 2003).

The consequences of these trends depend on the nature and magnitude of externalities associated with special education for disabled students. These externalities may take the form of fiscal or resource spillovers, changes in the frequency of disruptions, changes in pedagogy to accommodate a more heterogeneous classroom, or increased scarcity of the instructor's time as the number of students needing extra help increases. Evidence to date on this issue is mixed: Hanushek at al. (2002) find little if any effects of disabled same-grade peers on the test score gains of non-disabled students. In contrast, Fletcher (2008) finds that students who have a classmate with a serious emotional problem experience reduced first grade test score gains, and Aizer (2008) finds that the presence of classmates who are subsequently diagnosed with Attention Deficit Disorder adversely affects reading test scores.

This paper uses data from the Canadian province of British Columbia (B.C.) to investigate peer effects associated with disabled students in public schools. Specifically, we estimate the influence of the percentage of same-grade schoolmates in several disability categories on a given non-disabled student's academic achievement. Achievement is measured by the test score gain between grades 4 and 7 on province-wide numeracy and reading exams. We address endogenous selection into schools by using multiple cohorts of students and thus allowing for school-by-grade level fixed effects. This type of research design has been used by a number of authors investigating educational peer effects (e.g. Hoxby 2000; Hanushek et al. 2002, 2003, 2004).

Our main finding is that attending school with a higher percentage of students with learning disabilities or behavioral disorders has a small impact on the reading and numeracy test scores of non-disabled students. The relevant parameter estimates are generally negative but are statistically insignificant and small in magnitude given the range of peer group composition seen in the data. We find no evidence that attending school with a higher percentage of students with other disabilities, including physical, intellectual and sensory disabilities, adversely affects the test scores of non-disabled students. The achievement of regular-program students who are educated in environments with a larger proportion of disabled students does not appear to be compromised to a significant degree.

1.1 Related Literature

The growth and expense of special education in the US has attracted considerable attention in recent years. Cohen (2006) provides an overview of national trends, showing that the initial growth in students following the passage of the Education for All Handicapped Children Act in 1975 leveled off in the 1980s, and then accelerated over the 1990s. By 2002, roughly 14% of students in the U.S. received special education services, and over two-thirds of these students have been diagnosed with learning disabilities (Cohen 2006). Most of the growth in special education has taken place in this category, as well as in other so-called “soft” disabilities in which variations in diagnostic procedures lead to substantial variation in measured prevalence (Cohen 2006). Hanushek et al. (2002) show that almost all of the growth in the disabled population in Texas between 1977 and 1999 came through increases in the fraction of students classified as learning disabled, which grew from 2% to 6% of the school population. Jacob (2005) documents a substantial rise in special education enrollment in Chicago Public Schools following the introduction of accountability policies in 1996, and shows that much of this increase can be explained by the incentive to exclude low-achieving students from high-stakes testing. Cullen (2003) shows that fiscal incentives explain much of the growth in special education in Texas during the 1990s. Kwak (2007) demonstrates the sensitivity of disability classifications and spending to fiscal incentives in California. Dhuey and Lipscomb (2008) show that fiscal incentives associated with changes in funding formulas adopted in nine states between 1991/92 and 2003/04 led to significant reductions in special education enrollment rates.

The findings of the existing literature on peer effects in education suggest that disabled students would tend to have a negative impact on the academic outcomes of peers. A number of studies (Hoxby 2000; Hanushek et al. 2003; Betts and Zau 2004; Hoxby and Weingarth 2005; Lehrer and Ding 2007) find evidence that peer academic achievement has a positive impact on a student's own achievement. As most categories of disability are associated with substantially lower academic achievement, these earlier findings suggest a negative effect of peer disability status on achievement. In addition, one of the largest categories of disability is behavioral disorders ("emotionally disturbed" in the U.S.), and disruptive behavior has been identified by several authors (Lazear 2001; Figlio 2007) as likely to have a strong negative effect on peer achievement.

Surprisingly, Hanushek et al. (2002) find evidence that disabled peers have a *positive* effect on the achievement of non-disabled students in Texas. They investigate a number of potential mechanisms that might drive this puzzling result by controlling for class size and teacher quality, by distinguishing between disabled students who are "mainstreamed" versus those who are educated in separate classrooms, and by examining whether disabled students in specific categories that are likely to be more disruptive are associated with smaller positive spillovers. They find that the only significant positive spillovers are associated with those disabled students who are not included in the learning disabled, emotionally disturbed or speech impaired categories. However, these alternative specifications reinforce their central result: disabled students do not harm and may even improve the academic achievement of their peers.

Fletcher (2008) uses a nationally representative sample to measure the effects of having a classmate with a severe emotional problem on first grade test score gains. In contrast to the Hanushek et al. results with school/grade-level peers, Fletcher finds a substantial negative effect associated with classroom-level peers who have severe emotional problems. Strong classroom-level peer effects may be consistent with weak grade-level peer effects if disabled students are concentrated into particular classrooms within a grade. However, identifying classroom-level peer effects is more challenging because of the potential for non-random assignment to classrooms within a grade Fletcher includes a number of classroom level controls and uses matching techniques to address this issue. Aizer (2008) uses the same data set to measure peer effects associated with classmates with ADD. Her research design includes individual-level effects to control for non-random assignment to schools and classrooms. She finds that having classmates who are subsequently diagnosed with ADD adversely affects the reading test scores of boys.

2 Data and Institutional Background

2.1 Organization and funding of the B.C. school system

Education in Canada falls under provincial jurisdiction and is administered in B.C. by the provincial Ministry of Education. The federal government has a substantially smaller role in the education system than does its counterpart in the U.S.; in particular, there is no federal ministry of education and no federal data collection on disabled students or standardization of disability categories analogous to that mandated by the federal *Individuals with Disabilities Education Act* (IDEA) in the U.S.[2]

British Columbia is Canada's third largest province, with a 2001 population of just over 4 million, about half of whom live in Vancouver or its suburbs. Elementary schools in B.C. typically provide Kindergarten through grade 7, with secondary schools offering grades 8 through 12. School choice is primarily determined by residential location within catchment areas set by each district. However, there are several alternatives to the local school. Approximately 10 percent of students in the province attend a private school. Another 5 percent are enrolled in public school French Immersion magnet programs. Finally, a student can directly enroll in a public school outside his or her catchment area. In 2003, the provincial government instituted an official "open boundaries" policy. Under the previous policy, students wishing to attend an out-of-catchment public school required the permission of the principal of their catchment area

[2] The primary exception to provincial jurisdiction in education policy, funding and administration is the education of Aboriginal students on reservation land, which is a federal government responsibility.

school. Since 2003, the catchment area school principal no longer plays a role in cross-boundary admissions; any student in B.C. may attend any public school if there are spaces available after local students have enrolled.

Education finance is provided by the provincial Ministry of Education rather than being raised directly by individual districts. The Ministry provides operating and capital grants to the district public school boards, who then allocate funds to individual schools. The funding formula for operating grants to public school districts is based primarily on total district-level enrollment, with supplementary funding based on the number of Aboriginal students, the number of students enrolled in programs for English as a Second Language or English as a Second Dialect (ESL/ESD), the number of gifted students and the number of disabled students by category. We discuss the funding formula for gifted and disabled students in Section 2.2. In order to receive supplementary funding for Aboriginal and ESL/ESD students, districts are required to demonstrate to the province that they are delivering specific services to address these students' particular needs. Funding for Aboriginal students is targeted, meaning the funds must be used only to provide services to those students. In contrast, supplementary funding for ESL/ESD students can be spent at the discretion of the district, as long as some form of special services are provided for those students. Details of the funding formulas are provided in Table 1.

2.2 Special education in B.C.

B.C.'s policies for assessment of disabilities and service delivery in public schools are similar to those in many North American jurisdictions. After an initial referral from a teacher, parent, or physician, the student is assessed according to a procedure that involves parents, educators, school administrators, and health care professionals. If the student is determined to have a disability, the assessment produces a categorical designation as well as an Individual Education Plan (IEP).   Students who have multiple disabilities are classified according to their most severe need, and all identified needs are addressed in the IEP.

For the most part, B.C. follows an "inclusion" model, in which these services are provided to disabled students within regular classrooms whenever possible (Dworet and Bennet 2002). However, the province does not collect data on the proportion of time that disabled students spend in regular-program classrooms. Grade-level peer effects may differ from classroom-level peer effects if disabled students are concentrated into particular classrooms within a school. We are not able to identify individual classes in our data and therefore cannot measure the extent to which this is the case. However, since 2005/06, the B.C. Ministry of Education has posted school-level reports that indicate the number of disabled students in each class (B.C. Ministry of Education 2006b). Inspection of these reports suggests that schools typically distribute disabled children across classes, rather than concentrating them in particular classes.

B.C. currently uses eleven diagnostic categories for students with disabilities, and these categories have been stable over the time period of our study.[3] Funding for these categories changed substantially in March 2002. Table 1 reports the per-student funding formulas used during the period of our study. The eleven diagnostic categories are grouped into four categories for funding purposes: dependent (physically dependent or deafblind), severe behavior (intense behavior intervention or serious mental illness), low-incidence/high cost (moderate to profound intellectual disability, physical disability or chronic health, visual impairment, deaf or hard of hearing, autism), and high incidence/low-cost (learning disability, mild intellectual disability, moderate behavioral support or mental illness).[4] The overall funding formula was substantially revised in March 2002 from a "pupil weight" to a "census" formula for the high incidence/low cost category. Census formulas provide funding based on the total student count while pupil weight formulas provide funding based on the count of students with diagnosed disabilities (Parrish et al. 2003). As indicated in Table 1, supplementary funding of $3,132 for each high-incidence/low-cost disabled student was eliminated. Funds previously allocated for these students were rolled into the general per-pupil base grant. The March 2002 revision also led to a 6.4% decrease in funding for each dependent student, a 20.4% increase for each low-incidence/high cost student, and essentially no change in funding for students with severe behavior disorders.

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[3] Unlike the disability categories in studies that use U.S. data, B.C. has no category for speech impairment. Instead, speech-related services are provided on an as-needed basis without formal special needs assessment. This difference is more important in early grades: students designated as speech impaired account for roughly 65% of U.S. special education students at age 6 but only 7% by age 13. For more information on these categories see B.C. Ministry of Education (2006a).

[4] The relationship between disability categories, funding categories and the aggregations of categories used in our regressions are summarized in Appendix Table A1.

As we explain in greater detail below, changes in the assessment of disabilities in response to these changes in the funding formula could bias estimates of peer effects, and this bias would be compounded if the changes in assessment procedures varied systematically with school or district characteristics. We construct an instrumental variable based on the way that a student's peers were classified before the change in the funding rules in order to avoid this potential source of bias.

The change in the funding formula could also have implications for our estimates of peer effects if it led schools to alter the services they provide to disabled students. Changes in the behavior of disabled students or their teachers as a result of changes in services, or changes in the amount of time non-disabled students are exposed to disabled students, could alter the magnitude of spillovers. We note, however, that the province did not change any of its policies with respect to the inclusion of disabled students in regular classrooms or with respect to standards of practice in the treatment and support of disabled students during our period of study, and the base grant was increased in order to maintain overall funding levels at the time that the funding formula for disabled students was changed. However, to the extent that these practices did change, our estimates should be interpreted as an average peer effect associated with disabled peers during the period of study.

2.3 The Foundation Skills Assessment exams

The Foundation Skills Assessment (FSA) exams are administered in May of each year to students in grades 4 and 7 in all public and provincially funded private schools in British Columbia, beginning in the 1999/2000 school year.[5] These exams are based on a variety of questions, both multiple-choice and open-ended, and are graded 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 language skills to respond to the test, and severely disabled students. The FSA exams are relatively low-stakes for all parties. Students' scores do not contribute to their school grade and play no role in grade completion, and the results do not affect school or district funding, or teacher pay. However, school and district-level results are

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

made public and are widely discussed within both the educational system and the news media. In particular, the Fraser Institute, a libertarian research and advocacy organization, uses school-level FSA results to produce a widely-publicized and much-discussed annual 'report card' that ranks all elementary schools in the province (e.g. Cowley and Easton 2006).

2.4 Data description

The underlying administrative data used in this study are drawn from the Ministry's enrollment database and its FSA exam database. Each record in these databases corresponds to a particular student enrolled in the B.C. K-12 system observed during a particular year. Each B.C. student has a unique identification code, which we use to link records across the enrollment and FSA exam databases, and to construct a longitudinal record for each student. Records in the enrollment database are based on Form 1701, the annual enrollment form collected for each student on September 30 of each year. These forms are used by the Ministry to determine funding in accordance with the funding formulas described earlier. The enrollment record includes the student's current grade, school and district identifiers, year, gender, self-reported Aboriginal status, enrollment in a language program (e.g., ESL/ESD, French Immersion, and Francophone education), enrollment in a special education program, and self-reported language spoken at home. Records in the FSA exam database include the student's score on each exam, along with a flag indicating whether the student was excused from writing a given exam.[6]

The regression analysis reported in Section 5 is performed by constructing a longitudinal data set covering every student who is in grade 7 in B.C. from 2002 through 2004, and who is in grade 4 in B.C. three years earlier. Wherever such information exists, the longitudinal record also

[6] Because of confidentiality restrictions, our study is based on an extract from the original administrative data. The extract differs from the original data in the following ways: (1) enrollment records are provided only for students in grades 4 through 7; (2) student, school, and district identification codes are encrypted in such a manner as to allow for within-database linkage, but not linkage with external information; (3) language spoken at home is aggregated from the over 100 languages in the administrative data into English, Chinese (including Cantonese and Mandarin), Punjabi, and Other; and (4) both language spoken at home and Aboriginal status are provided based on the student's entire history rather than on the current year's self-report. In particular a student is categorized as Aboriginal if he/she ever self-reports as Aboriginal. A student is categorized as speaking English if he/she always self-reports as English, and is otherwise categorized by his/her most frequently reported home language other than English.

includes information from the student's enrollment records in grades 5 and 6.[7] A student's peer group is defined as all students attending the same grade in the same school in the same year.[8]

3 Disability rates in B.C.

Table 2 presents rates of assessed disability in several broad categories among our sample of Grade 7 students in the B.C. public school system, and compares them to those of comparable populations seen in other studies and to national U.S. statistics.[9] The first line of Table 2 shows that the measured overall disability rate among B.C. public school students in grade 7 is 9.1%. The largest disability category is students with learning disabilities (3.6%), followed by behavioral disorders (2.6%). Over 2.8 percent of students fall into one of the other, smaller disability categories (sensory disabilities, physical disabilities, intellectual disabilities and autism). Comparisons to measures from the U.S. displayed in the remaining rows of Table 2 show that B.C.'s overall disability rate is substantially lower than the rates of between 12.5% and 14.9% observed in the U.S. B.C.'s lower overall disability rate is due primarily to a much lower rate of assessed learning disability: 3.6% in B.C. versus between 7.4% and 10.4% in the US data. The prevalence of the more easily-diagnosed disabilities in the "other" category is similar across the various samples, suggesting that the differences in measured learning disabilities may reflect differences in classification procedures more than differences in the underlying student population. The proportion of students in public schools diagnosed with behavioral disorders is 2.6% in B.C., substantially higher than the 1.0% to 1.4% reported in the U.S. A likely explanation for this difference is that B.C. recognizes two distinct levels of behavioral disorder (intense and moderate), while the U.S. recognizes only one. A student who would be diagnosed in the moderate behavioral disability category in B.C. might not be classified as disabled in the U.S., or might be in a different category such as learning disabled.

[7] A minority of students who are observed in both grades 4 and 7 during the FSA exam period either repeat grades, skip grades, or are out of Province for one or more of the intervening years. We keep these students in our analysis whenever possible. If the student repeats either grade 4 or grade 7, the longitudinal record is constructed from the student's last year in grade 4 and first year in grade 7.

[8] We treat French Immersion and regular program students as attending different schools, even if housed in the same school building. French Immersion students receive instruction mostly in French, and do not attend classes with and rarely participate in organized activities with regular program students.

[9] National statistics for Canada are not available.

Table 3 shows the incidence of disability designations grouped according to their funding category and the variation in this incidence over time. The first column shows that B.C. saw a modest increase in the overall proportion of students with recognized disabilities from 8.6% in 1999 to 9.4% in 2004. Even at its peak, the overall disability rate in our sample is substantially lower than the range seen in the U.S. As discussed earlier, the incentives embedded in B.C.'s funding and accountability framework to designate children as disabled are weak relative to many U.S. jurisdictions. Nevertheless, disability designations in B.C. do appear to respond to fiscal incentives. The remaining columns of Table 3 show that the upward trend in disability rates is primarily attributable to growth in the low incidence/high cost category, with the remaining growth occurring in the severe behavior category. Both of these categories retained targeted funding at the same or higher level in 2002.

Table 4 displays patterns in the proportion of students with disabilities by specific disability group within the low incidence/high cost and high incidence/low cost funding categories. All three disabilities categorized as low-incidence/high cost grew throughout the six-year period, including physical disabilities. The rapid growth in measured autism prevalence has been observed throughout North America during this time period. The extent to which this growth in measured prevalence reflects an upward trend in the true incidence is controversial, but a substantial portion of the growth in the U.S. can be attributed to changes in diagnostic procedures and increased parental awareness (Shattuck 2006). The growth in B.C. may also reflect incentive effects associated with the 2002 change in funding rules. The results in Table 4 also suggest that the changes in funding rules have led to some upgrading of mild intellectual disabilities to moderate, and from moderate behavioral disorders or mild mental illness to intense behavioral disorder or serious mental illness, for the same reason. Interestingly, the proportion of students identified as having learning disabilities continued to grow, even after targeted funding for these students was eliminated in 2002.

Table 5 displays the patterns of entry and exit from the disabled population between grades 4 and 7, for the population of students that are observed in both grades. As the table shows, intellectual disabilities, physical disabilities and autism are relatively stable designations for a given student. For example, about 86% of students with moderate to profound mental disabilities in grade 4 were still designated in the same way in grade 7, while about 77% of students so designated in grade 7 received that designation before grade 5. The two categories of behavioral disorder are particularly unstable: a majority of grade 7 students in each of the categories were not in that category in grade 4, and a majority of grade 4 students in each category do not remain in that category through grade 7. Note that the behavioral categories exhibit high rates of movement between categories, in addition to high rates of entry and exit. Like the behavioral categories, the learning disabled category is somewhat volatile. Unlike the behavioral categories, very few students in the learning disabled category enter from or exit to another category.

4 Methodology

4.1 Model specification and research design

Our overall empirical strategy for measuring peer effects is based on a panel-data extension to the standard linear-in-means model of contextual peer effects (Manski 1993). As is now well known, peer effects are in general not identified from cross-sectional data whenever the assignment of individuals to groups is nonrandom. Whether through housing markets or private schooling markets, family income and education influence the quality of a child's school. Either of these factors will lead to nonzero correlation between peer group composition and unobserved school or student factors relevant to educational outcomes.

Our research design uses individual student-level panel data from multiple cohorts of students within each school, and exploits the small but plausibly random year-to-year variation in peer group composition within a school to consistently estimate school-by-grade level peer effects, while allowing for systematic cross-school variation in school or student quality via school fixed effects. Variations on this design are quite common in the recent literature on educational peer effects (e.g., Hoxby 2000; Hanushek et al. 2002, 2003, 2004; Betts and Zau 2004; Figlio 2007). The appropriateness of this methodology depends critically on the extent to which the year-to-year variation within schools is due to random fluctuations (i.e. the composition of any year cohort represents a finite sample drawn from the underlying population of families) rather than due to specific long-term trends (for example a gentrifying neighborhood, or changes to assessment procedures). As we have three years of data, it is possible in principle to allow for school-specific linear trends in achievement, as in Bifulco, Fletcher and Ross (2009).

Unfortunately, we do not have enough observations to estimate such models with a satisfactory degree of precision.

The education production function – the relationship between cumulative inputs and current test score – is assumed to follow the simple value-added (SVA) model (Todd and Wolpin 2005). In the SVA model, a given test score is a sufficient statistic for the effect of all relevant prior inputs on educational achievement, and past inputs enter into current performance with no "decay." Given these two assumptions, the contribution of current inputs to the test score can be estimated by a regression of the test score gain on the current inputs.[10]

The model is constructed as follows. Students are indexed by $i=1,2,\ldots,n$; schools by $s=1,2,\ldots,S$; grades by $g=4,7$; and time by $t=1,2,\ldots,T$. Let $y_{i,g}$ be the score of student i in grade g. Let $t(i,g)$ be the school year in which the student takes grade g, and let $s(i,g)$ be the school student i attends in grade g. Let $X_{i,g}$ be a vector of student i's individual background characteristics in grade g, let $D_{i,g}$ be a vector of indictor variables describing student i's disability status in grade g, and let the vectors $\overline{X}_{i,g}$ and $\overline{D}_{i,g}$ be the average value of X and D respectively among student i's same-grade schoolmates in grade g. The outcome of interest is the test score gain between grades four and seven and the model is:

$$\begin{aligned}
\Delta y_i &\equiv y_{i,7} - y_{i,4} \\
&= \beta X_{i,7} + \lambda \overline{X}_{i,7} + \gamma \overline{D}_{i,7} + a_{s(i,7)} + \delta_{t(i,7)} \\
&\quad + D_{i,4}\left(\beta_D X_{i,7} + \lambda_D \overline{X}_{i,7} + \gamma_D \overline{D}_{i,7} + a^D_{s(i,7)} + \delta^D_{t(i,7)}\right) \\
&\quad + v_{s(i,7),t(i,7)} + u_{i,t(i,7)}
\end{aligned} \qquad (1)$$

[10] A common alternative to the simple value-added model is the modified value-added (MVA) model, where the dependent variable is the grade 7 test score, and grade 4 test scores (in both subjects) are included as control variables (Todd and Wolpin 2003). The SVA model is a special case of the MVA model. While both models require that the earlier test score is a sufficient statistic for all relevant prior inputs, the MVA model does not require that past inputs should enter into current performance with no "decay." While the SVA model thus has the disadvantage of being less general, it has the advantage of not being subject to attenuation bias from measurement error in the earlier test score. The main results reported in Section 5 are based on the SVA model, but we also evaluate the robustness of the key results to an MVA specification.

where a_s is an unobserved school-specific fixed effect, δ_t is an unobserved year-specific fixed effect, $v_{s,t}$ is an unobserved school-and-year-specific effect and $u_{i,t}$ is an unobserved individual-and-year-specific effect. Note that equation (1) allows all coefficients including the fixed effects to vary with one's initial (grade 4) disability status. However, the parameters of interest in this paper will be the peer effects for nondisabled students (λ and γ), as the sample size is not large enough to reliably estimate peer effects for disabled students (i.e., λ_D and γ_D).

The identifying exogeneity assumption for OLS estimation is:

$$\begin{aligned} &E\left(v_{s(i,7),t(i,7)} \,\middle|\, \left\{X_{j,7}, D_{j,4}, \overline{X}_{j,7}, \overline{D}_{j,7}\right\}_{s(j,7)=s(i,7)}, a_{s(i,7)}\right) = 0 \quad \forall i \\ &E\left(u_{i,t(i,7)} \,\middle|\, \left\{X_{j,7}, D_{j,4}, \overline{X}_{j,7}, \overline{D}_{j,7}\right\}_{s(j,7)=s(i,7)}, a_{s(i,7)}\right) = 0 \end{aligned} \qquad (2)$$

That is, any unobserved factor specific to a particular individual and school in a particular year is unrelated to year-to-year changes in school composition. Given assumptions (1) and (2), the parameters of interest are consistently estimated by applying the standard linear fixed effects estimator using the subsample of nondisabled students.

As described earlier, one possible concern with the use of grade 7 disability status in our models is the possibility that year-to-year changes in disability rates may reflect changes in assessment practices in response to changes in funding rules. Such changes can lead to a mechanical relationship between the peer disability rate and the predicted test score given one's own disability status: if students with relatively mild disabilities (who are likely to have low scores relative to nondisabled students and high scores relative to disabled students) are moved from the nondisabled group to the disabled group this change will tend to raise the average test score in both groups. In this case, the second equality in (2) will be violated. Since all three cohorts were observed in Grade 4 before the change in the funding rule, disability status in grade 4 is not confounded by any response to the changing fiscal incentives. We can therefore address this issue by using grade 4 disability status as an instrumental variable for grade 7 status.

Let $\overline{D}_{i,7}^{4}$ be the proportion of student *i*'s grade 7 schoolmates who were designated as disabled when they are in grade 4. The identifying exogeneity assumption for IV estimation is:

$$
\begin{aligned}
&E\left(\varepsilon_{s(i,7),t(i,7)} \,\middle|\, \left\{X_{j,7}, D_{j,4}, \overline{X}_{j,7}, \overline{D}_{j,7}^{4}\right\}_{s(j,7)=s(i,7)}, a_{s(i,7)}\right)=0 \quad \forall i \\
&E\left(\varepsilon_{i,t(i,7)} \,\middle|\, \left\{X_{j,7}, D_{j,4}, \overline{X}_{j,7}, \overline{D}_{j,7}^{4}\right\}_{s(j,7)=s(i,7)}, a_{s(i,7)}\right)=0
\end{aligned}
\qquad (3)
$$

Given assumptions (1) and (3), along with the usual relevance condition on the instruments, the parameters of interest consistently estimated using the standard linear fixed effects IV estimator applied to the subsample of students who were not identified as disabled in grade 4.

A complication in interpreting our regression coefficients as parameters of a cumulative-input education production function is introduced by the fact that there is a three-year gap between exams. Our main regressions only include measures of grade 7 inputs, including both peer characteristics and the school fixed effect. With unlimited data it would be preferable to include grade 5 and 6 inputs as well, including grade-specific school fixed effects. As such an approach would rapidly exhaust degrees of freedom in our regressions, we prefer to estimate models with grade 7 inputs only. These results should be interpreted with the caveat that grade 7 peer characteristics are also acting as a proxy for grade 5 and 6 peer characteristics.[11] We estimate models with grade 5 and 6 peer characteristics as alternative specifications in Section 5.2.

4.2 Population under analysis and choice of explanatory variables

The population in our regression analysis is non-disabled B.C. public school students who attended grade 7 between 2002/2003 and 2004/2005, and who were enrolled in grade 4 (public or private) in B.C. in 1999/2000 or later. As described earlier, the population of students who are not classified as disabled may be changing over time in response to changes in the funding formula. Therefore, we define our sample of non-disabled students on the basis of their disability status in grade 4 in order to avoid possible problems associated with these changes. We exclude students who attend private school in grade 7 from our estimation sample because

[11] Note that this issue would still be present (though to a substantially lesser degree) in data with annual testing: students change schools during the year, and the peer group measured on a particular day during the year is used as a proxy for the peer group during the year as a whole.

they do not formally participate in the provincial special education system. However, private school students do take the FSA exams, so we are able to retain grade 7 public school students even if they attended private school in grade 4.[12]

The individual-level control variables include gender, Aboriginal status, home language, ESL status, and “English as a Second Dialect” (ESD) status. ESD is a term that has been used in research and in some jurisdictions to describe a student whose first language is English, but whose experiences with Standard English are sufficiently limited that they require ESL-type instruction.[13] An ESL/ESD student is categorized as ESD in our data if he or she meets two conditions: (1) self-reports as Aboriginal; and (2) self-reports as speaking English at home in all years enrolled in B.C. All other ESL/ESD students are categorized as ESL students.

Peer-level control variables include the percent male, percent Aboriginal, percent speaking a language other than English at home, percent ESL, and percent ESD. Our preferred specification aggregates the eleven administrative disability categories into two: learning/behavioral disability and other disability. We also report results for a specification that fully aggregates the disability categories.

5 Results

5.1 Descriptive statistics

Table 6 displays summary statistics for our regression sample. The first four rows describe exam results, including participation rates. Students in B.C. are highly likely to take the test; the grade 7 participation rate for non-disabled students is over 93% in B.C. versus, for example, 82% in

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[12] Some parents may choose private schools for their children in order to avoid having disabled peers. This will not affect estimates as long as parents are responding to the disability rate in the school as a whole rather than to the disability rate among their child’s grademates. Our analysis of the data (available on request) indicates that cohorts within a school with relatively more disabled students do not have higher rates of exit to private schools.

[13] The Ministry of Education does not administratively distinguish between ESD students and traditional ESL students, but its official definition of ESL (B.C. Ministry of Education 1999, footnote 2) explicitly includes ESD students. The data strongly suggests that the ESD concept has become influential in many B.C. districts since this definition was adopted, and has been applied almost exclusively to Aboriginal students. Between 1999 and 2004, the percentage of grade 7 English-speaking Aboriginal students in ESL grew from 2.3% to 9.8%, and the percentage in grade 4 grew from 3.9% to 13.1%. Among non-Aboriginal English-speaking students the grade 7 ESL rate actually fell from 0.6% to 0.4% during this same time period. The growth in ESL among Aboriginal students has taken place primarily in the form of individual districts suddenly moving from having no English-speaking Aboriginal ESL students to having a substantial number of such students within a single year.

Texas (Hanushek et al. 2002). As might be expected, a smaller proportion of our students have valid gain scores; about 89% have valid numeracy gain scores, and 91% have valid reading gain scores. These test score gains serve as dependent variables in the main regressions reported below. Exam scores have been standardized to have mean zero and unit standard deviation across all test takers (including private school students and disabled students, both of whom are excluded from our regression sample) in each subject and year.

The remaining rows of Table 6 provide mean values for all regressors, along with standard deviations for peer variables. The average non-disabled student attends a school in which 8.9% of their grade 7 peers are disabled. During these same years, the overall proportion of disabled students in public schools is 9.1%, suggesting that disabled students are not highly concentrated in a subset of schools.

Table 7 provides further information about the distribution of peer disability status across non-disabled students. As the table indicates, the overwhelming majority of students attend schools with fewer than 16% disabled peers. These results will be helpful in interpreting the peer effect estimates in Section 5: we will put the coefficient estimates into context by calculating the implied effect of a move from a school with no disabled peers (in a given category) to an otherwise-identical school whose proportion of disabled peers is in the median or 90th percentile of the distribution.

Table 8 documents the within-school variation in peer composition that is central to our identification strategy. When we decompose the overall variation in the percentage of peers who are disabled into within-school and across-school components, within-school variation accounts for about 37% of the overall variation in the sample in the percentage of peers who are disabled, 38% of the overall variation in the percentage of peers who have a learning or behavioral disability, and 52% of the variation in the percentage of peers who have an "other" disability. Because our econometric models include school fixed effects, data from the 6.8% of students who attend a school in which there is no variation in percent disabled over the three years of our study help to estimate the other coefficients in the model, but do not contribute to estimating the overall effects of disabled peers. Data from a somewhat larger proportion of the sample is not used for estimating the effects of disabled peers when they are disaggregated into the learning/behavioral (9.5%) and, especially, "other" categories (13.8%).

Table 9 shows the standard deviation of peer disability status for grade 7 students between 1999 and 2004. One potential concern with our approach is the possibility that the open boundaries policy introduced in 2003 may enable a greater degree of sorting. If the open boundaries policy increased sorting opportunities, some of the within-school variation in peer composition could be systematically related to the characteristics of students, biasing our estimates. As the table shows, the standard deviation of peer disability status increased somewhat between 2002 and 2004, but the change is well within the range of variation seen between 1999 and 2002. In other words open boundaries did not induce a detectable short-run increase in sorting.

5.2 Main estimates

Table 10 presents our main regression results. We report OLS and IV estimates for two specifications in each of the numeracy and reading panels. The first specification includes a fully aggregated measure of disabled peers, while the second includes disabled peers disaggregated into two categories: learning/behavioral disabilities and all other disabilities. In all specifications reported in this table, the education production function takes the simple value-added form (i.e., the dependent variable is the net test score gain) and school and year fixed effects are included. Estimated standard errors are robust to clustering at the level of the school. In interpreting the coefficients on peer variables, note that peer group composition is being reported in decimal rather than percentage units. Taking the model literally, each coefficient can be interpreted as the exam score increase (in standard deviations)[14] associated with the percentage of peers in a given category increasing from 0% to 100%. Since a compositional change of that magnitude is never observed in the data, we will also discuss the effects of more plausible compositional changes below.

Our IV specifications use the disabled status of grade 7 peers when they were in grade 4 as instruments for grades 7 peers' disabled rates. Given the close relationship between grade 4

[14] The exam scores have been standardized to have unit standard deviation in the tested population, so that all outcomes are interpreted in standard deviation units. To interpret coefficients as measuring the effect on the score gain, measured in standard deviations of the score gain, just multiply by 1.25 (since the standard deviation of the score gain is 0.80 for numeracy and 0.79 for reading).

disability status and grade 7 status demonstrated in Table 5, weak instruments are not a major concern. Table 10 reports Kleibergen-Paap (2007) “RK” statistics, as implemented in Baum et al. (2007) to verify[15] this more formally. The interpretation of the coefficients on these variables is somewhat different from their OLS counterparts; our IV estimates will measure the effect of variation in the number of grade 7 peers who are disabled as a result of more grade 7 peers having been assigned those designations in grade 4. If students who are diagnosed with disabilities at a younger age tend to be more severely disabled, we might expect the IV estimates to overestimate the average effect of disabled peers in grade 7. On the other hand, Aizer (2008) shows that early diagnosis may also result in effective treatment, thereby offsetting the first effect.

The coefficients in Table 10 on the individual and peer control variables appear robust across specifications, and roughly consistent with standard results in the literature. Boys appear to gain ground relative to girls on numeracy between grades 4 and 7, and lose ground on reading. Aboriginal students on average experience no relative decline in numeracy and a small relative decline in reading; however Aboriginal students in ESD programs experience somewhat larger relative declines in reading. Students who speak a non-English home language and students in ESL programs experience large relative gains in both subjects. Most of the peer background characteristics included in the regressions are statistically insignificant with fairly small point estimates. The point estimate for the effect of ESD peers on numeracy is large and negative, but is imprecise and not statistically significant.

The primary results in Table 10 pertain to the influence of peers with recognized disabilities. Specification (1) considers the pooled effect of disabled peers in general. This estimated effect is negative though statistically insignificant for both exams in both the OLS and IV cases. We can further investigate the magnitude of the implied effects by considering some hypothetical

[15] There is no currently accepted test procedure for weak instruments in a setting with clustering and multiple endogenous explanatory variables. Our (cluster-robust) first stage F-statistics are quite large, ranging from 84 to 417. The Kleibergen-Paap statistic is cluster-robust (unlike the Cragg-Donald statistic used by Stock and Yogo 2005) and accounts for dependencies among the first-stage fitted values (unlike the first-stage F statistic), and is thus an appropriate test statistic. However, weak-instrument critical values have not yet been tabulated for the Kleibergen-Paap statistic. Our expectation based on Stock and Yogo’s critical values for the similar Cragg-Donald statistic is that Kleinbergen-Paap statistics in the range reported in Table 10 will be well above the appropriate critical values.

composition changes. For example, the median of the % disabled variable is reported in Table 7 as 8.0%. For the numeracy exam, the IV point estimate in Table 10 for the coefficient on % disabled is -0.21 with a standard error of 0.24. Taking the IV point estimate as the true value of the parameter, a change in % disabled from zero to the median of the distribution will reduce a student's numeracy exam score by 0.21*0.080 ≈ 0.017, or 1.7% of a standard deviation. If we take the associated 95% asymptotic confidence interval as providing upper and lower bounds on the true parameter value, the effect of this change ranges from a 5.4% of a standard deviation decrease to a 2.1% of a standard deviation increase. Applying the same calculations, a move from zero disabled peers to the 90th percentile of the distribution (16.2% disabled peers) implies a 3.4% of a standard deviation reduction in test scores, with a 95% confidence interval ranging from a 11.0% standard deviation decrease to a 4.2% standard deviation increase. In other words, the overall effect appears to be small, even for a very large[16] (relative to the range of variation in the data) change in percent disabled.

Specification (2) separates disabled peers into the two categories of learning/behavioral and other disability. The point estimates suggest a negative impact of peers with learning and behavioral disabilities in both exam subjects. In both cases, the IV point estimate is substantially larger than the OLS point estimate, though both estimates are statistically insignificant. The OLS point estimates indicate a very small negative impact of peers with other disabilities on numeracy test scores, and a somewhat larger negative effect on reading test scores. The corresponding IV estimates have the opposite sign, indicating positive effects. However, none of these estimates approaches statistical significance.

The estimated peer effects in specification (2) are also small in magnitude given the narrow range of peer disability rates observed in the data. For example, the median of the "% learning/behavioral disability" variable is 5.1% and the 90th percentile is 12.0%. The IV point estimate for the effect of these peers on numeracy exam results thus implies that a change in this variable from zero to the median of the distribution would reduce a student's numeracy exam score by 0.53*0.051 ≈ 0.027, or about 2.7% of a standard deviation. The 95% confidence

[16] Note that peer effects are identified from small within-school variation, and so any use of these estimates to quantify the effects of larger changes in composition relies heavily on the assumption of linearity.

interval for this effect ranges from a 6.0% standard deviation decrease to a 0.7% standard deviation increase. A movement from a peer group with no learning or behaviorally disabled peers to a peer group in which the proportion of learning or behaviorally disabled peers is in the 90th percentile is predicted to reduce a student's numeracy score by 6.4% of a standard deviation.

5.3 Robustness checks

Table 11 reports IV estimates of the key parameters in our preferred specification under various alternative modeling choices. The first specification, labeled "A", is simply copied from column (2) of Table 10. The remaining specifications deviate from this baseline specification as described in the table.

Specification B uses a modified value added (MVA) model of the education production function, as described in Todd and Wolpin (2005). In the MVA specification the dependent variable is the level of the grade 7 test score rather than the gain in test score, and the grade 4 test scores (in both subjects) are included as additional control variables. The point estimates for the effects of learning disabled/behavior are somewhat smaller in this case, while the results for other disabilities are not changed substantively.

Specification C omits the individual and peer control variables (i.e., for gender, aboriginal status, home language, and ESL/ESD status), but keeps the fixed effects. The substantive assumption underlying our research design – that year-to-year fluctuations in school composition are essentially random – implies that our estimates should not be changed substantially by omitting these controls. As the table shows, the estimates do not change by an appreciable amount.

Specification D omits school-level fixed effects. This specification deviates from our research design, and so is included only to give the reader an idea of how important the school fixed effects are in generating our results. All coefficient point estimates in this specification are greater than the corresponding point estimates with fixed effects. The negative coefficients for "% learning disabled/behavior" are smaller in absolute value, and the positive coefficients on "% other disabled" are larger in absolute value. In the numeracy results, the coefficient on "% other disabled" is large, positive, and statistically significant. These results may be somewhat surprising, as they imply that students in the "other disabled" group are quite a bit more likely to attend schools with high average test score gains than schools with low average test score gains. Possible mechanisms by which this might happen are that parents with high-needs children ("other disabled" includes students with physical disabilities, sensory disabilities, intellectual disabilities, or autism) might be particularly selective, or schools with more resources may be more aggressive in diagnosing special needs.

Specification E estimates the model on a restricted subsample of schools that were continuously administered by the same principal between 2002 and 2004. Estimating the model on this subsample is a simple way of allowing for a type of principal fixed effects. Coelli et al. (2007) analyze administrative data from B.C. high schools and find both that principals in B.C. change schools frequently and that individual principals have substantial influence on graduation rates. These results suggest that principals might also influence test scores and failure to account for their influence may bias the peer effect estimates. We find that estimating the model on this restricted sample has little effect on the coefficient on "% learning disabled/behavioral," and reverses the sign of the coefficient on "% other disabled", though that coefficient remains small and far from statistically significant.

Specifications F, G, and H estimate the preferred model on subsamples restricted to students not in French Immersion, students who are native English speakers and non-Aboriginal students respectively. Excluding the French Immersion students reduces the precision of the estimated effects but otherwise has little effect. Excluding non-native English speakers leads to a larger and marginally statistically significant effect of learning/behaviorally disabled peers on numeracy scores. Excluding Aboriginal students leads to somewhat larger effects of learning/behaviorally disabled peers in both exams, with the effect being marginally statistically significant for the reading exam.

Specification I includes average peer characteristics from grades 5-7 rather than from grade 7 alone. Note that the instrumental variables are the same as for the baseline specification: peer disability status is instrumented using the proportion of grade 7 peers who were classified as disabled in grade 4. While it would be possible to add instruments based on the composition of the grade 5 peer group and the grade 6 peer group, we do not do so. The reason for this is that some students change schools, and our research design would require separate fixed effects for each school attended if these instruments were used. Estimating such a model directly would exhaust the degrees of freedom in the data. For both subject exams, the results indicate a slightly stronger peer effect from learning/behavioral disabled peers, and a similar to slightly weaker effect from peers with other disabilities.

5.4 Grade-level versus classroom-level peer effects

We follow much of the literature and consider peer effects that operate at the level of school/grade rather than at the classroom level. This choice is imposed by data limitations, as there is no information in our data identifying a student's classroom or teacher. At the same time, many of the interactions of interest between students occur within the classroom. This section investigates what our estimates of grade-level effects tell us about classroom-level effects. Intuitively, the disability rate of same-grade schoolmates is an imperfect proxy for the disability rate of classmates, and so the grade-level peer effect estimate will tend to combine the true same-grade schoolmate effect with some portion of the classmate effect. The quality of same-grade schoolmates as a proxy for classmates will depend on whether schools concentrate or disperse their disabled students across classes.

Although the student-level data do not contain classroom identifiers, the Ministry of Education began collecting and reporting data on classroom composition beginning in the 2005-2006 academic year (one year after the period covered in our main data set). These reports are published for each public school in the province, and include for each classroom the number of students, the number of disabled students, and the number of ESL/ESD students. We have used the 2005-2006 edition of this report (B.C. Ministry of Education 2006b) to assemble a data set describing the classroom environment of Vancouver's grade 7 students in 2005-2006. For each classroom, we have the school identifier, number of students, and number of disabled students.

Figure 1 shows the distribution of number of disabled classmates across Grade 7 students in Vancouver in 2005-2006. The figure indicates that classroom assignments are made[17] with at least some attention to inclusion: about 80% of nondisabled students in Vancouver have at least one disabled classmate, and about 77% of disabled students have fewer than three disabled classmates. These results suggest that classroom composition will tend to closely mirror grade composition, and so the grade-level peer effects estimated in Section 5.2 will be closely related to any classroom-level effects.

We can go somewhat further by analyzing a simplified version of our econometric model:

$$\Delta y_i = \beta + \gamma \overline{D}_{i,7} + \gamma^C \overline{D}_{i,7}^C + D_{i,7}\left(\beta_D + \gamma_D \overline{D}_{i,7} + \gamma_D^C \overline{D}_{i,7}^C\right) + u_{i,t(i,7)} \qquad (4)$$

$$E\left(u_{i,t(i,7)} \middle| D_{i,7}, \overline{D}_{i,7}\right) = 0 \qquad (5)$$

where $\overline{D}_i^C$ is the proportion disabled in student *i*'s classroom and the remaining variables are as used in equation (1). Note that we have abstracted from our main econometric model in several ways for tractability: the non-disability-related control variables including the fixed effects are left out of the model, as is the use of grade 4 disability status rather than current status. However, we have maintained the coefficient heterogeneity across disabled and nondisabled students, and added the feature that there are peer effects at the classroom level (γ^C) as well as at the grade level (γ). Also note that while the grade-level peer group is assumed to be exogenous, the composition of the classroom may be endogenous.

Suppose we were to estimate equation (4) using OLS on the subsample of nondisabled students, but under the incorrect restriction that all peer effects occur at the grade level (i.e., $\gamma^C=0$). This regression is the analogue in this simplified setting to the estimates reported in Sections 5.2. The probability limit of the resulting peer effect estimate would be:

[17] Note that we can only determine that formal classroom assignments follow an inclusion policy. If disabled students are regularly pulled out from their assigned classrooms for separate instruction, classroom assignments will tend to overstate the degree of inclusion.

$$
\begin{aligned}
\operatorname{plim}\hat{\gamma} &= \frac{\operatorname{cov}\left(y_i, \overline{D}_{i,7} \middle| D_{i,7}=0\right)}{\operatorname{var}\left(\overline{D}_{i,7} \middle| D_{i,7}=0\right)} \\
&= \frac{\operatorname{cov}\left(\beta + \gamma\overline{D}_{i,7} + \gamma^{C}\overline{D}_{i,7}^{C} + 0\left(\beta_D + \gamma_D\overline{D}_{i,7} + \gamma_D^{C}\overline{D}_{i,7}^{C}\right) + u_{i,t(i,7)}, \overline{D}_{i,7} \middle| D_{i,7}=0\right)}{\operatorname{var}\left(\overline{D}_{i,7} \middle| D_{i,7}=0\right)} \qquad (6) \\
&= \gamma + \gamma^{C}\frac{\operatorname{cov}\left(\overline{D}_{i,7}^{C}, \overline{D}_{i,7} \middle| D_{i,7}=0\right)}{\operatorname{var}\left(\overline{D}_{i.,7} \middle| D_{i,7}=0\right)}
\end{aligned}
$$

In other words, grade-level peer effects of the sort reported in Sections 5.2 and 5.3 can be interpreted as reduced form coefficients combining the true grade–level effect (γ) plus the true classroom-level effect (γ^C) times some weighting factor. The weighting factor in this simplified model corresponds to the coefficient from a linear regression of percent disabled classmates ($\overline{D}_{i,7}^{C}$) on percent disabled gradesmates ($\overline{D}_{i,7}$) using the subsample of nondisabled students ($D_{i,7} = 0$), and can be estimated using the Vancouver classroom composition data. To the extent that classroom placement policies in Vancouver in 2005-2006 are representative of those in other districts over the previous 3 years, and to the extent that exact results for the simplified model give approximate results for the more complex models, we can characterize how big classroom-level peer effects could be given our estimates of grade-level peer effects.

When we estimate this regression we get a coefficient of 0.95 with a school-clustered standard error of 0.03. This implies that if all of the relevant interactions are at the classroom level rather than the grade level (so that $\gamma = 0$), then the true classroom-level peer effect is about 5% larger than our estimates of the grade-level peer effect. In other words, it is unlikely that classroom-level peer effects are much larger than the grade-level peer effects we have estimated.

6 Conclusion

Disabled students bring both additional needs and additional resources to the classroom, implying that their influence on peer achievement may vary substantially across jurisdictions, as do policies for assessment, funding, and instruction. An accurate picture of peer effects thus requires studies of multiple jurisdictions. B.C. provides an interesting opportunity to study the effects of learning and behaviorally disabled peers during a period of time when, for the most part, these students were funded through a census-based system. A number of states have implemented census-based funding (Dhuey and Lipscomb 2008) and, given its attractiveness from a fiscal perspective, this trend is likely to continue. While census-based funding formulas eliminate the fiscal incentive to place students in special education, they may also weaken the connection at the school or classroom level between student needs and student resources, with potential consequences for their peers.

We find that peers with learning and behavior disabilities in B.C. have a negative effect on the test score gains of non-disabled students in B.C., but that peers with other disabilities have, if anything, a positive effect. It is interesting to compare these results to those of Hanushek et al. (2002) for Texas. Both jurisdictions fund students with "other" disabilities according to a pupil weight funding system, and our results are very similar to theirs in this case. Texas also provides funding for learning and behavior disabled peers according to a pupil weight funding system, while B.C. moved away from this system to a census-based funding system during our period of study, and we are measuring an average effect under these different funding schemes. Where Hanushek et al. find little if any effect of learning and behavior disordered peers, we find a small negative effect. These results suggest that there may be more adverse spillovers associated with peers who have learning and behavior disabilities under census-based funding. However, our results indicate that these spillovers may be sufficiently small that they need not be of major concern.

Our estimated effects for peers with learning and behavior disabilities are also smaller than those found by Fletcher (2008) and Aizer (2008). Two differences in our data and research design may explain our finding of smaller peer effects. First, the spillovers associated with the particular peers that Fletcher and Aizer identify (emotionally disturbed peers and peers with undiagnosed ADD respectively) may be larger than the average effect of all peers with learning or behavioral disabilities that we measure. Second, both Fletcher and Aizer define peer groups at the classroom level, while we define peer groups at the school/grade level. While our analysis in Section 5.4 implies most of any linear classroom level effect will be included in any grade-level peer effect estimates, classroom-level estimates like those of Fletcher (2008) and Aizer (2008) may be more effective in detecting nonlinear effects. This benefit comes at a cost of using a somewhat less plausibly exogenous source of variation in peer composition.

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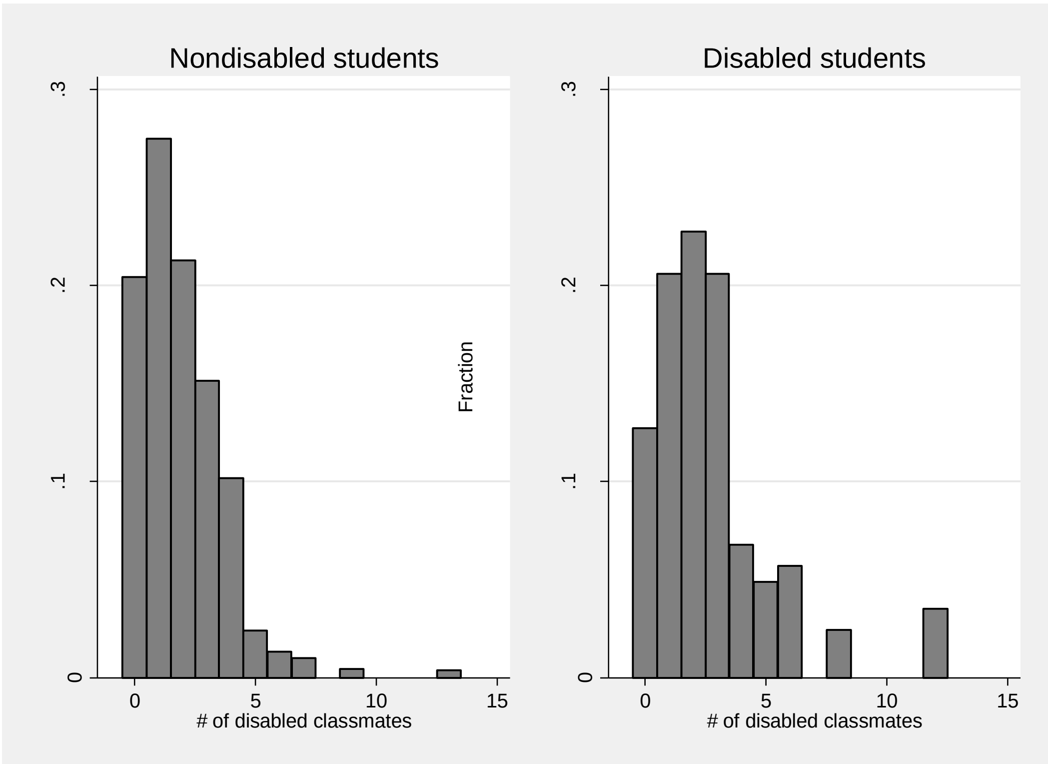
Figures

Figure 1: Histograms for number of disabled classmates, by own disability status. Data is from Vancouver school district, 2005-2006 academic year.



Source: Authors' tabulations from B.C. Ministry of Education (2006b).

Tables

Table 1: **Per student funding to B.C. public school districts, by funding category.**

Category	before March 2002	after March 2002
Base amount	$3,042	$5,308
Aboriginal supplement	755 – 1,030*	950
ESL/ESD supplement (maximum 5 years per student)	1,230 (Year 1) 1,060 (Years 2-5)	1,100
Special needs supplements:		
Dependent	31,910	30,000
Low incidence/high cost	12,460	15,000
Severe behavior	6,014	6,000
High incidence/low cost	3,132	0
Gifted	341	0

Source: B.C. Ministry of Education (2002), page 4.

*amount per student increases with total number of Aboriginal students in the district

Table 2: **Comparison of B.C. disability rates with those in other jurisdictions.**

Jurisdiction	Total	Learning Disabled	Behavioral Disorder	Speech Impaired	Other Disability
B.C. public grade 7, 2002-2004	9.1	3.6	2.6	--	2.9
Texas public grade 7, 1996/97	14.9	10.4	1.4	0.6	2.5
Chicago public elementary, 1996	12.5	7.4	1.0	1.9	2.2
U.S. age 13 population, 2002-2004	12.7	7.6	1.3	0.8	3.0

Source: Described in the Appendix. Note that B.C. does not have a diagnostic category for speech impairment.

Table 3: **Distribution of disabled students by funding category, as a percentage of 7th graders in B.C. public schools during each year.**

Year	All disabled	Low incidence, high cost	Severe behavior	High incidence, low cost	Dependent
1999	8.6	1.4	1.1	6.1	0.1
2000	8.7	1.7	1.0	5.9	0.1
2001	8.9	1.7	1.1	6.0	0.1
2002	8.7	1.9	1.1	5.7	0.2
2003	9.0	2.0	1.2	5.7	0.1
2004	9.4	2.2	1.3	5.9	0.2

Table 4: Distribution of disabled students by selected diagnostic categories, as a percentage of B.C. grade 7 students with a recognized disability in each year.

	Low incidence/high cost			Intense	High incidence/low cost		
Year	Moderate/ Profound Intellectual Disability	Autism	Physical Disability	Behavioral/ Serious Mental Illness	Learning Disability	Mild Intellectual Disability	Moderate Behavioral/ Mild Mental Illness
1999	3.7	1.3	7.1	12.2	41.0	8.9	20.4
2000	4.4	2.5	8.0	11.8	38.8	8.7	20.3
2001	3.8	2.4	8.5	12.1	38.9	9.2	19.9
2002	4.7	3.5	9.2	12.1	39.0	8.7	17.0
2003	4.5	3.6	10.1	13.4	40.5	7.5	15.3
2004	4.8	4.5	10.4	13.3	39.7	6.6	15.7

Table 5: **Movement of students among disability categories. Population is students attending B.C. public schools for both 4th and 7th grades between 1999 and 2004.**

Category	% of students in category in grade 4 whose grade 7 category was:			% of students in category in grade 7 whose grade 4 category was:		
	Same	Different	None	Same	Different	None
Moderate/Profound Intellectual Disability	85.8	12.1	2.1	77.1	19.0	3.9
Mild Intellectual Disability	69.3	21.3	9.4	63.9	9.4	26.7
Physical Disability	75.5	12.7	11.8	58.3	19.0	22.8
Learning Disability	70.4	9.6	20.0	41.8	5.1	53.1
Intense Behavioral/ Serious Mental Illness	46.1	32.4	21.6	27.1	28.8	44.1
Moderate Behavioral/ Mild Mental Illness	29.9	25.2	44.9	28.7	11.6	59.7
Autism	92.9	4.4	2.9	70.2	18.8	11.0

Table 6: **Summary statistics for regression data. Population under analysis is students who attended a B.C. public school in Grade 7 during 2002-2004, attended a B.C. public or private school for Grade 4, and were not classified as disabled in Grade 4.**

Variable	Mean	Std. Dev.	Part. Rate
FSA exam results:			
Grade 7 numeracy score	-0.03	0.97	93.1
Grade 7 reading score	0.01	0.98	94.5
Numeracy gain score	-0.05	0.80	88.9
Reading gain score	0.00	0.78	90.5
Individual control variables:			
Male, %	49.6		
Aboriginal, %	9.1		
Chinese language spoken at home, %	6.1		
Punjabi spoken at home, %	3.6		
Other non-English language spoken at home, %	7.4		
English as a second language (ESL), %	2.3		
English as a second dialect (ESD), %	0.8		
Peer control variables:			
Peer % male	51.2	8.7	
Peer % non-English	18.5	23.8	
Peer % Aboriginal	9.6	12.3	
Peer % ESL	4.9	7.7	
Peer % ESD	0.9	4.3	
Peer disability variables:			
Peer % disabled	8.9	6.3	
Peer % learning/behavioral disability	6.1	5.3	
Peer % other disability	2.8	2.9	
Sample size:			
# Observations	118,861		
# Schools	1,206		

Table 7: Distribution of peer disability status across non-disabled B.C. public school students in Grade 7, 2002-2004.

Peer group composition	Average	Percentiles				
		10	25	50	75	90
Peer % learning/behavioral	6.1	0.0	2.5	5.1	8.3	12.0
Peer % other disability	2.8	0.0	0.0	2.3	4.1	6.1
Peer total % disabled	8.9	1.7	4.8	8.0	11.6	16.2

Table 8: Within-school variation in peer group composition, regression data.

Peer group composition	% of total variation that is within-school	% of students in schools with no within-school variation
Peer % learning/behavioral	37.6	9.5
Peer % other disability	51.9	13.8
Total peer % disabled	37.1	6.8

Table 9: Trends in sorting, B.C. grade 7 students 1999-2004.

Year	Standard deviation of peer %...		
	Disabled	Learning/behavioral disability	Other disability
1999	7.2	6.2	3.4
2000	6.9	5.8	3.4
2001	6.6	5.6	3.2
2002	6.4	5.2	3.4
2003	6.8	5.6	3.3
2004	6.9	5.8	3.4

Table 10: **Main regression results. Population under analysis is students who attended a B.C. public school in Grade 7 during 2002-2004, attended a B.C. public or private school for Grade 4, and were not classified as disabled in Grade 4.**

Explanatory variable	Dependent variable: Numeracy test score gain				Dependent variable: Reading test score gain			
	OLS		IV		OLS		IV	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Individual control variables:								
Male	0.02***	0.02***	0.02***	0.02***	-0.09***	-0.09***	-0.09***	-0.09***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Aboriginal	-0.01	-0.01	-0.01	-0.01	-0.04***	-0.04***	-0.04***	-0.04***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Chinese spoken at home	0.24***	0.24***	0.24***	0.24***	0.14***	0.14***	0.14***	0.14***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Punjabi spoken at home	0.07***	0.07***	0.07***	0.07***	0.04**	0.04**	0.04**	0.04**
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Other language at home	0.14***	0.14***	0.14***	0.14***	0.10***	0.10***	0.10***	0.10***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
ESL	0.18***	0.18***	0.18***	0.18***	0.22***	0.22***	0.22***	0.22***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
ESD	0.13***	0.13***	0.13***	0.13***	-0.08**	-0.08**	-0.08**	-0.08**
	(0.04)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Peer control variables:								
Peer % male	-0.01	-0.01	-0.00	0.01	-0.04	-0.04	-0.04	-0.03
	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)
Peer % non-English	0.00	0.00	-0.00	-0.01	-0.01	-0.01	-0.01	-0.02
	(0.11)	(0.11)	(0.11)	(0.11)	(0.09)	(0.09)	(0.09)	(0.08)
Peer % Aboriginal	0.17	0.17	0.17	0.18	-0.03	-0.03	-0.03	-0.03
	(0.12)	(0.12)	(0.12)	(0.12)	(0.10)	(0.10)	(0.10)	(0.10)
Peer % ESL	0.17	0.18	0.17	0.19	-0.01	-0.01	-0.01	0.01
	(0.17)	(0.17)	(0.17)	(0.17)	(0.14)	(0.14)	(0.14)	(0.14)
Peer % ESD	-0.36	-0.38	-0.35	-0.41	0.01	0.02	0.01	-0.03
	(0.26)	(0.26)	(0.26)	(0.26)	(0.22)	(0.22)	(0.21)	(0.21)
Peer disability variables:								
Peer % disabled	-0.14		-0.21		-0.14		-0.14	
	(0.13)		(0.24)		(0.11)		(0.18)	
Peer % learning/behavioral disability		-0.20		-0.53		-0.12		-0.40
		(0.15)		(0.34)		(0.13)		(0.28)
Peer % other disability		0.01		0.17		-0.19		0.16
		(0.22)		(0.30)		(0.17)		(0.24)
Kleibergen-Paap RK statistic for instruments			683.0	172.8			682.7	171.1
# Observations	105644	105644	105593	105593	107603	107603	107550	107550
# Schools	1166	1166	1115	1115	1167	1167	1114	1114

Notes: Standard errors (clustered at school level) in parentheses. Both OLS and IV regressions include school and year fixed effects. IV regressions instrument current disability status of grade 7 peers with grade 4 disability status of grade 7 peers. (*** p<0.01, ** p<0.05, * p<0.1)

Table 11: Regression results, robustness checks. Each row reports the estimated coefficients on "peer % learning/behavioral disability" and "peer % other disability" for the regression described in the first column.

Description of regression	Dependent variable: Numeracy test score gain		Dependent variable: Reading test score gain	
	Peer % learning/ behavioral disability	Peer % other disability	Peer % learning/ behavioral disability	Peer % other disability
A. **Preferred specification** IV estimates from Table 10, specification (2)	-0.53 (0.34)	0.17 (0.30)	-0.40 (0.28)	0.16 (0.24)
B. **Modified value-added model** Dependent variable is grade 7 test score and controls for student's grade 4 test scores are added.	-0.43 (0.30)	0.20 (0.26)	-0.23 (0.25)	0.10 (0.22)
C. **No control variables** All individual and peer control variables omitted from model.	-0.51 (0.33)	0.15 (0.29)	-0.44 (0.27)	0.13 (0.24)
D. **No school fixed effects** School-level fixed effects omitted from model.	-0.28 (0.23)	0.67** (0.32)	-0.26 (0.16)	0.31 (0.22)
E. **Restricted sample (same principal)** Schools with change in principal excluded from sample.	-0.57 (0.48)	-0.03 (0.41)	-0.59 (0.37)	-0.32 (0.31)
F. **Restricted sample (no FI)** French immersion schools excluded from sample.	-0.47 (0.35)	0.20 (0.30)	-0.38 (0.28)	0.19 (0.25)
G. **Restricted sample (English speakers)** Students who do not speak English at home excluded from sample.	-0.71* (0.37)	0.19 (0.30)	-0.38 (0.29)	0.15 (0.25)
H. **Restricted sample (non-Aboriginal)** Aboriginal students excluded from sample.	-0.60 (0.36)	0.07 (0.31)	-0.48* (0.28)	0.13 (0.25)
I. **Grade 5-7 peers** Peer characteristics are based on average peer group composition over grades 5-7 rather than on grade 7 alone. Grade 7 peer group composition is used as an IV.	-0.63 (0.42)	0.12 (0.37)	-0.50 (0.34)	0.16 (0.30)

Notes: Standard errors (clustered at school level) in parentheses. The "preferred specification" result reported in row A is copied directly from IV model (2) in Table 10. The alternative models reported in rows B through I are identical to the preferred specification except as described. (*** $p<0.01$, ** $p<0.05$, * $p<0.1$)

Appendix

A.1 Sources for Table 2.

- Row #1 (B.C.) is based on authors' calculations from enrollment data.
- Row #2 (Texas) is based on Hanushek, et al. (2002), Table 1.
- Row #3 (Chicago) is based on Cohen (2006), Table 1.
- Row #4 (U.S.) is based on online tables provided by Westat Inc., calculated for OSEP's *Annual Report to Congress on the Implementation of the Individuals with Disabilities Education Act*, URL https://www.ideadata.org/docs%5CPartBTrendData%5CB2C.html, accessed July 17, 2007.

A.2 Additional Tables

Table A1: Special needs categories in British Columbia.

Provincial administrative categories		**Categories used for regressions**	
Diagnostic	**Funding**	**Specification (1)**	**Specification (2)**
AB: Physically dependent and/or deafblind (coded as A or B before 2002)			
C: Moderate to Profound Intellectual Disability	Dependent: AB		
D: Physical Disability or Chronic Health Impairment	Low incidence/ high cost: C, D, E, F, G		
E: Visual Impairment			Learning disability and behavioral: H, Q, R
F: Deaf or Hard of Hearing	Severe behavior: H	Disabled: AB, C, D, E, F, G, H, K, Q, R	
G: Autism			Other disability: AB, C, D, E, F, G, K
H: Intensive Behavior Intervention/Serious Mental Illness	High incidence/low cost: K, Q, R		
K: Mild Intellectual Disability			
P: Gifted	Gifted: P		
Q: Learning Disability(coded as J before 2002)			
R: Moderate Behavior Support/Mental Illness (coded as M or N before 2002)			

Source: B.C. Ministry of Education (2006a)

Table A2: Relationship between class composition and grade composition, Vancouver grade 7 students 2005-2006. Dependent variable is % disabled in student's class.

Variable	Nondisabled	Disabled	All students
% disabled in same school and grade	0.95***	1.07***	1.00***
	(0.03)	(0.11)	(0.00)
Constant	0.15	1.28	0.00
	(0.18)	(1.07)	(0.00)
R^2	0.66	0.70	0.69
N (# students)	4564	369	4933
# schools	75	71	75

Notes: Standard errors (clustered at school level) in parentheses. (*** p<0.01, ** p<0.05, * p<0.1)

Table A3: Linear probability model estimates of effect of grade 4 peer disability rate on probability of attending a private school for grade 7 (i.e., dependent variable equals one if attending a private school for grade 7, and zero if attending a public school for grade 7). Population under analysis is students attending a B.C. public school for grade 4 between 1999 and 2001, and attending any B.C school for grade 7 by 2004.

Variable	(1)	(2)
Grade 4 peer % disabled	-0.018	
	(0.012)	
Grade 4 peer % learning/behavioral disability		-0.021
		(0.014)
Grade 4 peer % other disability		-0.012
		(0.020)
# observations	118,702	118,702

Notes: Standard errors (clustered at school level) in parentheses. Both regressions include school and year fixed effects, as well as all control variables (as of grade 4) used for regressions in Table 9. (*** p<0.01, ** p<0.05, * p<0.1)