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Eric Brunner
Shaun Dougherty
Stephen Ross

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ABSTRACT

Participation in Career Technical Education (CTE) programs has been proposed as a valuable strategy for supporting transition to independence among students with disabilities. We exploit a discontinuity created by admissions thresholds from a statewide system of CTE high schools. Our findings suggest attending CTE high schools has large positive effects on completing high school on time, employment, and earnings, including for individuals 22 years or older. Attending CTE schools also results in more time spent with non-disabled peers and higher 10th grade test scores. These results appear concentrated among male students, but the sample of female students is too small to support strong conclusions about outcomes. Notably, these estimates are for a system of CTE high schools operating at scale and serving students across a wide spectrum of disabilities, and the estimated effects appear broad based over disability type, time spent with non-disabled peers in 8th grade and previous academic performance.

Eric Brunner
Department of Public Policy
University of Connecticut
10 Prospect Street, 4th Floor
Hartford, CT 06103
eric.brunner1@gmail.com

Shaun Dougherty
Harvard University
shaun.dougherty@bc.edu

Stephen Ross
Department of Economics
University of Connecticut
341 Mansfield Road, Unit 1063
Storrs, CT 06269-1063
and NBER
stephen.l.ross@uconn.edu

A data appendix is available at http://www.nber.org/data-appendix/w32867

Introduction

A central emphasis for individuals with disabilities is creating a transition plan to support a successful transition from secondary education to postsecondary education, employment, and a path to independent living (Test et al. 2009; Flexar et al. 2011). Supporting transition to adulthood is critical to achieving maximal independence for individuals with disabilities and reducing known concerns about social isolation and health disparities (Shandra 2018; Pettinicchio et al. 2022; Bixby 2023). These health and social disparities have known negative impacts on individuals with disabilities, their families, and also come at a broader social cost of providing additional public services. Federal law ensures that a range of services exist to support youth with disabilities in the transition to adulthood (Taylor et al. 2022), although prior research has documented disparities in both the timeliness and quality of those services (Vohra et al. 2014). Prior research has also shown that early intervention and high-quality services for children and youth with disabilities can promote better outcomes in adulthood (Ryndak et al. 2012; Lovett et al. 2017). Notably, studies have documented improved outcomes for youth with disabilities participating in school to work programs including (Shandra and Hogan 2008) positive impacts on employment, (Lindstrom et al. 2020) career development skills, (Sheftel et al. 2014) self-efficacy and self-determination, and (Shogren et al. 2016) autonomy.

Among the programs coordinated at the state and local level, career and technical education (CTE) -- previously vocational education -- is often included in education and transition plans for school-aged youth with disabilities. Most prior research on the impact of CTE for students with disabilities has been forced to rely on observational study designs that can only control for observable differences between students that participate in CTE programs and those that do not (Dougherty 2018; Theobald et al 2019). Overall, these studies find that CTE participation in high school is associated with better rates of on-time high school completion and higher earnings in the short term (Theobald et al 2019; Daviso et al 2016; Lee et al 2016; Wagner et al. 2016; Wagne et al 2017; Dougherty et al 2018). However, to the best of our knowledge, the only study to examine labor market outcomes more than two years after graduation found no evidence of better long-term outcomes for CTE participants (Wagner et al. 2016).

Scope of the Study

In this paper, we examine the effect of attending a statewide, oversubscribed system of stand-alone CTE high schools on the short- and long-term outcomes of students with identified disabilities. CTE integrated schools have been shown to have large effects on outcomes of non-disabled students (Dougherty 2018, Brunner et al. 2023). We employ a fuzzy discontinuity research design to address selection into CTE high schools on student unobservables exploiting admissions thresholds to compare students just above the admissions threshold to students just below. As a result, the estimates are based on comparing treated and untreated students who without treatment would be expected to have very similar outcomes as adults. We estimate the impact of being admitted to and attending one of these schools on high school graduation, test scores, college going, labor force participation, and post-high school earnings for students with identified disabilities. We follow students long enough to observe labor market outcomes five to ten years after expected high school graduation. Our data also contains critical information about disability type and share of time students with disabilities spend with their typically developing peers, which is important because prior research suggests that the relationship between CTE participation and employment outcomes varies by type of disability (Daviso et al 2016; Lee et al 2016; Wagner et al. 2016; Wagne et al 2017).

For male students, we find that attending a CTE high school has a large positive impact on state test scores, on-time high school graduation, and post-high school earnings and employment. On-time graduation rates increase by over six percentage points, quarterly earnings increase by 25%, and students have almost three additional quarters with earnings; a 15% increase compared to an increase of 11% for typically developing peers (Brunner et al. 2023). Given the policy emphasis on successful transition to employment and independence, the positive effects on quarterly earnings and quarters with earnings are especially important. Further, the quarterly earnings gains persist even when focusing on individuals aged 22 years or older. In fact, the point estimate on quarterly earnings increases by an additional 19% for the 22 years or older sample, while the quarterly earnings gains in Connecticut for typically developing peers (Brunner et al. 2023) are smaller for older compared to younger cohorts.

A key contribution of this paper is our ability to observe not only disability category, but also a continuous measure of the share of time that students with Individualized Educational Plans (IEPs) spend with their typically developing peers. Notably, the positive effects of attending these CTE high schools are broad based and experienced by: 1) students across a wide range of admission scores based on treatment effects identified at admission thresholds, 2) students across a broad set of disability categories, and 3) students who in middle school had either an above or below average share of time spent with typically developing peers. In these CTE high schools, students with disabilities are immersed in the mainstream educational environment, spending virtually all their school time (98% compared to an average of 83% for students not in CTE high schools) with typically developing peers. Finally, we do not find statistically significant evidence of an impact on female student outcomes, similar to Brunner et al. (2023) for students without identified disabilities. However, given the small size of the female sample we cannot rule out positive effects, and in fact we observe sizable positive point estimates for female applicants with disabilities for quarters with earnings and math test scores.

Our finding of improved earnings among young-adult males is particularly important given that nationwide, adults with disabilities experience poverty at twice the rate of their otherwise similar peers (Rabren et al. 2014, Goodman et al. 2020).

Study Setting

The Connecticut Technical Education and Career System (CTECS) is a statewide school district consisting of 16 high schools. Table 1 compares the composition of students with disabilities statewide to students with disabilities who apply to the CTECS system. While applicants are selected towards more disadvantaged students, the final regression discontinuity sample is reasonably representative of state population averages, especially on academic performance. Notably, students with learning disabilities are overrepresented and students with lower incidence disabilities, primarily emotional disturbance are underrepresented. However, this pattern is common in other studies as well, with emotional disturbance underrepresented and learning disability overrepresented in (Lee et al 2016; Wagner et al. 2016; Wagne et al 2017; Dougherty et al 2018; Doren et al. 2011) for the effects of CTE and (Lindstrom et al. 2020) for the effects of school to work programs.

All CTECS schools are oversubscribed for our entire sample period. Eighth graders can apply to these schools during the winter before 9th grade. Their middle school grades, test scores, attendance, and in later years an interest survey are used to create an overall application score. To ensure fair evaluation, information about whether a student has an IEP and what type of identified disability they have are not included in the application process or scoring. Students can apply to up to four schools, but most students apply to one school that is located close to where they live. Individual schools then rank applicants in descending order based on their application score. Fig. 1 presents the distribution of admission scores that have been adjusted to assure a constant maximum score of 100. The distributions are presented separately by whether a student has a documented disability or not, and a sizable share of the score distribution falls between the minimum and maximum adjusted, admissions thresholds of 27 and 62.

Because not all students who receive initial offers choose to enroll, some students who were not recipients of an initial offer end up being admitted. Students not admitted at their first-choice school can have their application transferred to schools further down on their list and could be admitted if space allows and their score is at or above that school's threshold for admission. All students apply to schools in the same manner, but students with an identified disability are subject to an additional level of review prior to admission as part of a transition IEP meeting. However, neither imperfect compliance nor this additional level of review for students with disabilities influences our estimates because our research design is based on comparing all students just above the relevant admissions threshold to students just below the threshold to capture an intent to treat effect, whether or not the student was actually admitted to, or attended, a CTE high school. Then, the two stage least squares model yields estimates of the treatment on the treated effects by inflating outcome differences at the threshold using the increased likelihood of attending the CTE high school if above the threshold.

There are several mechanisms through which high school CTE might affect student outcomes. These include engaging and interactive coursework, connections made between state graduation requirements and applied content, smaller student-teacher ratios, and opportunities for work-based learning. Students with identified disabilities have an additional layer of formal channels that might further support the efficacy of CTE in promoting transition outcomes. All students with disabilities in the State of Connecticut are required to have a formal transition plan as part of their IEP beginning at age 14, and access to vocational rehabilitation services that are designed to build employment connections and skills also has the potential to reinforce the CTE experience. For example, quality CTE pathways with clearly articulated experiences across a variety of programs of study have been shown to boost career aspirations (Brand et al. 2013). Further, the work-based learning opportunities and apprenticeships available to CTE students provide valuable mentoring experiences which can enhance the educational and vocational development of students with identified disabilities (Daughtry et al. 2009). Finally, these high schools are better resourced overall with lower teacher student ratios (10.4 vs. 13.6) and higher per pupil spending (13.6K vs. 9.9K) than traditional high schools in Connecticut (Dougherty and Smith 2024). However, we cannot say whether on average students with disabilities receive more or less resources in CTE highs schools because these students are typically mainstreamed when they enter a CTECS school, which will reduce special education expenditures that would be incurred in non-mainstreamed classes (e.g. additional instructors, aides, or curricular supports).

Data and Sample

Our data includes 9 cohorts of applicants (from 2006 to 2014) to 16 Career and Technical Education high schools in Connecticut and includes nearly 6,000 students with identified disabilities. All schools are oversubscribed in all years of our study. We merge school application data with state student-level longitudinal administrative data, which includes National School Clearinghouse records. These records are then merged with unemployment insurance (UI) records of earnings for individuals who are employed in the state of Connecticut in a job that is covered by the UI system. The application data contains the CTE high schools to which each student applied, the application score along with the individual score components, and whether the student received an admission letter. The state administrative data provides standard information on the school attended in each grade, middle and high school test scores, high school graduation, all spells of college attendance, as well as whether a student is free and reduced-price lunch eligible, an English language learner, or has an identified disability. Further, for students with identified disabilities, the administrative data identifies the type of disability and the time spent with typically developing peers each year.

Finally, the UI data contains information on quarterly earnings for every quarter when an individual was employed in a UI covered job and spans the first quarter of 2006 through the first quarter of 2022, though results are robust to dropping earnings data post the first quarter of 2020 (i.e. during the COVID-19 pandemic). Our labor market sample is constructed allowing for five years to graduate from high school and two quarters to enter the labor market, and so we examine earnings starting with the first quarter of the year following a five-year anticipated May graduation. This structure implies that the number of potential quarters in the labor market data varies by cohort. For this reason, all of our models include school by cohort fixed effects so that we are essentially estimating separate models for each cohort and application school. Further, when estimating quarterly earnings when applicants are age 22 or older, the variation in number of potential quarters is dramatically reduced and estimates are robust.

From the full list of applicants, we create a sample of all students with disabilities who apply to Connecticut CTE high schools and create one observation for each school to which a student applied, although results are nearly identical dropping students who applied to more than one school. Table 1 presents descriptive statistics for students with disabilities for the state overall, our sample of CTECS applicants, and the subsample of applicants who fall within the bandwidth for our regression discontinuity analysis. As with applicant students without disabilities, applicants with disabilities tend to be selected into applying to CTE high schools, with applicants characterized by a smaller share of female students, more applicants who are Black or Hispanic, more free and reduced price lunch applicants and a larger share of applicants who fail to meet key proficiency levels on 8th grade standardized test scores. Therefore, in general, our population of applicants with disabilities is more disadvantaged than the overall state population of students with disabilities. We also observe selection based on the type of disability with a higher share of applicants with a learning disability (51.7% vs. 44.8%) and substantially lower share of applicants with disabilities falling into our “Lower Incidence” disability category, which includes emotional disturbance, intellectual disability, autism and traumatic brain injury, 15.2% versus 23.5% statewide. Note that emotional disturbance represents over 80% of the students in this category. This feature of our sample composition over disability type is comparable to samples of CTE participating students in Massachusetts (Dougherty 2018), Oregon (Doren et al.

2011) and the National Longitudinal Transition Study-2 (Lee et al 2016; Wagner et al. 2016; Wagne et al 2017), as well as participants in a school to work program in the U.S. Pacific northwest (Lindstrom et al. 2020). Note that Table S15 presents descriptive statistics for the sample of CTE applicants without disabilities for comparison to applicants with identified disabilities.

Further, for comparison purposes, Table S14 presents the composition of special education students nationally and in Connecticut showing that the composition in Connecticut is broadly comparable to the population nationally with a few exceptions. National data from National Center for Education Statistics (2016) and state administrative data from Connecticut, reveal that the State of Connecticut has substantially more students classified as having ADD or ADHD than the U.S. overall (19.1% versus 12.1%), and a smaller share of students classified as having a physical disability (16.3% vs 23.6%). Hispanic representation among the state's population of students with disabilities is also much larger (25.7% vs. 14.4%), see Table S14.

To create our regression sample, we match students to an application score threshold associated with the school to which they applied and their application year. The means arising from restricting our sample of applicants to within 16 points (our bandwidth) of their admission threshold is shown in the last two columns of Table 1 and in more detail in Table S2. On average, this restriction mitigates some of the negative selection arising from the decision to apply to CTE high schools in Connecticut, especially in the area of test score proficiency. In terms of type of disability and time spent with non-disabled peers, the composition of the sample within the admissions threshold bandwidth is quite similar to the composition for the entire applicant sample. Fig. 1 illustrates the distribution of the sample with the blue bars showing a histogram of admission scores for students with disabilities and the tan bars showing the histogram for students without disabilities. Since maximum possible admission scores vary over time between 100 and 120, we subtract the excess of the maximum above 100 so that all thresholds and scores fall at or below 100. The two red vertical lines illustrate the lowest and highest adjusted admission scores observed across schools and cohorts during our sample period with thresholds ranging between 27 and 62 points out of 100. Given our 16-point bandwidth, applicants with adjusted admissions scores as low as 11 points are in some cases included in the sample. This adjustment is not used in any of our regression analyses, except for splitting the sample into terciles for the models presented in Table S13. Note that test scores are only available for the sample through the 2011 application cohort because the last year for administering the 10th grade Connecticut Mastery Test was 2013.

Methods

Our analyses follow the approaches in (Brunner et al. 2023) who estimated analogous impacts for students without identified disabilities. The oversubscribed nature of the schools, as well as the admissions process of admitting students in rank order based on admissions criteria creates the conditions for a natural experiment in which we can apply a fuzzy regression discontinuity research design. First, for all students regardless of disability status, we identify an admissions threshold associated with a discrete jump in the probability that a student receives an offer of admission for each school and application cohort. Specifically, we estimate separate models of the probability of receiving an admission letter by CTE high school and application year using the full sample of applicants with different candidate admissions thresholds and identify the threshold for a given school and year as the threshold that yields the largest discontinuity in the probability of being admitted. We then create a centered score by subtracting each school and year threshold value from each student's application score. Next, we select the sample of students with an identified disability and with an application score within 16 points of the admissions threshold for each CTE high school and application year. As shown in Table S6, results are robust to narrowing the 16-point bandwidth.

We then use the thresholds to estimate a first-stage model for the likelihood that a student receives an admission letter and attends a CTECS school controlling for school-by-application year fixed effects and 8th grade sending town fixed effects so that each application school and year is treated as a separate quasi-experiment and effects are also identified by comparing students who applied from the same town. We then use the results of this first-stage model to estimate instrumental variable models for student outcomes including high school test scores, discipline, time spent with typically developing peers, on-time graduation, college enrollment, and employment and earnings outcomes. These instrumental variable models should be interpreted as Treatment on the Treated models with the Intent to Treat estimates being scaled up by the increase at the threshold in the share of students receiving an admissions letter and attending a CTECS school. Standard errors are two-way clustered at the application school by application cohort and 8th grade sending town. To address concerns about manipulation, all models are estimated using a donut hole approach where we drop observations exactly at the threshold, but we note that results are robust to not dropping those observations.

We test for sample balance over the threshold, a requirement for valid application of our analytic approach, by estimating a regression discontinuity model (described below) using the predetermined variables in Table S16 as the dependent variable and demonstrating that predetermined variables evolve smoothly across the threshold. The pre-determined attributes include race, ethnicity, whether free and reduced-price lunch eligible, whether an English language learner, 7th grade test scores, time with typically developing peers in 8th grade, type of disability in 8th grade, and school-level pupil-teacher ratio and 6th grade average test scores for sending middle schools. As shown in Tables S16 (full sample) and S17 (labor market sample), all of the estimated coefficients tend to be small in magnitude and statistically insignificant for both male (top panel) and female (bottom panel) applicants indicating that all observables vary smoothly across the discontinuity, even though we detect large discontinuities in outcomes.

Results

Fig. 2 and Table S1 show the first stage effect of being above the admission threshold. All models include controls for the student attributes listed in Table S2. For the full sample, being above the admission threshold leads to an 87 percent increase in the likelihood of receiving an admissions letter and a 66 percent increase in the likelihood of attending one of the 16 CTECS high schools. We observe similar effects for male and female students and, as shown in Table S3, for students that we observe in the labor market.

Table 2 and Fig. S1 show the estimated impact of attending a CTE high school for both male and female students, the former of which constitute nearly 75% of our sample. Fig. S1 presents reduced form (intent-to-treat) graphs on the impact of being above the admission threshold for on-time high school graduation, college attendance, and the log of quarterly earnings. For male students there is clear evidence of a jump in on-time high school graduation and the log of quarterly earnings on the right side of the admission threshold but little evidence of a jump in college attendance. In contrast, for female students, there is minimal evidence of a discontinuity at the admission threshold on these three outcomes.

Table 2 presents instrumental variable (treatment on the treated) estimates for our main outcomes based on a 16-point bandwidth. For male students, attending a CTE high school is associated with a 6 percentage-point increase in on-time high school graduation and no discernible effect on college participation. For labor market outcomes, we first examine if treatment affects whether the individual is observed in the labor market or not and find no evidence of selection into our labor market sample over treatment. Next, using a sample one and a half to ten years after expected high school completion, male students attending a CTE school experience a 45% increase in total earnings (based on the coefficient estimate for log of total earnings), almost three additional quarters in paid employment, and 25% higher quarterly earnings, which increases to 30% higher earnings when we restrict the sample to only quarters worked while age 22 or older. Note that average quarterly earnings are calculated only for quarters with observed earnings in order to separate the likelihood of having quarters with earnings from earnings observed when employed. The increase in quarterly earnings at older ages is a clear point of contrast with estimates for non-disabled students (Brunner et al. 2023). Further, students with disabilities also experience an increase in quarters with earnings of 15% over the control group mean as compared to only an 11% increase for non-disabled students (Brunner et al. 2023).

In contrast, for female students, none of the estimates are statistically significant. However, it is important to note that we have limited power to detect effects for the female subsample because only 27% of applicants with disabilities are female. Most notably, the treatment on the treated estimate for quarters with earnings in the female subsample is sizable at over 2 additional quarters of work or a 12% increase over the control group mean.

We also conduct a series of robustness tests. First, we add controls for high school graduation and semesters observed in college, and find estimates (Table S4) that are nearly identical to Table 2. While these controls are clearly endogenous, these models allow us to examine labor market effects while recognizing that early exit from high school may influence labor market outcomes due to increased experience and that participation in secondary education may have an incapacitation effect on labor supply. Next, as shown in Table S5, estimates are also nearly identical in specifications without controls, as is expected if our RD models mimic a randomized experiment by generating sample balance. Results are also robust to selecting narrower bandwidths (Table S6), and falsification tests do not detect any relationship between outcomes and being above fake thresholds set either 16 or 20 points above or 16 points below the actual score threshold (Table S7).

In Fig. 3 and Table S8, we complement our estimates of the impact of CTE attendance by examining possible mechanisms behind our findings for male applicants. Fig. 2 presents point estimates with 95% confidence intervals for the impact of attending a CTE high school on discipline, time spent with typically developing peers, and state standardized test score outcomes. Students with identified disabilities that attended a CTE high school were slightly more likely to be suspended in high school (5-10pp), but suspensions were primarily in-school suspension without any higher likelihood of being expelled, spent a substantially larger share of their time with typically developing peers (12pp), and had higher math and reading scores than otherwise similar students who applied but were not admitted to a CTE high school. Further, these higher test scores arose even though admission to a CTE high school lead to higher test taking rates (as shown by being less likely to have missing 10th grade test scores) among students who were defined as having disabilities in 8th grade. These estimates suggest that CTE high schools in Connecticut may have had stricter enforcement of school discipline policies, but were more inclusive of students with identified disabilities and produced substantially better outcomes on required state tests of math and reading. Each of these mechanisms are theorized to explain the better graduation and workforce outcomes we observe for these students. Being included in mainstream settings, having enforced behavioral expectations, and better opportunities to develop core general skills could also explain the large positive impacts on our more distal outcomes.

These estimates for the female subsample are show in Table S9. Time spent with non-disabled peers is highly significant with an effect size about two percentage points smaller than the male subsample, but also a control group mean that is two points higher, consistent with very high levels of immersion in mainstream learning for both male and female students. For all other intermediate outcomes, estimates are relatively noisy. However, we observe sizable point estimates consistent with higher math test scores and higher rates of in-school suspension similar to male students, and so given the imprecision of our estimates we cannot rule out positive effects for female students.

We next examine whether these positive effects for students with disabilities are heterogeneous by splitting the sample and estimating reduced form models. Here we focus on male students, given the noisy estimates arising with the female subsample. In Fig. 4 and Table S10, we test for heterogeneity based on a student's type of disability, which we divided into four broad categories: physical or health impairments, ADD or ADHD, learning disability, and lower incidence disabilities, where the lower incidence category is primarily students with emotional disturbances (over 80%). Fig. 4 presents the difference between the estimates for all other types of disabilities and the largest type, learning disability. For ease of presentation, quarters with earnings estimates are divided by 10 so that a two-quarter difference in the effect of attending a CTE high school is represented by 0.2. None of the differences across subgroups in the reduced-form estimates are statistically different for any of the outcomes considered, and overall there is no consistent pattern in terms of differences in the magnitude of estimates across samples. For example, we observe a large negative difference for on time high school graduation arising for physical/health impairment, consistent with a zero point estimate for the disability type, while this disability classification has very similar point estimates to learning disability in the labor market. At the same time, we acknowledge the lack of labor market gains in terms of point estimates for our lower incidence disabilities subsample. The difference estimates for this subsample relative to learning disability are sizable and negative for both quarterly earnings and quarters with earnings, but very noisily estimated due to the small sample size. Therefore, we cannot determine whether CTE high schools were providing a labor market benefit for students in this disability category.

Second, we split the sample into students who spent more than 90% of their time in mainstreamed settings (approximately the sample median) in 8th grade and those who spent less than 90%. For our regression sample, the mean time spent with non-disabled peers in the above median sample is 97.0% of time with a standard deviation of only 2.8, while for the below median sample the mean is 74.1% with a standard deviation of 22.1. Notably, these statistics are nearly identical when we restrict the sample to applicants above the admissions threshold. In Fig.

5 and Table S11 we present the difference between the estimates for the below and above 90% of time with non-disabled peers subsample estimates on quarters with earnings, quarterly earnings, and on-time graduation from high school separately by these two groups. None of the estimates for below and above median time spent with typically developing peers are statistically different from each other. Further, while the quarters with earnings estimate for below median is less than the estimate for above median, as illustrated by a negative point estimate in the figure, the estimates for quarterly earnings and on time graduate for below median are larger so there is no consistent pattern, suggesting these differences are likely due to estimation error. Therefore, students with disabilities in our below median subsample were able to successfully transition to near universal integration with non-disabled peers upon admission to CTE high schools in Connecticut, even though on average those students had 23 percentage points less time spent with non-disabled peers in 8th grade compared to the above median subsample.

Finally, we test for heterogeneity based on admission threshold scores to examine how broad-based our core results are over prior academic performance. We first separate the sample of male students into terciles based on admission threshold scores that are adjusted to a maximum score value of 100 and create indicators for each tercile. Note that this adjustment is only used for selecting the tercile subsamples, not the regression analyses. The thresholds contained in each tercile differ substantially with mean thresholds of 39.7, 48.2, and 55.3 in the bottom, middle and top terciles respectively. Notably, as shown in Table S12, the distributions of students over type of disability and time spent with non-disabled peers are relatively stable across the terciles. We then interact the three tercile indicators with the above the admissions threshold (offer) indicator and re-estimate our main reduced-form models replacing the offer indicator with the three interactions between the admission threshold terciles and offer. As shown in Table S13, effects for on-time high school graduation and quarters with earnings appear to be concentrated in the lower terciles. We observe virtually no differences across terciles for the estimates on quarterly earnings. Although we cannot statistically reject that the estimates are the same across terciles, we can conclude that any heterogeneity would imply larger effects for students with weaker pre-treatment academic performance.

In summary, the evidence suggests relatively broad-based positive effects of admission to a CTE high school over disability type (with the exception of emotional disturbances) and over time spent with typically developing peers in middle school. These positive treatment effects for male students are also relatively broad based across prior academic achievement, with potentially larger effects for applicants with worse prior academic performance. In the remainder of Table S11, we present reduced-form impacts for free or reduced-price lunch eligible students (panel c), students not eligible for free or reduced-price lunch (panel d), black and Hispanic students (panel e) and all students other than black and Hispanic students (panel f). In general, there is once again little evidence of heterogeneity based on these student attributes with no estimates being statistically significant at the 5% level.

Discussion

Our findings of a positive effect of attending a CTE high school on educational and workforce outcomes for male students with identified disabilities is consistent with earlier findings from studies that can only control for selection on observables (Wagne et al 2017; Dougherty et al 2018). Despite this consistency, our paper make several important contributions to the literature and the future of educational and disability related practice. First, given concerns about selection on unobservables, our estimates very strong causal evidence of the impact of participation in CTE programs for students with identified disabilities. Second, they represent impacts in a system of stand-alone CTE high schools operating at scale. Third, our study is one of the first to follow students long enough to observe positive labor market outcomes five to 10 years after high school graduation, which is critical given the emphasis on transition to employment and independent living for students with disabilities. We find sizable increases in labor force participation, as captured by quarters with earnings, and sizable earnings gains that persist for individuals 22 years old or older. Furthermore, our finding that male students with identified disabilities experience substantial increases in quarters with earnings and gains in quarterly earnings that persist, and even increase by age 22, stands in contrast to earlier findings for non-disabled students who experienced modest erosion of earnings gains at older ages and smaller effects on quarters with earnings (Brunner et al. 2023). While our estimates may not be informative for students with more severe disabilities who may be unlikely to apply to or obtain admission to these schools (Lombardi et al. 2018), we find improved outcomes for students with disabilities across a diverse sample of students with disabilities as measured by type of disability, time spent with non-disabled peers, and academic performance in middle school. Notably, point estimates suggest that any heterogeneity over prior academic performance would arise as larger effects for students with lower prior performance.

Our lack of findings for female applicants is consistent with several related literatures. As observed in the literature on intersectionality, gender gaps are substantially larger for students with disabilities suggesting that female students with disabilities face additional barriers in the labor market (Blackorby and Wagner 1999; Maroto et al. 2019), which might limit their benefit from participation in CTE. Further, the literature on CTE for non-disabled students has often found that effects are concentrated among male, rather than female students, especially for programs focused on career pathways rather than college readiness (Brunner et al 2023; Page 2012; Bertrand et al. 2021). Further, completion of vocational rehabilitation has been associated with higher initial wages for males with disabilities but not females (Doren et al. 2011). For students in Connecticut CTE high schools, a large portion of the wage gains for male students arise due to an increased likelihood of placement in higher paying industries. In contrast, CTE high schools have virtually no impact on the industry placement of female students (Brunner et al. 2022). Similarly, for students with disabilities, career counselling and school to work programs for disabled students has also been shown to be heavily influenced by gender stereotypes (Blackorby 1993; Powers et al. 2005; Powers et al. 2008). At the same time, we must acknowledge that we have limited power to detect positive effects for female students with disabilities and that we observe sizable point estimates for quarters of work, math test scores, and likelihood of in-school suspensions that are in the same direction as our results for male students. In our opinion, it is notable that male and female students with disabilities attending CTE high schools were successfully able to transition to a completely immersive educational environment and perform academically at comparable or even superior levels to students attending traditional high schools.

Notably, a parallel literature on the experiences of youth with disabilities at the point of transition to adulthood highlights limits and obstacles facing these students. For instance, youth with disabilities appear to experience less social contact, and what social contact they do experience is disproportionately in the context of their immediate family (Wikle and Shandra 2023). The increased exposure to typically developing peers in CTE high schools and the smoothing of the transition to the workforce for students in those schools may help reduce such social isolation and expand the context for their own social inclusion and benefit. Relatedly, family involvement appears to be crucial to postschool transition (Hirano et al. 2018). The focus in CTE high schools on creating work-based learning and out-of-school learning experiences, as well as the support for student agency in choosing CTE pathways early in high school, may serve to create mechanisms to involve families in the education and transition process beyond what is typical experienced in comprehensive high schools.

Critically, our estimates are generated in an educational setting that is relatively unique across the U.S. educational system. Nonetheless, schools like Connecticut's CTE high schools also exist in Massachusetts, New York, New Jersey, and similar models may be expanding as the PTECH model of schooling grows nationally (Dixon and Rosen 2022). Further, we believe that documenting the sizable positive effects of stand-alone CTE educational experiences is very important and illustrates a model that could be adopted in other states and potentially improve outcomes for both disabled and non-disabled students who have interests in CTE education. In fact, the lack of labor market effects eight years after graduation from high school found in prior studies (Wagner et al. 2016) is suggestive that the less intensive treatment provided by CTE courses in traditional high schools is not sufficient to have the same long-lasting effects that we observe for CTE dedicated high schools. The CTE focused high schools in Connecticut are only modestly more expensive than traditional high schools in Connecticut (Brunner et al. 2023), and those additional costs may in fact be less than the savings in special education expenditures that arise when students attending these CTE high schools are completely mainstreamed. Therefore, our research points strongly to a model that could be adopted more broadly and be very effective for students with identified disabilities.

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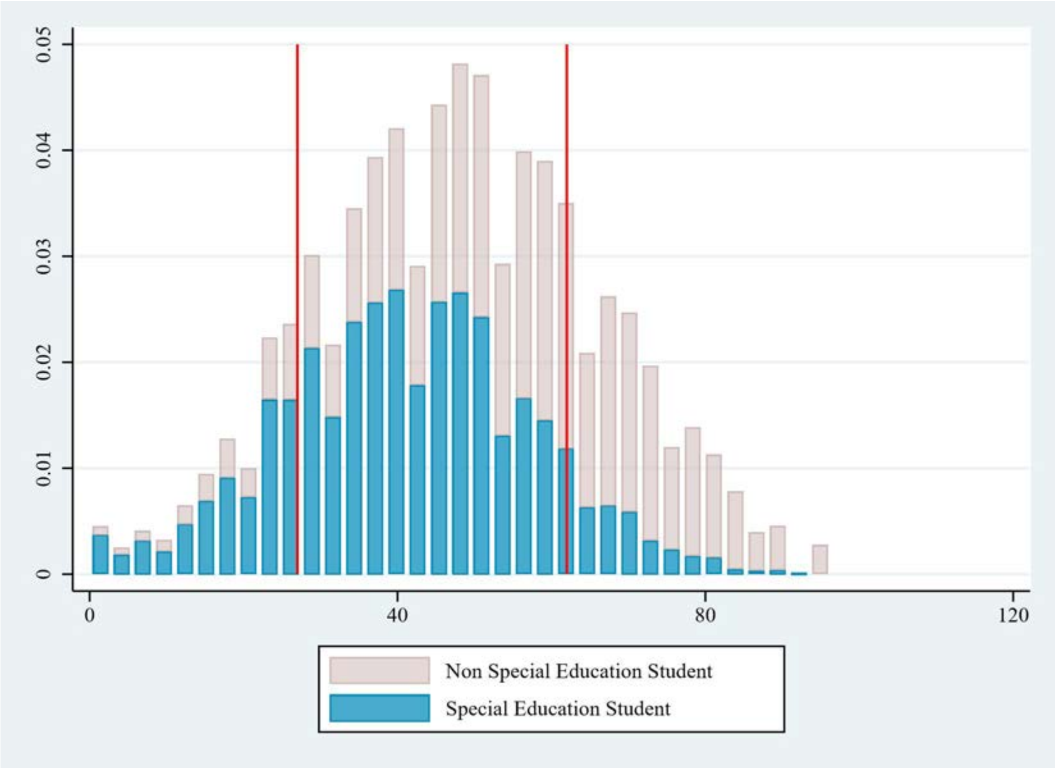
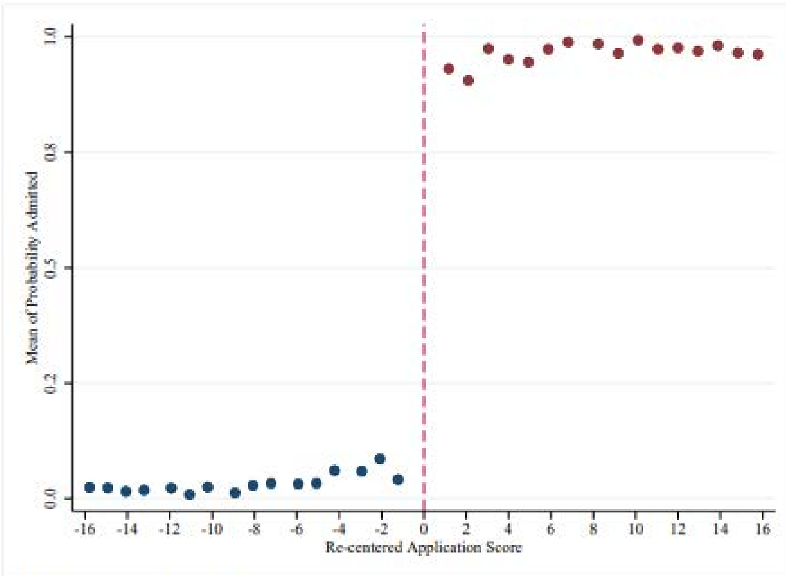


Fig. 1. Histogram of Student Admission Scores. Figure shows density of admission scores for special education students (Blue) and non special education students (Tan). Admission scores and thresholds are adjusted by subtracting 6 points during the 2007-08 and the 2008-09 academic years when the maximum score was 106 points, and by subtracting 20 points between the 2009-10 and the 2013-14 years when the maximum score was 20 Vertical red lines correspond to minimum and maximum adjusted CTECS school admission cutoff scores.

Panel A: Probability of Being Admitted to a CTHSS School Full Sample



Panel B: Probability of Attending Full Sample

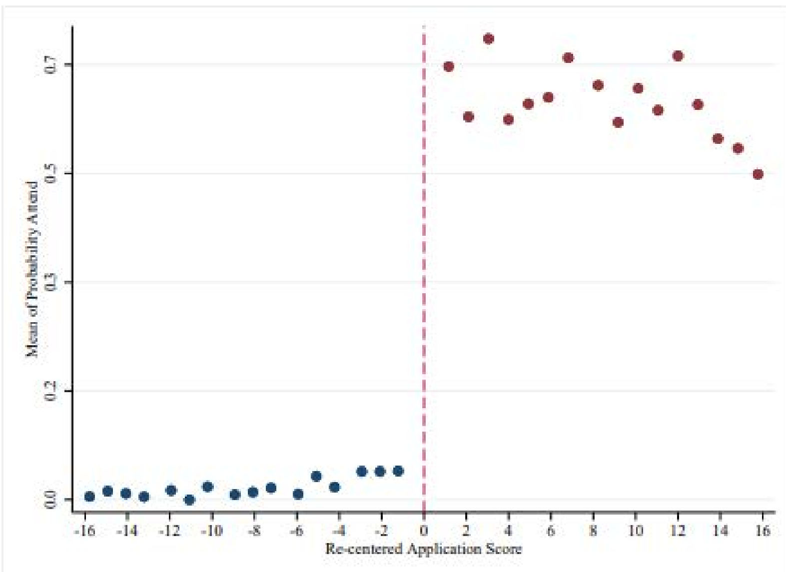


Fig. 2. First Stage Discontinuity Plots. The scores forming the horizontal axis have been re-centered by subtracting the threshold for each school and year from the scores associated with the applicants from those schools and years. The figures are based on all applications from 8th graders with an IEP from 2006-2014. Panel A shows the results for admission, panel B shows the results for acceptance, and panels C and D show the results separately for male students. Full set of estimates and standard errors are reported in Appendix Table 3A.

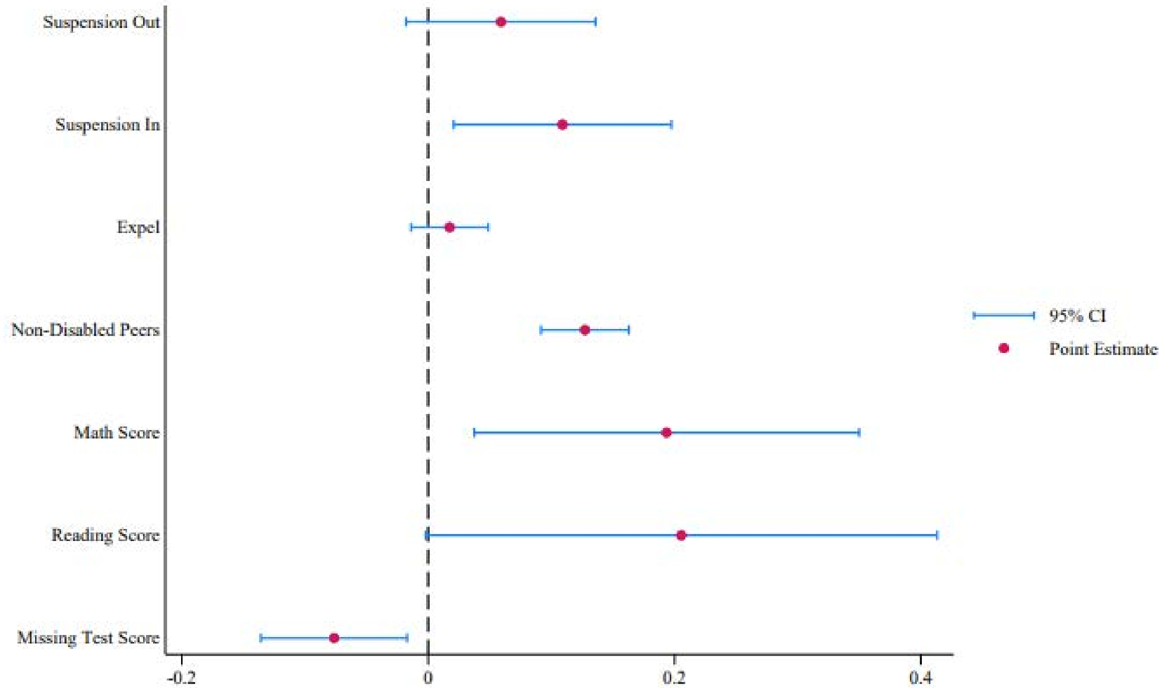


Fig. 3. Intermediate High School Outcomes as Potential Mechanisms. Figure reports point estimates and 95% confidence intervals for potential mechanisms underlying the results reported in Table 1. All results are based on a RD local linear regression with a 16 point bandwidth. Full set of estimates and standard errors are reported in Appendix Table 10.

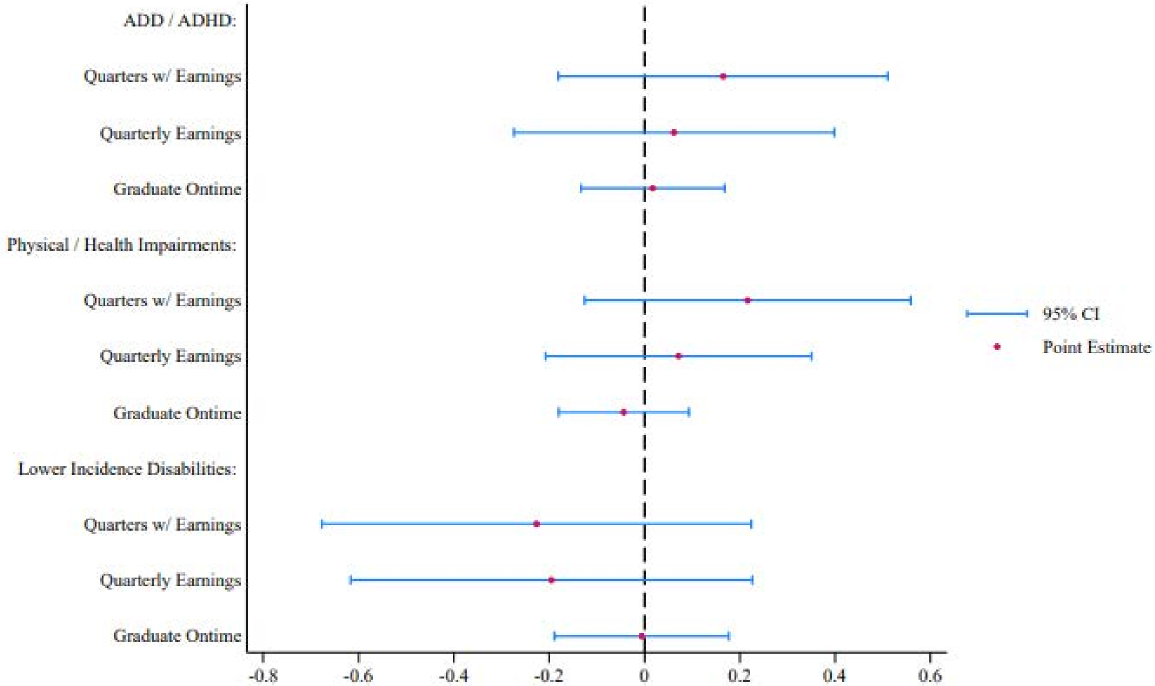


Fig. 4. Heterogeneity by Type of Disability relative to Learning Disability. Figure shows the difference between point estimates for each disability type (lower incidence, physical/health, ADD/ADHD) and the point estimate for learning disability, the largest subsample based on disability type, with 95% confidence intervals. Estimates for each disability type arise from seperate regressions for each subsample based on student's identified disability in 8th grade, and standard errors are calculated exploiting the independence between estimates resulting from the use of seperate subsamples for estimation. All results are based on a RD local linear regression with a 16 point bandwidth. A full set of estimates and standard errors are reported in Appendix Table 11.

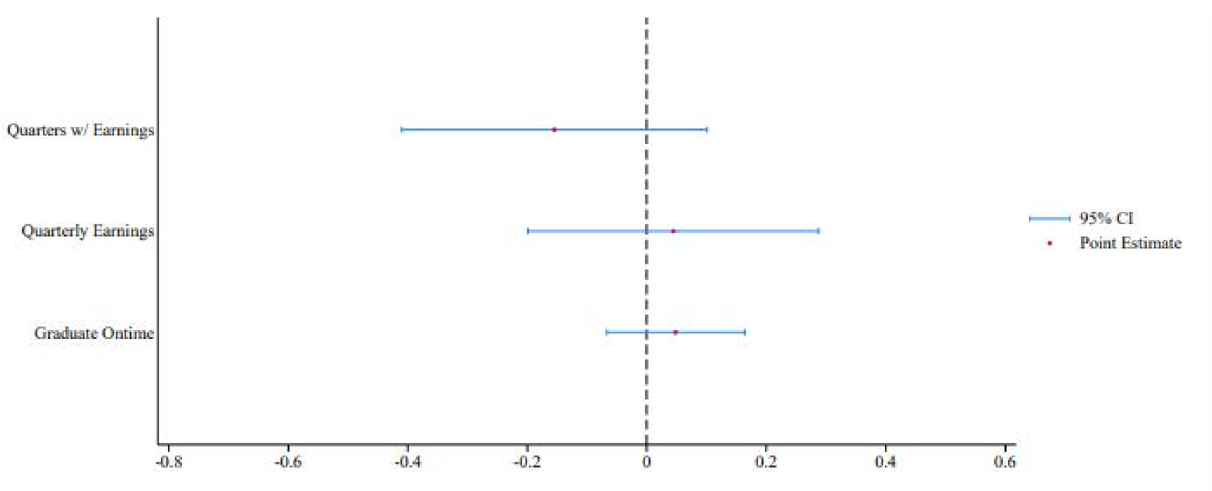


Fig. 5 Heterogeneity by Time Spent with Non-Disabled Peers (Below relative to Above 90% of Time). Figure shows the difference between the point estimate for the below median subsample based on 8th grade time spent with non-disabled peers and the point estimate for the above median subsample with 95% confidence intervals. Estimates for the below and above median subsamples arise from seperate regressions for each subsample , and standard errors are calculated exploiting the independence between estimates resulting from the use of seperate subsamples for estimation. All results are based on a RD local linear regression with a 16 point bandwidth. A full set of estimates and standard errors are reported in Appendix Table 11A.

	Statewide Sample		CTECS Sample		within 16 Point Bandwidth	
	(1)	(2)	(3)	(4)	(5)	(6)
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Female	0.339	0.474	0.271	0.444	0.269	0.443
Asian	0.022	0.146	0.008	0.087	0.009	0.096
Black	0.152	0.359	0.190	0.393	0.190	0.392
Hispanic	0.257	0.437	0.323	0.468	0.288	0.453
Free Lunch	0.496	0.500	0.680	0.466	0.661	0.473
English Learner	0.091	0.288	0.114	0.318	0.092	0.289
8th Grade Learning Disabilities	0.448	0.497	0.517	0.500	0.523	0.500
8th Grade ADD/ADHD	0.156	0.363	0.161	0.368	0.165	0.372
8th Grade Physical/Health Impairments	0.161	0.368	0.170	0.376	0.171	0.377
8th Grade Lower Incidence Disability	0.235	0.424	0.152	0.359	0.140	0.347
8th Time Spent with Non-Disabled Peers	82.241	21.730	85.599	18.507	85.504	19.087
Reading：						
Below Basic	0.274	0.446	0.337	0.473	0.292	0.455
Below Proficient	0.428	0.494	0.540	0.499	0.525	0.500
Below Goal	0.582	0.493	0.704	0.457	0.708	0.455
Writing：						
Below Basic	0.271	0.444	0.280	0.449	0.236	0.425
Below Proficient	0.522	0.499	0.593	0.491	0.553	0.498
Below Goal	0.787	0.409	0.868	0.339	0.866	0.340
Math：						
Below Basic	0.169	0.374	0.182	0.386	0.128	0.334
Below Proficient	0.410	0.491	0.478	0.500	0.434	0.496
Below Goal	0.722	0.448	0.794	0.405	0.810	0.393

Table 1: State and CTECS District Means. Table presents means and standard deviations for the 2013-14 school year for students with disabilities in the State of Connecticut, for those students with disabilities in the state who applied to a CTE High School, and for those applicants who test scores place them within the 16 point bandwidth around the admissions threshold given the application school and year. The aggregate categories for disability type are defined as follows: Learning Disabilities include the learning disabilities; ADD/ADHD is a category by itself; Physical/Health Impairments include Hearing Impairments, Visual Impairments, Orthopedic Impairments, Other Health Impairments, and Speech/Language Impairments; Lower Incidence Disabilities include Intellectual Disabilities, Emotional Disturbances, Autism, and Traumatic Brain Injury. The results of 8th grade test scores are presented as percent of students below a given standard where proficient is the standard established for compliance with federal No Child Left Behind legislation, while goal is the state's established standard of performance and basic is a level below the federal standard.

Outcome	(1) On Time H.S. Grad	(2) Any College	(3) In Labor Market	(4) Log of Total Earnings	(5) Log of Quarterly Earnings	(6) Quarters with Earnings	(7) Log of Quarterly Earnings Age 22+
				Male Students			
Attend	0.0633	-0.0293	-0.00977	0.453**	0.245**	2.917**	0.292**
	(0.0364)	(0.0333)	(0.0104)	(0.142)	(0.0835)	(0.943)	(0.0901)
Observations	4,639	4,639	4,639	4,039	4,039	4,039	3,292
Mean CG	0.696	0.176	0.897	11.136	8.441	19.155	8.626
St. Dev. CG	0.460	0.381	0.304	1.489	0.814	11.394	0.857
				Female Students			
Attend	0.00729	-0.0874	-0.0431	0.142	0.0882	2.160	0.0843
	(0.0960)	(0.0590)	(0.0385)	(0.254)	(0.150)	(1.395)	(0.163)
Observations	1,618	1,618	1,618	1,327	1,327	1,327	1,048
Mean CG	0.716	0.316	0.837	10.701	8.059	17.820	8.234
St. Dev. CG	0.451	0.465	0.370	1.448	0.793	10.327	0.852

Table 2. 2SLS Estimates (Bandwidth 16) with Controls. Table presents 2SLS estimates and clustered standard errors for main outcomes. Top panel presents estimates for male IEP students. Bottom panel presents estimates for female IEP students. All results are based on a RD local linear regression with a 16 point bandwidth and include applications from 8th graders from 2006-2014. Mean CG is the mean of the dependent variable for the control group and is defined as the mean to the left of the cutoff within the 16 point bandwidth. St. Dev. CG is the standard deviation of Mean CG. All specifications include controls for standardized 7th grade combined test scores in English and math and indicators for whether an applicant is Black, Hispanic, Free or reduced price lunch eligible and whether the student is an English language learner. All specifications also include CTECS school-by-year fixed effects and 8th grade sending town fixed effects. Robust standard errors, clustered at the school-by-year and town levels in parentheses. ** $p<0.01$, * $p<0.05$

Methodological Appendix

Please note that this material is drawn heavily from previous published material by the authors in (Brunner et al. 2023). We employ a fuzzy, local-linear regression discontinuity framework using a uniform kernel. These models will capture the Local Average Treatment Effect (LATE) for students near the admissions threshold, and we estimate treatment on the treated effects by instrumenting for actual school attendance using the admission threshold as an instrument. Further, given variation in cut-offs across schools and over time, the estimates are representative over a broad set of scores.

Specifically, using a school (*s*) by application year (*y*) admissions threshold ($\widehat{X_{sy}^*}$), we center each student's (*i*) admission score (X_{isyt}) from town *t*, $\tilde{X}_{isyt} = X_{isyt} - \widehat{X_{sy}^*}$ and pool the data across schools and years. We then estimate models of student outcomes (y_{isyt}) using Two Stage Least Squares conditional on school-by-application year fixed effects (δ_{2sy}) and applicant town of residence fixed effects (γ_{2t}) effectively identifying the likely counterfactual high school or schools:

$$y_{isyt} = \beta A_{isyt} + \theta_{21}\tilde{X}_{isyt} + \theta_{22}X_{isyt}d\left(0 \leq \tilde{X}_{isyt}\right) + \delta_{2sy} + \gamma_{2t} + \varepsilon_{2ist} \qquad \text{(S1)}$$

where A_{isyt} denotes whether the individual attends the school to which they applied and being above the threshold, $d\left(0 \leq \tilde{X}_{isyt}\right)$ is used as an instrument for A_{isyt}. The first stage equation for A_{isyt} is:

$$A_{isyt} = \tilde{\alpha}\; d\left(0 \leq \tilde{X}_{isyt}\right) + \theta_{31}\tilde{X}_{isyt} + \theta_{32}X_{isyt}d\left(0 \leq \tilde{X}_{isyt}\right) + \delta_{3sy} + \gamma_{3t} + \varepsilon_{3ist} \qquad \text{(S2)}$$

where $\tilde{\alpha}$ represents the composite or sample average effect of being above the threshold. The parameter of interest in equation (S1) is β capturing the effect of attending a CTHSS school for students who are just above the admissions threshold compared to those who just missed the threshold.

Standard errors are clustered following our fixed effects structure: application school by application year and sending town. While many prior studies with discrete running variables have clustered standard errors by the running variable, clustering by the running variable has been shown to provide confidence intervals with poor coverage properties (Kolesár and Rothe 2018). As an alternative to our two-way clustering, we have also conducted inference using finite-sample exact randomization inference tests following Cattaneo et al. (2019), but we find that randomization inference leads to much less conservative inference because changes the null hypothesis as noted by Cattaneo et al. (2019).

Estimating Admissions Thresholds

Since admission thresholds are not observed, thresholds are identified empirically for each school and year as the threshold that yields the largest discontinuity in the dependent variable. The location of each threshold is identified by selecting the threshold that maximizes the size of the discontinuity (Porter and Yu 2015), or specifically:

$$\widehat{X^*} = argmax_{X^*}\hat{\alpha}(X^*) \qquad \text{(S3)}$$

where the treatment (T) is defined by

$$T = \begin{cases} 1 & if\ y^* \geq 0 \\ 0 & if\ y^* < 0 \end{cases},\ T^* = \begin{cases} f_1(X) + \varepsilon & if\ X < X^* \\ f_2(X) + \alpha + \varepsilon & if\ X \geq X^* \end{cases},\ f_1(X^*) = f_2(X^*) \tag{S4}$$

where $f_1(X)$ and $f_2(X)$ are continuous and differentiable functions. The inclusion of different functions on either side of the threshold allows for differential processes for non-compliance. In practice, for every possible integer value of the admissions score, we estimate an equation similar to (S2) for whether the student was mailed an admissions letter. This implies that we estimate linear probability models and specify $f_1(X)$ and $f_2(X)$ above as linear functions of X. The resulting estimated thresholds $\widehat{X_{sy}^*}$ are used to center student admissions scores for estimating (S1) and (S2).

The disadvantage of this approach is that our analysis is conditional on the estimated discontinuity and the estimated discontinuity may not represent the true discontinuity. In a 2SLS context, we need to establish the power of the instrument and the validity of the exclusion restriction. Determining the power of the instrument, however, is not straightforward since the cutoff has been selected using the same data that is then used to estimate the first stage equation. Naturally, treatment (receiving an acceptance letter) affects attendance and so the F-test may be biased upwards providing misleading evidence on instrument power because we selected $\widehat{X^*}$ to maximize the discontinuity for T which is strongly correlated with A.

We address this concern using a hold-out sample in Brunner et al. (2023). Specifically, we divided the applicants in each school and year into equal sized analytic and hold-out samples so that we could use the analytic sample to select the thresholds and use the hold-out sample to estimate the first stage for attendance and examine the power of the instrument. Specifically, we did the following:

1) For each school and year, divide all applicants into deciles, assign each applicant a random number, place applicants in the hold-out sample if they are above the median on the random number and in the analysis sample if below, split median applicants half in hold-out/half in analysis samples, and in the case of an odd number of median applicants assign the last median applicant randomly to either the hold-out or analysis sample.

2) Using a bandwidth of 10 points (due to the larger sample size for applicants without disabilities) and linear running variables, estimate equation (S2) using admission as the outcome for each school and year starting with a candidate cutoff score at 10 so that the bottom of the 20-point band is at a score of zero using the analysis sample.

3) Re-estimate these models incrementing the candidate cutoff score by 1 each time and ending 10 points away from the maximum score so that the top of the band is at the maximum.

4) Select the cutoff for each school and year as the cutoff that provides the maximum estimate of α.

5) Center the scores for each school and year by subtracting the cutoff and pool all years and schools.

6) Estimate equation (S2) for school attendance and calculate the *F*-statistic associated with the indicator $d(\widehat{X^*} \leq X)$ using the hold-out sample.

We conducted this hold-out simulation four times, and the resulting *F*-statistics always fell between 456 and 628 for the full sample and between 458 and 674 for the donut hole sample. We also estimated the first stage models separately for each school and year. The means of the estimated discontinuities over all schools and years ranged between 0.525 and 0.540 for the four simulations, very close to our full sample first stage estimate of 0.582. See the supplemental material for Brunner et al. (2023) for detailed results.

Validation of the Identification Strategy

In terms of the validity of the exclusion restriction, the key assumption in regression discontinuity analyses is that the attributes of individuals evolve smoothly with the running variable across the discontinuity so that the estimated effect of the discontinuity does not capture the effect of individual attributes on outcomes after controlling for the running variable. As mentioned in the paper, we provide evidence on this assumption by estimating balancing tests where we demonstrate that observable student attributes (Z_{isyt}) vary smoothly over the threshold. Specifically, we estimate reduced form models based on S2 where we replace the dummy for being above the admissions threshold with each student attribute.

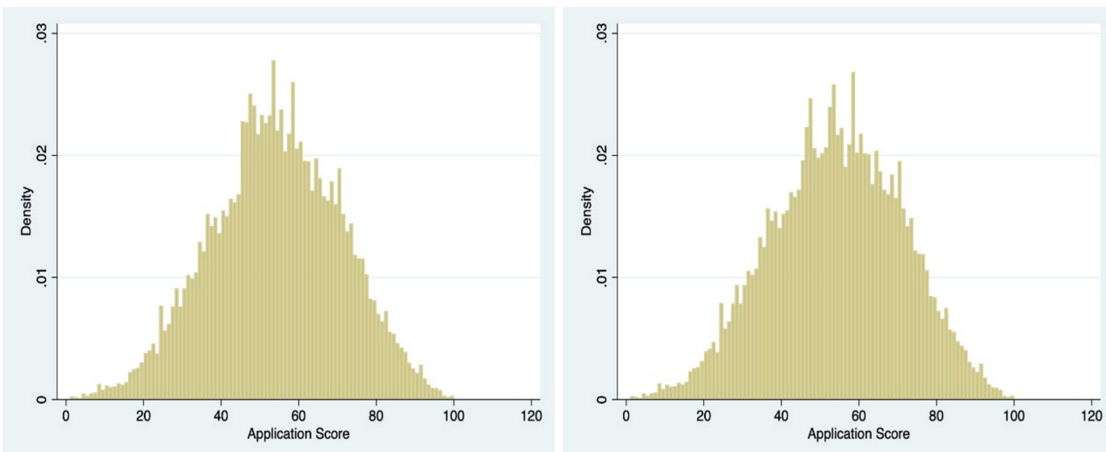
$$Z_{isyt} = \tilde{\alpha}\ d\left(0 \leq \tilde{X}_{isyt}\right) + \theta_{31}\tilde{X}_{isyt} + \theta_{32}X_{isyt}d\left(0 \leq \tilde{X}_{isyt}\right) + \delta_{3sy} + \gamma_{3t} + \varepsilon_{3ist} \qquad \text{(S5)}$$

These results are presented in Appendix Tables S16 and S17.

A second common test used with regression discontinuity analyses is the McCrary test for bunching at the threshold that is used to test for whether scores might have been manipulated to systematically move individuals above or below the threshold. As noted in (21), our data on CTEC high school admissions fails these tests for bunching at the threshold. However, manipulation by students in the current context is highly unlikely given the admission process used by CTECTS. Schools set the threshold after observing the pool of applicants, all their scores, and all their provided materials. As a result, it is nearly impossible for students to know the exact position of the threshold at their application school. While there is potentially more room for manipulation by school personnel, manipulation also seems unlikely in this situation. First, school administrators have no incentive to manipulate the score given that they are free to depart from any threshold that they set and that their admission decisions are not monitored. Further, the four primary components of a student's total score, standardized 7$^{\text{th}}$ grade test scores in math and language arts (reading and writing), GPA, and attendance in middle school, are clear and objective with little to no room for manipulation. Manipulation of the final two components, namely the points assigned for extracurricular activities and a student's written statement for why they want to attend a technical high school, appears more feasible, but students applying to CTECS most likely never interacted with school officials and we observe a non-standard distribution prior to the consideration of these additional components. We also verify that the components sum to the composite score for all students in our sample so any manipulation would have to involve school administrators manipulating components to get a desired result on the total score.

Nonetheless, to be conservative, all analyses in the paper are conducted using the standard "donut hole" strategy for addressing manipulation at the threshold. This strategy involves dropping observations just on either side of the threshold where manipulation is most likely to have an effect. Specifically, the sample is selected based on the following criteria: $X_{isyt} \in [X_{sy}^{*} - BW, X_{sy}^{*} - 1] \ or \ [X_{sy}^{*} + 1, X_{sy}^{*} + BW]$. Results are very similar whether or not we use a donut hole specification. Further, the distributions with and without the observations at the threshold are similar, and the elimination of observations immediately around the threshold does not eliminate the irregular distribution of scores. As an illustration we show the distribution of scores for the 2006-2008 admission cohorts, a three-year period where the score definition was stable at a total of 100 points and prior to the inclusion of subjective criteria.

Actual Distribution | Dropping Observations at the Cut-off



Finally, simulation analyses in (21) (see supplemental material for that paper), strongly suggest that the McCrary failure arises from the way in which the admission score was created (see below for more detailed discussion). The failure of the McCrary test for our data appears to arise because even though admission score components like test scores, grade point averages and attendance data are relatively continuous, the system for assigning points divides students into more aggregated bins leading to both mass points and holes in the empirical distribution of application scores. We demonstrate this in (21) using three different simulation analyses that eliminate any actual manipulation in the data: 1. Showing that we can generate most of the variation between the true distribution and the distribution dropping observations at the threshold by selecting fake thresholds from the population of observed thresholds and dropping observations at these fake thresholds, 2. Generating score distributions that look similar to true score distributions by randomly simulating the components of the admission score while preserving the correlation between components and building a sample of false admission scores, 3. Generate centered score distributions that look similar to the true centered score distributions based on fake thresholds that arise by simulating a population of applicants for each school and year to create a false thresholds that arise at the score where the simulated population fills the target incoming class.

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