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Does technical education improve academic outcomes? Evidence from Brazil

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Abstract:

Despite the renewed interest in technical education, only a handful of studies analyze its effect on academic outcomes. In this paper we apply a regression discontinuity design to oversubscribed technical high school tracks in Pernambuco, Brazil, to identify the impact of technical education during high school on student academic outcomes. We find that students above the technical high school admission exam score cutoff drop out less from high school and have Math and Portuguese standardized test scores over 0.1 standard deviations higher than students below the cutoff. We also find that students above the cutoff were more likely to attend schools offering a longer school day and better school, teacher, and peer characteristics. Comparing technical high schools with academic schools with similar characteristics, we find no differences in terms of achievement but significantly lower dropout rates. This evidence suggests that the estimated effect of having the opportunity to enroll in technical high schools on student achievement may be driven by the school characteristics while the nature of the instructional content seems to be effective in reducing dropout rates during high school.

Keywords: Education, technical education, high school, Latin America, Brazil

JEL codes: I21, J24

1 Introduction

In recent years many countries have reevaluated the role of technical education as a path to decent and productive jobs and as a possible solution to country skill shortages (UNESCO, 2017). In fact, technical education at the secondary level has been perceived as the best alternative to equip youth with skills that are valuable in the labor market while helping them begin a sustainable employment trajectory. In addition, due to its hands-on focus and close link with the world of work, it appears as a viable alternative to motivate more practically oriented youth and/or to reengage students in formal education, especially non-college bound students.

Brazil has been at the forefront of this renewed trend, substantially increasing resources devoted to technical education. Investments in technical education as a percentage of GDP in Brazil multiplied by 5 between 2003 and 2016 (from 0.04% to 0.2%), and the number of students enrolled in technical education during high school increased by 45% between 2007 and 2013. Furthermore, the ongoing secondary education reform (*Reforma do Ensino Médio*) will expand access to technical education even further.

Despite the renewed interest in technical education, there is no consensus on whether governments should expand this type of education. Advocates maintain that technical education can increase student motivation and engagement (e.g., Shernoff et al., 2003; Carbonaro, 2005), reduce student dropout (Kemple and Willner, 2008; Kemple and Snipes, 2000; Hall, 2012) and increase the probability that students graduate from high school (e.g., Polidano and Tabasso, 2014; Dougherty, 2015). All these outcomes are important for governments to determine the effectiveness of their education systems and for students, since their final education level has a significant effect on labor market outcomes (e.g., Psacharopoulos and Patrinos, 2018). On the other hand, skeptics counter that technical education takes time of more transversally relevant subjects, such as Math (World Bank, 2018), provides skills that are too specific, limiting adaptability (Hanushek et al., 2017), which may set up a barrier to pursue further studies, and is significantly more costly than academic education. Almeida et al. (2015) estimate that, in 2008, a pupil enrolled in high school integrated with technical education in Brazil was 3.1 times more expensive than a student enrolled in the general academic track.

Furthermore, rigorous literature on the effect of technical education on schooling outcomes is still scarce and focused mostly on experiences in the US. Additionally, since students self-select into technical education instead of academic education, analyses that do not causally address student self-selection may report biased effects of technical education, making credible work even scarcer. For example, if less able students are more likely to enroll in technical education instead of academic education, non-experimental or quasi-experimental methods may report negative effects of technical education on student achievement, as we would compare students in technical education to students in academic education, that have higher levels of ability.

Experimental and quasi-experimental literature on the impact of technical education during high school on student achievement generally shows no effect on test scores or grades (Kemple and Snipes, 2000; Dougherty, 2018; Neild et al., 2015). In contrast, technical education during high school has been shown to reduce dropouts among students at high risk of dropping out and to increase the likelihood of graduating on time among students least likely to drop out (Kemple and Snipes, 2000). This work focuses on experiences in the US that are not representative of vocational education in the country. Consequently, results may not be transferable to other vocational education systems, and, particularly, to Latin American Countries.

Literature in developing countries, and particularly in Latin America, is even scarcer and generally non-causal. Using a lottery of scholarships to attend private technical education in addition to public academic high school in Santa Catarina, Brazil, Camargo (2017) finds negative effects on school grades for male students that enroll in technical education instead of academic high schools.

Using unique technical high school admission data in Pernambuco, a state in the Northeast of Brazil, we exploit a discontinuity in the probability of enrolling in technical high school education to estimate the causal effect of this type of education on standardized test scores, dropout and repetition rates. In Pernambuco, students who want to enroll in technical integrated high school (TIHS), one of the three modalities of secondary technical education offered by state schools, must take an admission exam. If a technical track in a school is oversubscribed (which happens in 94% of the cases in our data), students are then ranked within the technical track and the school they applied to according to their admission exam score. Seats in the technical track and school are assigned to students according to their rank. This vacancy-assignment method creates a discontinuity in the probability of being offered a seat in a technical track and, consequently, in the probability of enrolling in this modality of technical high school.

We find that students just above the admission exam cutoff are about 40% more likely to enroll in TIHS than students just below the cutoff. These students are less likely to drop out during high school, and score about 0.1 standard deviations higher in both Math and Portuguese than students just below the cutoff on a standardized test that takes place during the last year of high school. This effect is large in comparison to other education policies. For instance, the average effect on learning of lengthening the school day is 0.08 standard deviations and the average effect of vouchers, subsidies or scholarships to attend private schools is even smaller, 0.03 standard deviations (Busso et al., 2017).

However, students above the admission exam cutoff were also more likely to attend schools with higher per pupil spending, higher quality infrastructure, better teacher characteristics, higher teacher salaries, and better peer characteristics at baseline and a longer school day. In order to control for these important differences, we compare TIHS to full-time academic high schools.

These schools have the same school day length and offer the same course load (number of hours) in Math and Portuguese and, generally, they have similar characteristics.

Results comparing TIHS to full-time academic high schools indicate that the extra hours devoted to technical courses reduce high school dropout rates without negatively affecting test scores in Math or Portuguese. These results are consistent with the evidence from developed countries showing that technical education has a significant impact reducing dropouts (Kemple and Snipes, 2000) and no differential effect on achievement (Kemple and Snipes, 2000; Dougherty, 2018; Neild et al., 2015). This suggests that most of the estimated effect on academic achievement of having access to TIHS might be caused by the longer school day and/or the better school, teacher and peer characteristics of TIHS compared to regular academic high schools.

The contributions of this paper are multiple. First, this paper causally identifies, using quasi-experimental methods, the effect of technical high school integrated with academic high school on schooling outcomes, adding to a relatively thin causal literature on the schooling effect of technical education. In fact, to the best of our knowledge, it is the first to casually identify schooling effect, and particularly effect on standardized test scores, of technical high school in a Latin American country. Second, in this work we can further analyze possible mechanisms behind the effect of technical education during high school on schooling outcomes. Our conclusions are relevant for the body of literature analyzing educational policies that intend to increase high school completion. Finally, this work comes at a crucial time for Brazilian education policy. At this moment the Brazilian government is approving an educational reform to include technical education as an option track during regular academic high school (*Reforma do Ensino Médio*). This paper informs about some of the potential effects of this policy change.

The remainder of the paper is organized as follows. The next section describes in detail technical education during high school in Brazil and in Pernambuco. Section 3 reviews the relevant literature about the effect of technical education during high school on schooling outcomes internationally and in Brazil. Section 4 describes the data used in this analysis, how different administrative databases were matched and analyzes attrition in our sample. Section 5 explains the methodology used to estimate the effect of technical integrated high school on schooling outcomes and section 6 shows the results of our analysis. Section 7 discusses some potential threats to our analysis and presents some robustness checks. Finally, section 8 concludes.

2 Background

Technical education is very heterogeneous in several dimensions. The provision of technical education varies greatly depending on the system and the country, ranging from alternatives to general education within the formal education system at the secondary or post-secondary levels, to a variety of short vocational courses or different forms of on the job training. Even at the high school level, technical education can be offered as a selection of elective career-oriented courses integrated to the traditional high school curriculum, as in the case of US, or offered as a separate education track during 3 to 4 years, as in the case of Germany and most countries in Latin America and the Caribbean. In addition, technical education encompasses a wide variety of fields that affect the type, nature and intensity of the learning experience. Finally, quality is highly heterogeneous across institutions, as it is true in all types of types of schooling. The heterogeneity of technical education, even within countries, complicates reaching uniform conclusions about the benefits or disadvantages of this type education.

Furthermore, the analysis of the effect of technical education on educational outcomes entails a second challenge: students generally self-select into technical education instead of academic education. In most countries, technical education has more of a reputation of attracting low achieving students than traditional academic schools (Ryan, 2001; Bassi et al 2012). This could lead to negative biases in the estimates of the effect of technical education on academic learning. In contrast, in the Dominican Republic and in some states of Brazil, such as Pernambuco, students who enroll in technical education have higher pre-enrollment test scores, which could lead to positive biases.

Given the differences in technical education across systems and countries, this section describes technical education in Brazil and in Pernambuco, the modalities of technical education offered during high school and the application process to technical integrated high school.

2.1 Technical education in Brazil and upper secondary education in Pernambuco

Public expenditure in technical education has experienced an exceptional increase over the past years in Brazil. Between 2003 and 2016, the percentage of GDP that the federal government spent on technical education multiplied by 5 (from 0.04% to 0.2%), creating 539,566 new enrollments. Despite this increase, technical education during high school is still small compared to all upper secondary[1] enrollments, making up only 9%[2] of enrollments. This is significantly smaller than the average for Latin America and the Caribbean, which is 23% (UIS, 2019). Technical education is expected to increase significantly in the coming years, as the Ministry of Education aims to triple the number of students attending a technical course by 2024.[3]

[1] Brazil's formal education system is divided into *Ensino fundamental* (1st to 9th grade) and E*nsino medio* or upper secondary (grades 10th-12th), which includes technical education.
[2] Brazil's school Census of 2016.
[3] Brazil's educational priorities of 2014 states that the government aims to triple enrollments in technical courses by 2024.

The country offers three main modalities of technical education at the upper-secondary level:[4] (i) *Integrated* – where high school students receive a mix of academic and technical curricular content in one technical institution for 3 years; (ii) *Concurrent* – where students enroll in a separate technical institution either in the 2nd or 3rd year of high school; (iii) *Subsequent* – where technical education is offered following the completion of the general upper secondary education.

Upper Secondary Education in Pernambuco

Pernambuco is a State of Brazil located in the Northeast region, one of the poorest regions of the country. It has 7 percentage points more people living in poverty than the national average. In addition, out of the 27 federal states and the federal district, Pernambuco has the 7th largest population, the 10th largest GDP and the 3rd highest quality education index[5] in secondary public school.

Pernambuco is an interesting setting to study because it has experienced unprecedented changes in its educational landscape in the last decade. On one hand, the expansion of technical education has exceeded the country average. Between 2009-2017 enrollment in technical education increased by 60% in Pernambuco while it increased by only 31% in Brazil. This increase was driven by the expansion of full-time academic schools. During this time span 36 TIHS institutions were created and enrollment increased by 20 times.[6] At the same time, the state has significantly expanded the number of schools offering academic full-time and *semi* full-time curriculum.[7] In fact, Pernambuco is one of the states with a larger fraction of academic full-time and *semi* full-time school with a share of 57% out of all enrollments in high school in 2017, compared to 9.5% in Brazil[8]. On the other hand, regular academic schools decreased 50% since 2009 in the state.

Upper secondary education in Pernambuco is offered mostly by the State education network[9] and includes six types of education: the same three modalities of technical education described above: concurrent, integrated, and subsequent, and three types of academic high schools (regular, *semi* full-time and full time). Each academic school type and technical school modality has a different

[4] Technical education at upper secondary refers to both, the technical education offered to students attending high school and the technical education offered after high school graduation (which generally lasts between 1.5 and 2 years).
[5] According to the basic education development index of 2017 (*Índice de desenvolvimento da educação básica - IDEB*), Pernambuco ranks third in education quality amongst all states in Brazil.
[6] In 2009, Pernambuco only had one THIS institution. Enrollment in the integrated modality in Pernambuco rose from 598 students in 2009 to 11,364 in 2017. The increase in Brazil was from 84,560 to 246,516 in the same period.
[7] Full-time high schools offer a total of 2,400 more hours of academic instruction than regular high schools while *semi* full-time high schools offer a total of 1,200 more hours than regular high schools. See Table 1 for more detail on the hours of instruction in each high school type.
8 http://portal.inep.gov.br/artigo/-/asset_publisher/B4AQV9zFY7Bv/content/censo-escolar-2018-revela-crescimento-de-18-nas-matriculas-em-tempo-integral-no-ensino-medio/21206.
[9] Since Brazil is a decentralized country, there are three public-school networks in addition to the private system: Municipal, State, and Federal. Some of the networks, such as Municipal and State, can overlap in some education levels. Generally, the municipality provides day care, preschool and the primary education levels, whereas the secondary education level, is mostly provided by the state.

course load, as shown in Table 1. Regular high school has a total course load of 3,000 hours, with *semi* full-time high schools offering an additional 1,200 hours of academic instruction, adding up to a total of 4,200 hours. Full-time high schools offer an even larger course load, totaling 5,400 hours of academic instruction. With regards to TIHS, this type of education combines 4,200 hours of academic course load along with 1,200 hours of technical content. The other technical modalities, concurrent and subsequent take place in a separate institution than academic high school. For this reason, these two modalities include from 800 to 1,200 hours of technical course load and no academic course load.

As shown in Table 3, most enrollments in the academic and technical *integrated* modalities in upper secondary in Pernambuco are in schools run by the state network. This pattern of enrollment is representative for other states and for Brazil as a whole.

During this period, TIHS has gained increasing attention due to its better infrastructure and higher availability of resources. For instance, per pupil spending in TIHS is about 30% larger than in academic high schools in the State.

Consequently, these high schools are perceived as higher quality and TIHS tracks are, usually, oversubscribed. In order to assign seats to candidates, all TIHS tracks in all technical schools use an admission process. The admission process usually starts in October from the previous calendar year,[10] when eligible candidates apply to the school and choose a track. To be eligible to apply, a student must be attending 9th grade at the time of application and be 17 years old or younger. Additionally, the student must graduate from elementary school by the end of the school year to be able to enroll in TIHS. In November, the pool of candidates takes Portuguese and Mathematics exams. After the exam, students are ranked according to their score and seats in TIHS tracks in each school are assigned by the ranking until all vacancies in the track and school are filled. In order to guarantee that public school students are the majority in TIHS, 75% of all seats in TIHS tracks are reserved for students who were enrolled in public schools in 9th grade.[11] Since students who attended private schools in 9th grade only have 25% of seats available, in practice this means that there are two effective score cutoffs in each TIHS track and technical school combination: the score of the first student who was enrolled in a private school in 9th grade and is not assigned a seat, and the score of the first student who was enrolled in a public school in 9th grade and is not assigned a seat.

Candidates below the exam cutoff may still enroll in technical education during high school. These students could potentially enroll in a TIHS track that is not oversubscribed or enroll in concurrent technical education modality. As explained above, this modality consists in enrolling in an

[10] In Brazil the school year starts in February and ends in early December.
[11] The public-school quota applies only to TIHS belonging the state school network.

academic high school and, from the 2nd year of high school, additionally attending technical training in another institution. These two alternatives are not very prevalent in our sample (see Panel B in Table 4).

3 Literature Review

This literature review concentrates on the studies analyzing the effect of technical education at the high school level on schooling outcomes, with an emphasis on the research that addresses the self-selection of students into technical education[12]. First, we discuss literature on the effect of technical education on academic achievement and then we review the literature that examine other schooling outcomes such as dropout rates, high school attendance, probability of graduating from high school, and probability of progressing towards higher education levels. Finally, we present the findings of the literature on Brazil.

Causal estimates of the effect of technical education during high school on academic achievement, obtained using experimental or quasi-experimental methods, generally show no differences on test scores or grades. However, most of this work focuses on technical education in the US. Given the differences in technical education from country to country and in self-selection across technical education systems, these results may not be informative about the effect of technical education on academic learning in developing countries and, more specifically, in Brazil.

Regarding literature that uses methodologies to credibly address self-selection bias, Dougherty (2018) finds no effect on test scores for students admitted in Massachusetts's regional vocational and technical high schools using a Regression Discontinuity Design on the admissions exam score in oversubscribed schools[13]. In the case of Career and Technical Education (CTE) schools in the Philadelphia school district, results on GPA and achievement using the randomization of vacancies are inconsistent across cohorts and statistical tests, with Neild et al. (2015) not being able to reach a conclusion. Similarly, to Dougherty (2018), Kemple and Snipes (2000) find no effect on

[12] Literature on the effect of technical education during high school on labor market outcomes is significantly more extensive, although mostly descriptive, as it does not address the self-selection of students into vocational education (Kreisman and Stange, 2017; Bishop and Mane, 2004; Kang and Bishop, 1986; Gustman and Steinmeier, 1982, Neuman and Ziderman, 1991; Neuman and Ziderman, 2003, Moenjak and Worswick, 2003; Polidano and Tabasso, 2014). Causal estimates, obtained with methodologies that address the self-selection bias, show positive or no effect of technical education on wages and the probability of being employed (Kemple and Willner, 2008; Malamud and Pop-Eleches, 2010; Zilic (2018), Chen, 2009; Bucarey and Urzúa, 2013). Lastly, technical high school seems to have a positive effect on time employed, as shown descriptively by Gustman y Steinmeier (1982) and Kang and Bishop (1986) for the US, and for Chile by Bucarey and Urzúa (2013) using instrumental variables. Studies for Brazil report a positive effect of technical education on wages (e.g., Camargo, 2017; Camargo et al., 2018; Amoroso Neto et al., 2017; Silva et al., 2015; Almeida et al., 2015; Biondi Nastari, 2015; Fresneda, 2012 and Vasconcellos et al., 2010). Almeida et al. (2015), additionally find that large heterogeneity in the returns varying with the modality of technical education (concurrent or subsequent), with the institution where the student completed this level of education, with the professional sector of the vocational course, and with student characteristics.

[13] Although the provision of technical education in the US is very different from most countries in Latin America, Massachusetts's regional vocational and technical high schools is a special case and it is very similar to TIHS analyzed in this paper.

standardized math and reading achievement test scores for students who enrolled in Career Academies, a high school program with technical education components. This paper uses the randomization of vacancies in Career Academies to identify the effect of attending this type of high school.

Work that does not properly address the self-selection of students is likely to present negatively biased estimates of the effect of vocational education on academic achievement, as, in most countries, generally lower ability students self-select into vocational education (Ryan, 2001). Indeed, papers in this category report negative estimates for Chile (Larrañaga et al., 2013), China (Loyalka et al., 2015), Indonesia (Chen, 2009), and the USA (Plank, 2001). Most of this work attempts to correct the self-selection bias through the use of matching methods (Larrañaga et al., 2013; Loyalka et al., 2015) or instrumental variables (Larrañaga et al., 2013; Loyalka et al., 2015; Chen, 2009). However, given the fact that it is not possible to match on unobservable variables, such as ability or motivation, matching methods are likely to provide biased estimates. Similarly, in most cases instruments do not seem to satisfy the exclusion restriction. Availability of vocational tracks in the municipality, percentage enrolled in vocational education in the municipality and the proportion of vocational schools among all frequently mentioned schools could be correlated with area characteristics (such as industrialization or average education level of the population) that could have a direct effect on achievement through motivation, parents' support or other unobserved variables.

Relevant literature has additionally analyzed the effect of technical education on other educational outcomes, such as dropout rates, high school attendance, the probability of graduating from high school, and the probability of attending higher education.

Despite generally finding no effect on academic achievement, most relevant literature shows that technical education is successful at reducing dropouts. Experimental and quasi-experimental work reports that students enrolled in technical education have a lower dropout rate compared to the control group in the US (Kemple and Snipes, 2000) and in Sweden (Hall, 2012), and show an increase in male dropout when the general curriculum was extended in the technical track in Croatia (Zilic, 2018). Descriptive research or analyses using matching methods, which are likely to be biased towards more dropouts, show mixed effect of technical education on dropouts in the US (Plank, 2001; Agidini and Deke, 2004; Loyalka et al.; 2015; Pittman, 1991).

Regarding school attendance, Kemple and Snipes (2000) show that technical education increases school attendance in the US. Bishop and Mane (2004) reach the same conclusion using descriptive methods.

Kemple and Snipes (2000) also find a positive effect of technical education in the USA (Career Academies) on the probability of graduating from high school using the randomization of vacancies in these institutions. This finding is additionally supported by causal estimates from Dougherty (2018), Neild et al. (2015) and Cullen et al. (2005) in the US. Outside of the US, Propensity Score Matching results in Polidano and Tabasso (2014) for Australia also report a positive effect of vocational education on the probability of graduating from high school.

Finally, with respect to the probability of enrolling in higher education, Kreisman and Stange (2017) show descriptively that students who complete a higher proportion of upper level technical education courses during high school have a higher probability of enrolling in 2-year colleges than students who complete more core and elective courses during high school, but a lower probability of enrolling in 4-year colleges in the US. For Australia, Polidano and Tabasso (2014) find, using propensity score matching (PSM), that vocational high school increases the probability of studying at a higher-level post-high school VET course and reduces the probability of enrolling in higher education.

In Brazil, literature analyzing the differences between technical and academic education on academic outcomes is scarce and not conclusive. While Araújo et al. (2016) find that technical education students have better test scores on the National High School Exam (ENEM) than students in academic education, Camargo (2017) reports negative effects on school grades for male students more likely to enroll in the concurrent modality in private technical schools in Santa Catarina.

However, these results are not fully comparable because the two papers differ in four important dimensions. First, each paper focuses on different populations. Araújo et al. (2016) analyzes all students in Brazil while Camargo (2017) concentrates only on male students in Santa Catarina. Second, the outcome of interest is also different. Araújo et al. (2016) focuses on test scores on the university admission exam, while Camargo (2017) on school grades, which are lower stakes. Third, the two papers consider different types of technical education and providers. While Araújo et al. (2016) include two modalities, TIHS and concurrent, and both public and private institutions, Camargo (2017) only includes the concurrent modality offered in private technical education institutions. TIHS has more of an academic course load than academic high schools where students enroll in the concurrent modality, which could explain the positive effect in Araújo et al. (2016). Fourth, Araújo et al. (2016) use PSM, a methodology that cannot take into account matching on unobservable variables and, thus, could lead to biased estimates of the effect of technical education. Since students self-select into technical education, PSM estimates reported could be positively or negatively biased depending on the type of students that enroll in technical education. In contrast, Camargo (2017) uses the randomization of scholarships to enroll in technical education in the private system, which should address the self-selection bias.

Other educational outcomes addressed in the literature are the probability of graduating from high school, the probability of graduating from technical education in a private institution and the probability of enrolling in higher education. Camargo et al. (2018), using the same scholarship lottery in Santa Catarina as Camargo (2017), find that men scholarship recipients are more likely to graduate from academic high school than lottery losers. With respect to the probability of enrolling in tertiary education, Camargo (2017) and Camargo et al. (2018) find no effect of winning a scholarship and enrolling in a private technical institution on the probability of enrolling in tertiary education. Almeida et al. (2015), in contrast, find an increase in the probability of enrolling in tertiary education of 2.7% for technical high school students in TIHS and concurrent modalities in public and private technical education institutions in Brazil with respect to academic high school students. This positive effect could be explained by the inability to control for unobservable characteristics using Propensity Score Matching and by the fact that Almeida et al. (2015) include TIHS together with concurrent modality and public and private institutions.

4 Data

4.1 Data sources

We use three main data sources: a) school censuses for the State, Municipal, Federal, and Private school networks, which together allow us to observe the universe of students in Pernambuco in a given school year; b) test scores and socioeconomic information from a standardized test and c) the technical integrated high school (TIHS) applicant lists. With this information we built a panel dataset for Pernambuco from 2012 to 2017 in which we can follow three cohorts of students from 9^{th} grade to 3^{rd} grade of high school.

The school census is an annual national survey that provides information on students, teachers, and schools. It contains a unique student identifier (INEP ID), along with the student's full name, date of birth and, for a minority of students, Brazilian ID number (CPF). Using this information, we can follow the student over time and build the student's schooling trajectory. Moreover, since 2007, there is information on whether the student attends technical education and the corresponding technical modality. The school census also includes school and teacher characteristics, allowing us to better understand the educational environment the student was exposed to.

The second database used is the educational evaluation system of Pernambuco (*Sistema de Avaliação Educacional de Pernambuco*, SAEPE). SAEPE is a standardized exam that is applied in grades 5^{th} and 9^{th} of elementary school and in 3^{rd} grade of high school. It evaluates student achievement in Portuguese and Mathematics in all state and municipal schools in Pernambuco. In addition to taking the exam, students fill out a socioeconomic questionnaire, from which we obtain student demographic background information. Additionally, the SAEPE database includes the student's full name. We use SAEPE information for students in 9th grade in 2012, 2013 and 2014 and for students in 3rd grade of high school in 2015, 2016 and 2017.

Finally, we use the TIHS tracks applicant lists corresponding to the 2013, 2014 and 2015 admission processes.[14] As explained above, students are selected into technical integrated high school (TIHS) through a classificatory exam. The applicant lists data provides information on TIHS school and the track the student applied to, the number of vacancies per track and school, the candidate score on the admission exam and his rank within the TIHS track and her school of choice, whether the candidate was offered a seat in the TIHS track, and student's background information, which includes Brazilian ID number (CPF), student's full name, date of birth, gender and a variable equal to one if the student was enrolled in a public school in 9th grade and is eligible for a "quota" vacancy.[15]

The years of the three datasets allow us to observe students at three key points in time. We use school census and SAEPE information from 9th grade to determine whether the student was enrolled in a public or private school (and could benefit from the public school TIHS "quota") and to obtain student socioeconomic information and student baseline test scores. We then observe whether students apply to TIHS in the TIHS applicant lists and their actual enrollment in 1st grade of high school. We use the school census between 1st and 3rd grade of high school to identify whether the student repeats any grades or if the student drops out from the Pernambuco education system. [16] Finally, we observe student's SAEPE test scores in the 3rd year of high school.

To build the data for our analysis, we combine students' data in the school census with SAEPE's test scores and socioeconomic information, matching over 83% of students in the SAEPE database to the school census data. Then, we merge the resulting dataset with the lists of students applying to TIHS. We match over 73% of students in the TIHS applicant lists to the school census and SAEPE datasets.[17]

We exclude from our dataset students that were enrolled in private schools in 9th grade and students that apply to TIHS tracks and school combinations that are undersubscribed. In the first case, students in private schools in 9th grade do not have baseline socioeconomic and achievement information, since private schools do not take the state standardized test. This makes it impossible to include these students in regressions that check the balance of the characteristics of students across the TIHS/ school admission cutoff. Therefore, we exclude them from our main analysis. In the second case, students who apply to undersubscribed TIHS track/school combinations do not

[14] The year of the admission process corresponds to the year in which students enroll in the 1st grade of high school. Students take the TIHS admission exam while they are in 9th grade, in October of the previous year.
[15] As mentioned, 75% of seats in TIHS are reserved for students who were enrolled in public schools in 9th grade.
[16] Unfortunately, we cannot identify if a student drops out from the education system or moves to another state. In both cases, the student would disappear from the sample.
[17] For detailed information on the matching process, please, see Appendix B.

have an admission exam cutoff, as all students are accepted in the track/school combination. These students cannot be used in our analysis, given our empirical strategy.

We start with 435,285 students in the first grade of high school in years 2013, 2014 and 2015. Since technical education still only represents a small proportion of students in Pernambuco, there are only 36,484 students, less than 10%, in the TIHS applicant lists for 2013-2015. We match around 73% of these students to our other databases, totaling 26,673 students. 3,766 students in the applicant lists do not take the exam and do not have a score, these students are removed from our sample. From the remaining students, we exclude students enrolled in private schools in 9th grade, 7,491 students, and students in TIHS tracks and school combinations that are not oversubscribed, 147 students. Our final sample includes 15,269 students, as shown in Panel A of Table 4.

4.2 Descriptive Statistics

Table 4 shows descriptive statistics for the population in the first grade of high school (both in academic and technical high school) in 2013, 2014 and 2015, and for the sample we will use in our analysis. Column (1) presents descriptive statistics for the population and Column (2) for the subpopulation from Column (1) matched to the technical integrated high school (THIS) applicant lists excluding students in private schools in 9th grade, students without admission exam scores and students who apply to undersubscribed TIHS tracks and school combinations. Panel A shows student characteristics, Panel B enrollment choices and Panel C school characteristics.

Comparing Columns (2) to Column (1) we see that students who apply to TIHS are, generally, from a better socioeconomic background. They are slightly younger, more likely to attend school in Recife, the capital city of Pernambuco, have more educated mothers and are more likely to live on a paved street. Additionally, their Math and Portuguese test scores in 9th grade were, on average, higher than students who did not apply to TIHS. This is consistent with concern that the most-advantaged students self-selecting into technical education. A possible explanation as to why students who apply to TIHS have better socioeconomic characteristics on average than the population may be that THIS has longer school days. Students from more vulnerable backgrounds may have to work after school and, thus, not have the option to enroll in this type of school.

With regards to enrollment choices, Panel B shows that the population of students, in Column (1), enrolls, mostly, in academic regular high school, followed by *semi* full-time academic high school and full-time academic high school. Instead, students in the TIHS applicant lists, Column (2), enroll in technical schools, followed by academic regular high schools and then full-time academic high schools. The percentage of students in Column (2) in full-time academic high schools and *semi* full-time academic high schools combined is, however, larger than the percentage of students who attend academic regular high schools. Other technical education modalities, concurrent and subsequent modalities, enroll fewer students, the population and our subsample, as shown in Column (1) and (2), respectively.

Finally, as shown in Panel C, students that apply to TIHS are more likely to go to schools that have better schooling inputs. For example, these schools have a higher per pupil expenditure, a larger fraction of these schools have a laboratory, pay higher teacher salaries, have more experienced and better educated teachers, and less students per teacher on average.

One important concern for our analysis is that 12% of students who do not drop out of our sample do not have information on one of the outcomes of interest, SAEPE test score in 3rd grade of high school. There are three main reasons why this information may be missing: some schools do not participate in SAEPE;[18] the student did not attend school on the day the SAEPE standardized test took place, or the student was attending a private or federal school. These school networks are not included in Pernambuco's evaluation system. As presented in Table 5, most attrition in our sample is explained by students not taking the SAEPE test, except for students in the 2015 TIHS applicant lists, in which the most prevalent reason for attrition is that students were enrolled in private or federal schools.

Generally, students who attrit in our sample have worse socioeconomic characteristics. However, attrition in taking the standardized test is not biasing our results because the student characteristics around the cutoff for students who attrit are still balanced (see Tables 11 and 12 in Appendix A for details).

5 Empirical Strategy

In Pernambuco, students who want to enroll in a technical integrated high school (TIHS) must take an admission exam. The score on the admission exam determines whether the student can enroll in the technical program and school where she applied in two different ways. First, the student must score more than 0 points on both the Math and Portuguese sections of the exam.[19] Second, if the TIHS track and school combination in which the student wants to enroll is oversubscribed, seats are allocated according to student rank. This endogenously determines an admission exam score cutoff such that students with scores below the cutoff cannot enroll in the program.

Out of 160 school-year-technical tracks that we observe for the admission processes to TIHS in 2013, 2014 and 2015, 94% (151) have binding admission exam score cutoffs. That means, there

[18] Despite the effort to universalize SAEPE from 2013 to 2015 in Pernambuco, some small schools still do not participate.
[19] This criteria is binding, as 1,173 students in our sample do not pass the TIHS admission exam.

was at least one student who passed the admission exam but was not eligible to enroll in his program and school of choice because his admission exam score was lower than the score cutoff.[20]

We use the discontinuity in the eligibility to enroll in TIHS around the admission exam cutoff in a Regression Discontinuity Design (RDD) to analyze the effect of TIHS in Pernambuco on standardized test scores and other schooling outcomes.

Intuitively, if we assume that admission test scores change smoothly with student characteristics,[21] the discontinuous change in the probability of enrolling in TIHS caused by the score cutoff allows us to identify causal effects of this type of education. We can then use students in a small neighborhood below the cutoff as an adequate control group for students just above the score cutoff. Any difference in their educational outcomes at the end of TIHS can be attributed to the fact that they had different probabilities to access this type of education. This strategy allows us to address self-selection into TIHS, since students close to the admission test score cutoff, scoring above or below the cutoff, is almost random.

As shown in Figure 1, while a significant proportion of students who are eligible to enroll in TIHS (i.e., have admission exam scores above the cutoff) take this opportunity, not all of them do. Additionally, even though candidates below the cutoff are not allowed to enroll in the (oversubscribed) TIHS track/school combination of choice, there were students with scores below the cutoff who managed to enroll in a TIHS track.[22] Since the probability of enrolling in a TIHS program changes by less than 1 over the admission exam score cutoff, the RDD in this analysis is a fuzzy RDD. The RD analysis can identify the treatment effect in this type of design and the estimated results correspond to the average effect of "intent to treat", which means, the effect of having the opportunity to be treated.

[20] 41 of the binding admission exam score cutoffs occur in the 2013 admission process, 52 in 2014, and 58 in 2015.

[21] Table 12 in Appendix A shows that there are no significant differences in student socioeconomic characteristics with scores at either side of the cutoff. Students at either side of the cutoff are as likely to participate in the standardized exam that takes place in 9th grade, to be male and they are about the same age. However, for students who took the standardized test in 9th grade, we see that students above the cutoff are less likely to have mothers that completed high school (about 6 percentage points). In contrast, there are no significant differences in the probability that the student's mother attended university and that the student lives on a paved street. We interpret the fall in the probability that the student's mother completed high school as an indication that students above the cutoff may be from a slightly lower socioeconomic background than students below the cutoff. Any bias caused by this difference would reduce our estimates, as test scores are highly correlated with socioeconomic status (Mizala, Romaguera and Urquiola, 2007). In this case, our estimates can be interpreted as a lower bound for the effect of TIHS. With respect to differences in student performance, there are no differences in 9th grade standardized test scores for Math and Portuguese across the cutoff. Finally, regarding changes in density around the cutoff, manipulation of scores in this case is not a risk since the cutoff is unknown ex-ante, given that it depends on the number of vacancies and applicants. Nevertheless, Table 14 in Appendix A shows that the density of students is similar on both sides of the cutoff.

[22] About 7% of students below the admission exam cutoff enrolled in TIHS. Unfortunately, we cannot observe in our data whether these candidates enrolled in the school/track combination they had applied to or in a different TIHS track/school combination. Anecdotal evidence suggests that these students may enroll in undersubscribed TIHS tracks in their initial school of choice.

Therefore, we estimate the effect of having the opportunity to enroll in a TIHS on educational outcomes using the following regression:

$$y_{ispt} = \alpha + \beta\mathbf{1}\{s_{it} - \overline{s_{spt}} \geq 0\} + f(s_{it} - \overline{s_{spt}}) + \theta_s + \gamma_p + \rho_t + \varepsilon_{it} \quad (1)$$

where y_{ispt} is the educational outcome of interest for student i applying to the technical track p in school s and in year t, $\mathbf{1}\{s_{it} - \overline{s_{spt}} \geq 0\}$ is an indicator equal to one if student i has an admission test score higher or equal to the admission score cutoff ($\overline{s_{spt}}$) of the TIHS track and school he applied to in year t, β is the parameter of interest capturing the effect of having the *opportunity* to enroll in TIHS, $f(s_{it} - \overline{s_{spt}})$ is a flexible parametric specification that includes higher-order polynomials of the difference between admission exam score and score cutoff and can vary on either side of the enrollment cutoff and θ_s, γ_p and ρ_t are application school, application TIHS track and year fixed effect, respectively. In order to maximize statistical power, we pool data across TIHS tracks (p) schools (s) and application years (t) and use distance of student admission exam score to the relevant test score cutoff ($s_{it} - \overline{s_{spt}}$), as in Pop-Eleches and Urquiola (2013).

Our main specification uses bandwidth 3, which is roughly twice the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) – henceforth, IK.[23] The IK bandwidth is very narrow in this case. Additionally, we include a linear spline on admission exam score distance to cutoff interacted with a dummy indicating whether the student falls to the left or the right of the cutoff. Results using the IK bandwidth are also reported for all outcomes in our main tables.

6 Results

This section presents results that pool the cutoffs for all different school/TIHS track combinations and years. First, it shows how enrollment decisions change for students who obtain scores on the TIHS admission exam above the cutoff. It then turns to analyzing the impact of having an admission exam score above the cutoff on academic and schooling outcomes. Finally, we explore the potential mechanisms behind the effect on academic outcomes taking advantage of the existence of a set of high schools with similar school indicators and the same school day length than TIHS.

6.1 Changes in Enrollment Decisions

The probability of enrolling in technical integrated high school (TIHS) changes with admission exam score and jumps discontinuously at the admission score cutoff. Specifically, it increases by about 40 percentage points for students with admission scores above the cutoff. This is shown in

[23] Since our running variable is discrete, we cannot use the method described in Calonico et al. (2015).

Figure 1 where each dot shows the proportion of students who enroll in TIHS by distance of the admission exam score to the cutoff.

To explore in more detail how the admission score affects the first year of high school enrollment choices, Table 6 reports the results from the regression discontinuity analysis for the probability of enrolling in TIHS and in every available high school type offered in Pernambuco. Consistent with Figure 1, the probability of enrolling in TIHS (Columns (1) and (2)) increases by about 40 percentage points for students above the admission exam score cutoff.[24] Students at the cutoff also have a higher probability of enrolling in TIHS than students strictly below the cutoff. In some cases, a few students who score at the cutoff will be admitted into the technical track they applied to, while other students at the cutoff for the same TIHS track/school combination will not be admitted. This makes our first stage fuzzier, since it increases the proportion of treated students in the control group and may bias downward our estimates. To get a magnitude of the bias, we repeat the analysis excluding students at the cutoff in the Robustness section. As expected, results are consistent and higher in magnitude.

Columns (3) – (12) present the change in the probability of enrolling in other school types for students above the cutoff. These results allow us to analyze what are the alternative schools where students accepted to TIHS would have enrolled if had they obtained scores below the cutoff.[25] As expected, the probability of enrolling in all non-TIHS high school types falls for students above the cutoff. These results show that the preferred alternative to TIHS is regular academic schools, with a fall in the probability of enrolling in this school type of between 16 and 18 percentage points (Columns (7) and (8)). However, the fall in the probability of enrolling in *semi* full-time and full-time academic schools combined is even larger than the fall in the probability of enrolling in regular academic schools (Columns (3) to (6)). Together, the probability of enrolling in *semi* full-time and full-time academic schools falls by 24 to 30 percentage points for students above the cutoff, more than 50% the increase in the probability of enrolling in TIHS. This shows that over 50% of students above the cutoff would have enrolled in the extended school day schools had they scored below the cutoff. Finally, the probability of enrolling in academic private school and in federal technical schools decreases about 2 percentage points (Columns (9) to 12)).

[24] Since our running variable is discrete, the optimal IK bandwidth of 1.55 only includes one admission exam score bin at either side of the cutoff. Such a narrow bandwidth does not allow us to include a flexible linear spline that could control for possible trends in the outcome. Therefore, Column (2) uses bandwidth 3, which is effectively double the IK bandwidth in this case, and a flexible linear spline on the distance of the admission exam score to the cutoff. Column (2) is our preferred specification and reports a slightly lower first stage (from 0.48 to 0.40).

[25] Besides State technical schools, there are two other school types that offer technical integrated high school (TIHS) in Pernambuco: schools in the federal network and a handful of full-time academic schools that offer technical modules during high school. Nevertheless, almost 70% of students in TIHS are enrolled in this State technical schools. This percentage increases to 96% if we consider students in TIHS who took the TIHS admission exam.

6.2 Impact on Academic Outcomes

The estimates of the effect of having the opportunity to attend a TIHS on academic outcomes are summarized in Table 7 and Figure 2. We explore four academic outcomes: the probability of repeating at least one grade during high school (Columns (1) - (2) of Table 7 and Panel A in Figure 2); the probability of dropping out (Columns (3) - (4) and Panel B) and Math and Portuguese SAEPE standardized test scores in the 3rd grade of high school (Columns (5) - (6) and Panel C, and Columns (7) - (8) and Panel D, respectively).

Our estimates suggest that students who have access to TIHS are, on average, around 3 percentage points less likely to repeat at least one grade during high school. The point estimates are high considering that the repetition rate in the control group is around 6.5%. Unfortunately, the result is not robust to different specifications, in particular it is not statistically significant using alternative bandwidths (see Column (4) in Table 19).

Regarding the probability of dropping out, we find that students just above the TIHS admission cutoff are, on average, 6 percentage points less likely to dropout during high school.[26] This result is consistent with the literature (Kemple and Snipes, 2000; Hall, 2012) and implies that having the opportunity to enroll in a TIHS results in a large decrease in the probability of dropping out, which is 12% on average for the control group.

With regards to learning, Columns (5) to (8) of Table 7 and Panels C and D of Figure 2 show that Math and Portuguese SAEPE standardized test scores are significantly higher for students above the cutoff, who are more likely to enroll in TIHS. For both Math and Portuguese, the increase in test scores is 0.12 standard deviations using the preferred specification and over 0.20 standard deviations when we use the IK bandwidth. The IK bandwidth is very narrow, given that our running variable is discrete, this bandwidth effectively includes only one bin of admission exam score at either side of the cutoff. Therefore, we cannot control for trends in test scores in this specification (Columns (5) and (7)). The magnitude of the effect on Math and Portuguese test scores is cut in half in our preferred specification that uses a wider bandwidth (3, roughly twice the IK bandwidth) and fits a linear spline that can change at either side of the cutoff, as shown in Columns (6) and (8). We believe that the results in these last specifications are more reliable, as Panels C and D in Figure 2 suggest that there is some linear trend in Math and Portuguese test scores with admission exam scores.

[26] As discussed in section 4, we cannot differentiate whether a student drops out of the education system or moves out of the state, as in both cases students would disappear from the state administrative records.

Overall the estimates show that students who enrolled in TIHS obtained test scores in 3rd grade of high school about 30% to 40% higher than if they had enrolled in other high school types. These effects are large and significant.[27]

These results report "intent to treat" effects (ITT), which means that they show the effect of having the *opportunity* to enroll in TIHS. The effect of TIHS on students that do enroll in this type of high school, "average treatment on the treated" or ATT, can be easily obtained dividing our ITT estimates by our first stage coefficient, the increase in the probability of enrolling in TIHS for students above the cutoff. Since our first stage coefficient is 0.4, our ATT effect would be roughly equal to our ITT estimates divided by 0.40, which is equivalent to multiplying our ITT results by 2.5.

The results on student outcomes suggest that, in Pernambuco, TIHS is effective in improving student's academic proficiency and reducing dropouts at the high school level. Importantly, since TIHS reduces the probability of dropping out for students at the margin of making this decision, the magnitude of the effect in tests scores could represent a lower bound of the actual effect. Students who drop out are usually from a lower socioeconomic background (see Table 15 in Appendix A), which has been shown to be correlated with academic achievement (Mizala, Romaguera and Urquiola, 2007). Thus, since dropout is larger for students below the cutoff, there is a higher selection of the "best" students below the cutoff than above. This unbalanced attrition could bias downwards our achievement estimates.

6.3 Potential Mechanisms

Our estimates show that students that have the opportunity to enroll in TIHS have a lower probability of dropping out from high school and higher test scores in the last year of high school. There are many reasons why TIHS could have an impact on those indicators. As shown in Panel C of Table 4, TIHS have, on average, better schooling inputs. They tend to have better infrastructure and may be able to attract the best teachers. Additionally, since admission to this type of high schools is competitive, it is possible that peers have better characteristics. Secondly, it has been shown in the literature that a longer school day can have a positive effect on achievement (Hincapie, 2016; Bellei, 2009). TIHS has a higher course load than regular high school (see Table 1) and even more hours in Math and Portuguese instruction. Finally, technical content can increase student motivation and engagement (e.g., Shernoff et al., 2003; Carbonaro, 2005), which may have an effect on student outcomes.

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[27] A systematic review of the evidence on programs that improve learning in secondary school identified four program types with strong evidence of effectiveness: providing monetary incentives for students, the "no excuses" model, extended school day and vouchers/subsidies/scholarships. The first two have the largest average effect on student learning 0.16 and 0.14 standard deviations, respectively; while the last two have 0.08 and 0.03. See Busso et al. (2017) for more details.

This section analyzes how different TIHS are from schools where students below the cutoff enroll in and takes advantage of the existence of full-time academic high schools. This academic high school type has similar school inputs as THIS, the same course load and school day length, and even the same Math and Portuguese course load, making it a good comparison school to investigate the effect of technical content.

Table 8 compares the average characteristics of schools where students above the cutoff enrolled in to schools where students below the cutoff enrolled in. Results show that students above the cutoff attend schools that spend more per student, are more likely to have a laboratory and are more likely to have Math teachers who graduated in exact science and from prestigious Federal universities. Additionally, these schools have more experienced and better paid teachers. Finally, students above the cutoff are exposed to better peers, as shown in columns (15)-(18). At baseline, using SAEPE 9th grade information for the incoming class in the first grade of high school in 2014, schools where students above the admission exam cutoff enrolled had a higher proportion of students with mothers who attended university and had higher average Math scores on SAEPE.

These regressions show that students above the cutoff enrolled in schools that had different infrastructure, teacher and peer characteristics than students below the cutoff. Since schools were different in many dimensions, we cannot conclude from these results what was the driver behind the reported outcomes. Additionally, these differences, along with technical education and longer school days may explain why our estimates of the effect of TIHS are so large.

For this reason, we conduct an additional analysis. We repeat our main outcome regressions keeping only students who enroll in TIHS and in full-time academic schools.[28] This high school type is the most comparable to TIHS, since they also have an extended school day, have the same amount of Portuguese and Math hours (see Table 2 in Appendix A), and generally similar school characteristics, being a higher quality alternative to regular academic high schools.[29] However,

[28] Within the group of students in full-time and *semi* full-time schools, students who take the TIHS admission exam and, consequently, are included in our sample, tend to have better socioeconomic and go to school with slightly better characteristics than the population of students in these school types, although not significantly. Therefore, in this analysis we compare the "best" students from the control group to the "worst" students in the treatment group. This is not a threat to our identification strategy but may bias downwards our results.

[29] Table 17 in Appendix A shows that when we include only students in TIHS and in full-time academic schools in regressions that compare school characteristics, students above the cutoff go to schools with similar teacher characteristics and teacher wages. Teacher wages are a function of underlying teacher characteristics such as teacher experience and teacher education, among other factors. However, we find differences in other schooling inputs, such as per-pupil expenditure, the probability of having a laboratory and peer characteristics. Our results suggest that students below the cutoff (more likely to attend full-time academic high school) go to schools with higher expenditure. With regard to the probability that the school has a laboratory, we find that students above the cutoff are more likely to go to schools that have a laboratory, which is consistent with the fact that technical schools must have a laboratory given the nature of its education program. Also, students above the cutoff are exposed to less experienced teachers. Finally, we find that students above the cutoff are exposed to peers with better baseline scores, which is consistent with the fact that students above the cutoff enroll in TIHS rather than full-time academic high school. Literature on peer effects generally shows no or small effects on achievement of having more able peers (e.g., Abdulkadiroglu et al., 2014; Rao, forthcoming; Zárate, 2019). Therefore, we expect the contribution of being exposed to better peers on test scores and dropouts to be small. For these reasons,

full-time academic high schools do not teach technical education, focusing on purely academic content. Table 9 shows that when we compare TIHS to full-time academic high school the only significant academic effect of being above the TIHS admission exam cutoff is a reduction in dropouts. In this case, there are no significant differences in achievement for students above the cutoff.

These results suggest that the drivers behind the increase in student achievement for students above the TIHS admission exam cutoff when all schools were included were the extension of the school day together with the fact that students in TIHS were exposed to better schooling inputs. At this point we cannot disentangle these mechanisms, but our results suggest that technical content does not explain the increase in achievement.

However, Columns (3) and (4) of Table 9 show that students above the cutoff of the TIHS admission exam, who are more likely to attend TIHS instead of full-time academic high school, are less likely to drop out. Since the largest difference between the two school types is the instructional content, this result suggests that teaching technical content in high school may reduce student dropout rates.[30]

Additionally, the decrease in dropouts for students above the cutoff suggests that our achievement estimates are likely to be downward biased. Dropout is higher for students below the cutoff. Since students from a lower socioeconomic background are more likely to dropout (as reported in Table 15 of Appendix A), students below the cutoff are being selected and only the "best" remain, while students above the cutoff include students who may have potentially dropped out below the cutoff. This can create an unbalance in the characteristics of students at either side of the cutoff and negatively bias our estimates of the effect on achievement.[31]

These results are consistent with estimates of the impact of technical education during high school in the US and internationally. Our results suggest that, compared to academic full-time high schools, technical integrated high school had no effect on achievement, consistent with results in Kemple and Snipes (2000), Dougherty (2018) and Neild et al. (2015). However, technical

despite some significant differences in schooling inputs when we compare TIHS to full-time academic high schools, we expect the largest contribution to the school effect to be explained by the technical content.

[30] As explained above, we find differences in other school characteristics that could bias downwards our estimates. Additionally, we find that peer characteristics for students above the cutoff are better, suggesting that this could be an alternative mechanism behind the decrease in dropouts. Since the literature generally finds small or no effect of peer characteristics on achievement (e.g., Abdulkadiroglu et al., 2014; Rao, forthcoming; Zárate, 2019), we believe that the contribution of this mechanism, if existent, should be small.

[31] Additionally, in a separate analysis not reported in this paper, we find that students above the cutoff (and more likely to attend TIHS) are less likely to have mothers with high school education. This suggests that students above the cutoff may be already from a lower socioeconomic background, which could have a negative bias on the estimate of the effect on schooling outcomes. These results are available upon request.

education during high school seems to significantly reduce student drop out, consistent with results in the US (Kemple and Snipes, 2000).

Since including technical content during high school, as in the TIHS, instead of academic-related content, as in the full-time academic high schools, did not negatively affect achievement, this suggests that teaching technical education does not necessarily hinder student learning, as some have asserted (Dougherty, 2018; Kemple and Snipes, 2000). In fact, technical content could provide students with useful abilities for the labor market while not impacting learning in core subjects such as Math and Portuguese. Additionally, since technical education has a negative effect on student dropout rates, including technical content during high school could be effective to retain disadvantaged students in school.

7 Robustness

This section assesses the robustness of our results to the inclusion of students in private schools in 9th grade, to alternative bandwidths and to excluding students at the cutoff. Finally, we carry out a falsification test in which we move our cutoff two points to the left of the actual cutoff.

First, we replicate our main analysis including students who were enrolled in private schools in 9th grade. These students were not included in our sample because we do not have information to test the balance in student characteristics in the baseline period. Private schools do not participate in the State standardized exam (SAEPE) from which we obtain student socioeconomic information, making it impossible to obtain student characteristics in 9th grade.[32] Table 18 shows that results are consistent when students in private schools in 9th grade are included. Both, the magnitude and the significance of the results remain similar for most outcomes except Math and Portuguese test scores, for which both are smaller. Nevertheless, despite the decline in significance and magnitude, these results show that the effect of TIHS on schooling outcomes are positive, even when students who were previously in private schools are included.

Next, we evaluate the consistency of our results when we use alternative bandwidths and specifications. Table 18 presents the estimation results for the first stage and for our main outcomes when we use double the bandwidth computed using the procedure in Imbens and Kalyanaraman (2012), which is in most cases our preferred bandwidth, 3, but without a flexible linear spline (Columns (1), (3), (5), (7) and (9)) when we use a narrower bandwidth, 2, but include a flexible

[32] An alternative is to use socioeconomic information collected on the standardized test that takes place in the 3rd grade of high school. However, a significant number of students drop out during high school, which affects the sample composition. Additionally, students enrolled in private schools that obtain admission exam scores below the cutoff are likely to enroll in private high schools, which do not take the standardized test in the 3rd grade of high school. This selection through dropouts caused by the use of 3rd grade of high school information together with the fact that we may not observe socioeconomic information for students who were in private schools in 9th grade and are below the cutoff, could bias the results of our analysis of balance of student characteristics.

linear spline (Columns (2), (4), (6), (8) and (10)). All of the results are consistent with those in our main specifications, with the estimate of the effect on repetition not being significant when we use bandwidth 2 and a flexible linear spline. Unfortunately, given the width of the bandwidth, it is not possible to fit a flexible quadratic spline, as the bandwidth only includes a few bins of admission exam score. However, we believe that it is not necessary to use a flexible quadratic spline since, as illustrated in Figure 1 and Figure 2 we can observe that the data seems to follow a linear trend.

Table 20 shows the first stage and the relevant outcomes when we exclude students with admission exam scores at the cutoff. As explained above, in many cases some students at the cutoff are accepted to the TIHS track/school combination they applied to while some other students at the cutoff are not. This translates into a relatively high proportion of students at the cutoff enrolled in the relevant TIHS track/school combination compared to students right below the cutoff. The enrollment of students classified as "control" in TIHS contaminates our control group, as it increases the proportion of students in the control group (below the cutoff) that are actually treated and can underestimate the effect of TIHS on student outcomes.

Consistent with this interpretation, when students at the admission exam cutoff are omitted from the analysis, the estimates of the first stage and the effect on student outcomes increase in magnitude. The probability of enrolling in TIHS for students above the cutoff increases by about 60 percentage points, while the increase was about 40 when students at the cutoff were included. The impact on repetition is significant in both specifications in this case and about twice as large, but there are no changes neither in magnitude nor in significance in the estimated effect on dropout. Finally, the estimate of the effect on test scores almost doubles. These larger results when students at the cutoff are excluded suggest that our main estimates are downward biased and, indeed, a lower bound.

Table 21 presents the results of our preferred specification when we use a cutoff two points to the left of the actual TIHS admission exam cutoff. This is a placebo test to check whether the discontinuities we observe at the admission exam cutoff are caused by the discontinuity in the probability to enroll in TIHS.

Results show that when we use an alternative cutoff there are no significant effects on any of the schooling outcomes, with the estimates for some outcomes being of opposite sign than the estimates in the regressions with the actual admission exam cutoff. The estimate of the discontinuity is, however, significant for the probability to enroll in TIHS. This estimate has the opposite sign than our actual estimate (students above the cutoff should be more likely to enroll in this type of high school) and is much smaller in magnitude. Therefore, these results suggest that the discontinuities we observe at the TIHS admission exam cutoff are not replicated when the cutoff is moved two points to the left.

8 Conclusion

Despite the renewed interest in technical education and its relevance for policy, the evidence on the impact of this type of education on academic outcomes is still limited. Since students self-select into technical education, identifying causal effects of technical education during high school poses a methodological challenge. Very few papers have credibly identified the effect of technical education and, in most cases, these papers have been centered on developed country experiences (e.g., Kemple and Snipes, 2000; Dougherty, 2018; Neild et al., 2015; Hall, 2012; Zilic, 2018).

Our study addresses this challenge by exploiting oversubscription in the process of application to technical education and presents compelling evidence on the effectiveness of technical education in Pernambuco to improve academic outcomes. Overall, we find positive effects with relevant magnitudes on the probability of dropping out from high school and academic achievement (Math and Portuguese). Further analysis suggests that students above the TIHS admission cutoff attend schools with longer school days, better infrastructure and better teacher and peer characteristics.

In addition, we exploit the structure of the educational system in Pernambuco to further explore the mechanisms behind the results on academic achievement and dropout rates. More specifically, we use the fact that students in full-time academic high schools receive the same number of hours of instruction as students in TIHS, but in contrast to these schools, the courses are purely academic. Full-time academic high schools are also similar to TIHS in other dimensions, such as teacher characteristics. Comparing only these two types of high schools, we find no differences in test scores but a significant effect in dropout rates. This evidence suggests that the estimated impact of having the opportunity to enroll in TIHS in achievement may be driven by the extended school day along with better school, teacher and peer characteristics of TIHS compared to general academic high schools while the nature of the instructional content seems to be effective in reducing dropout rates during high school.

In this context, the time spent on non-academic courses, does not seem to be affecting academic performance. On the contrary, it appears that spending more time in school may have a beneficial impact on academic achievement that does not depend on the specific content of instruction. Furthermore, technical education offered in TIHS provides an additional benefit to students by reducing the probability of dropping out. Our results are consistent with the literature on the effects of technical education during high school in developed countries (e.g., Kemple and Snipes, 2000; Dougherty, 2018; Neild et al., 2015) and confirm the possible role of technical education as a mechanism to keep disengaged youth in the formal education system.

Finally, our results suggest that students in Pernambuco will benefit from a further increase in the coverage of technical education. Our empirical strategy identifies effects for students at the bottom of the ability distribution within the technical education student population. Since an expansion of technical education would allow lower ability students to access this type of education, we believe that our estimates are a good indication of the effects of technical education on these potential new students.

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Tables and Figures

Table 1: Secondary Education Course loads, Total Hours by Modality in Pernambuco.

Modality of upper secondary academic and technical education	**Starting in**	**Accumulated Academic course load (1st to 3rd year)**	**Technical course load (hours)**	**Total hours**
Academic regular	1st year of high school	3,000	–	3,000
Academic *semi* full-time	1st year of high school	4,200	–	4,200
Academic full-time	1st year of high school	5,400	–	5,400
Technical integrated (TIHS)	1st year of high school	4,200	1,200	5,400
Technical concurrent	2nd or 3rd year of high school	–	800-1,200	
Technical subsequent	After high school	–	800-1,200	

Source: Diário Oficial do Estado de Pernambuco – Poder Executivo, 2012 and 2018.
Notes: This table presents the number of hours of academic and technical education that students must complete by the end of the 3rd year in each of the technical education modalities and in academic high school. The academic course load of technical subsequent corresponds to a regular school for the sake of illustration. Students who attended academic full-time school may also attend technical subsequent.

Table 2: Portuguese and mathematics course loads by upper secondary high school modality in Pernambuco.

Modality of upper secondary education	**Accumulated Academic course load in Portuguese (1st to 3rd year)**	**Accumulated Academic course load in Mathematics (1st to 3rd year)**
Academic regular	560	560
Academic *semi* full-time	720	720
Academic full-time	720	720
Technical Integrated (TIHS)	720	720

Source: Diário Oficial do Estado de Pernambuco – Poder Executivo, 2012 and 2018.

Table 3: Enrollment in academic high school, technical integrated high school (1st, 2nd and 3rd year) and technical modalities by school network in Pernambuco (2016).

	Federal	%	State	%	Private	%	Total	%
Academic	4,607	1.30%	302,926	87.20%	39,856	11.50%	347,389	100%
Technical integrated high school (TIHS)	**5,536**	**32.80%**	**11,364**	**67.20%**	**0**	**0.00%**	**16,900**	**100%**
Technical concurrent	317	4.70%	2,430	36.20%	3,960	59.00%	6,707	100%
Technical subsequent	8,966	14.70%	17,124	28.20%	34,714	57.10%	60,804	100%
Total	19,426	4.50%	333,844	77.30%	78,530	18.20%	431,800	100%

Source: School census (2016).
Notes: The table above shows the number of students enrolled in each modality of technical education and in academic high school by school network in 2016.

Table 4: Summary statistics of the population and the sample included in this analysis in 1st grade of high school in 2013-2015.

	Population	All TIHS matched applicants	Sample included in the analysis
	(1)	(2)	(3)
Panel A: Student characteristics			
Number of observations	435,285	26,673	15,269
Male (%)	46.0%	45.8%	45.4%
	[0.498]	[0.498]	[0.498]
Average age	12.92	12.82	12.78
	[20.698]	[2.236]	[2.207]
Attending school in Recife (capital city, %)	13.7%	22.0%	20.8%
	[0.344]	[0.414]	[0.406]
Mother completed high school (%)	31.7%	48.8%	49.4%
	[0.465]	[0.5]	[0.5]
Mother attended university (%)	9.6%	14.0%	14.1%
	[0.295]	[0.347]	[0.348]
Student lives in a paved street (%)	54.1%	63.4%	63.6%
	[0.498]	[0.482]	[0.481]
Average normalized Math test score in 9th	0.020	0.454	0.491
	[0.992]	[1.008]	[1.008]

	Population	All TIHS matched applicants	Sample included in the analysis
	(1)	(2)	(3)
Average normalized Portuguese test score in 9th	0.024 [0.986]	0.512 [0.976]	0.533 [0.974]
Panel B: Enrollment			
Attends a technical integrated high school (TIHS, %)	2.4% [0.153]	33.4% [0.471]	44.5% [0.497]
Attends academic regular high school (%)	50.1% [0.5]	21.5% [0.411]	22.9% [0.42]
Attends *semi* full-time academic high school (%)	21.2% [0.409]	14.6% [0.350]	14.4% [0.348]
Attends full-time academic high school (%)	17.5% [0.380]	14.6% [0.353]	16.0% [0.366]
Attends private high school (%)	10.6% [0.308]	14.6% [0.353]	3.4% [0.181]
Attends federal high school (%)	1.3% [0.113]	1.6% [0.124]	1.3% [0.115]
Attends technical concurrent (%)	1.6% [0.124]	3.7% [0.190]	2.3% [0.149]
Attends technical subsequent (%)	2.8% [0.164]	6% [0.237]	5.9% [0.235]
Panel C: School characteristics			
Total enrollment in school	888.7 [447.672]	809.2 [761.705]	790.7 [744.474]
Annual per pupil spending (R$)	3137.33 [1610.57]	4147.67 [1571.27]	4053.66 [1848.94]
Hourly teachers' salary in school	14.68 [3.915]	18.4 4.409	18.51 [4.477]
School has a laboratory (%)	48.0% [0.5]	69.9% [0.459]	70.8% [0.455]
Teacher has more than 5 years of experience (%)	83% [0.183]	82% [0.337]	84% [0.199]
Teacher is graduated in a Federal university (%)	12% [0.13]	20% [0.14]	20% [0.14]
Average students per teacher in school	28.22 [6.558]	25.16 [9.777]	24.55 [9.672]

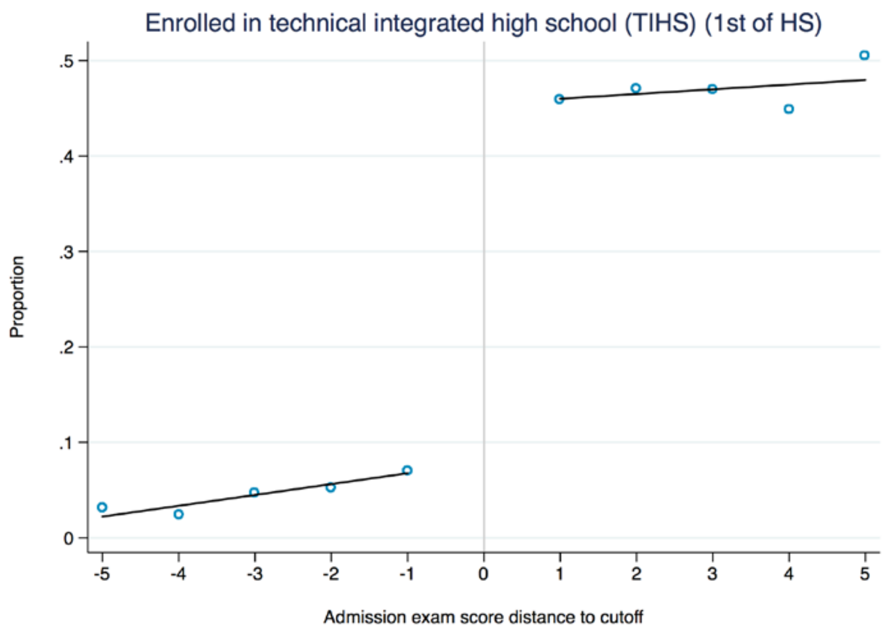
Notes: Column (1) shows summary statistics for all students in the population and Column (2) shows summary statistics for students in Column (1) who were matched to the technical integrated high school (TIHS) applicant lists (using official identification number (CPF), date of birth and name) and excluding students who were in private school in 9th grade and students who applied to technical courses and schools that were not oversubscribed. Test scores are normalized within year and grade and have mean zero and standard deviation 1. Standard deviations are presented in brackets. Federal Universities are public and considered the best universities in Brazil. To attend a course in a Federal University, the candidate must take an exam through a very competitive selection process.

Table 5: Student attrition from our sample by type of attrition and by applicant list year.

	2013 applicant lists (1)	2014 applicant lists (2)	2015 applicant lists (3)	All applicant lists (4)
Total students	4,308	5,769	5,192	15,269
Total attrition from 3rd to standardized test in 3rd grade of high school	**19.1%**	**12.8%**	**5.5%**	**12.1%**
School did not participate in standardized test in 3rd grade of high school	1.6%	0.6%	0.8%	0.9%
Student was in a private or federal school and did not take standardized test in 3rd grade of high school	4.0%	3.2%	3.3%	3.5%
Student did not take standardized test in 3rd grade of high school	13.5%	9.0%	1.5%	7.7%

Notes: This table reports the percentage of students in our sample by year in the applicant lists that attrit from the sample through not taking the standardized exam in 3rd grade of high school. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff.

Figure 1: Change in the probability of enrolling in a technical integrated high school (TIHS) in state schools for students above the admission exam score cutoff



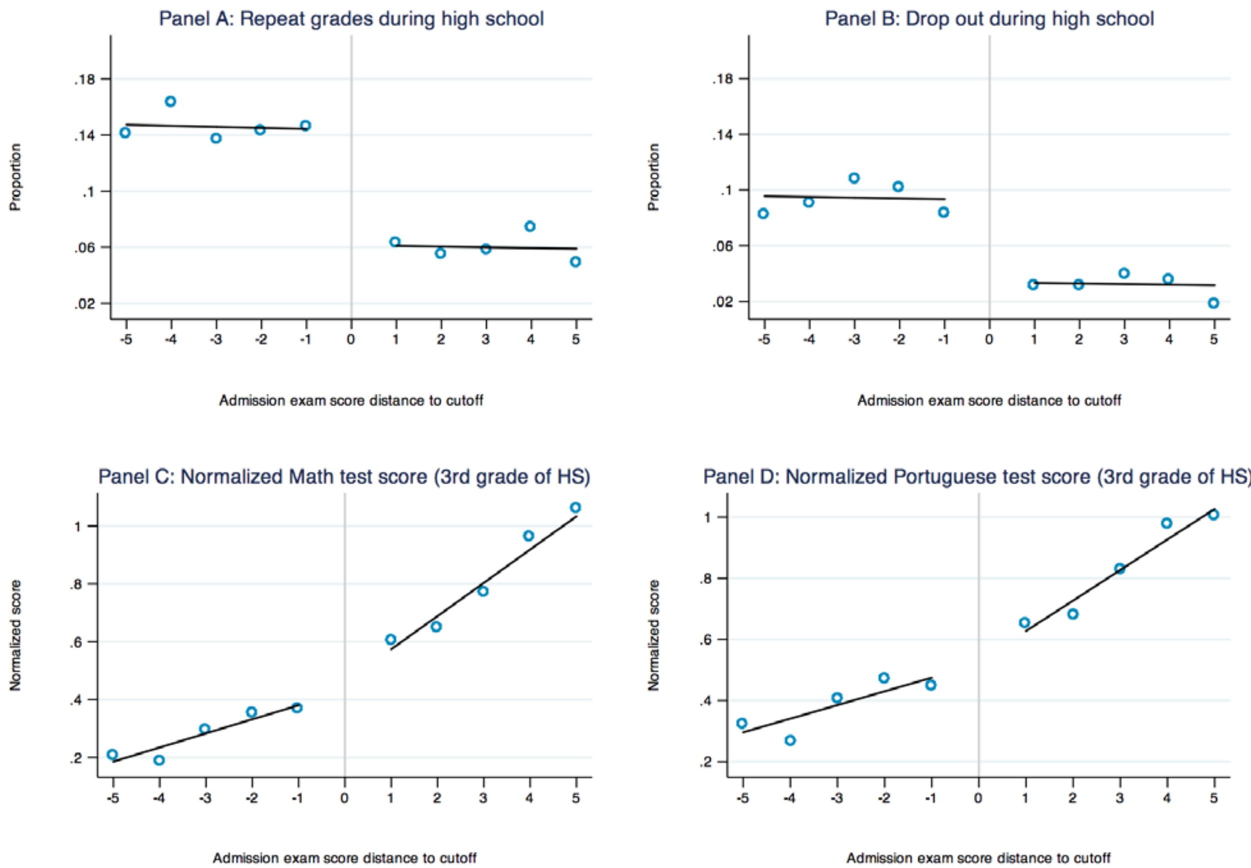
Notes: The graph above shows the proportion of students within each bin of admission exam score distance to cutoff that were enrolled in technical integrated high school (TIHS) in state schools in 1st grade of high school. Admission exam cutoff is computed as the score of the first student who was not eligible to enroll in the program even though he/she had passed the admission exam. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff. Additionally, the graph above excludes students at the cutoff, since some of these students are administratively classified as above the cutoff.

Table 6: Changes in the probability of enrolling in 1st year of high school in technical integrated high school (TIHS) and in each type of high school for students above the admission exam score cutoff.

	Enrolled in technical integrated high school (TIHS)		Enrolled in full-time academic school		Enrolled in *semi* full-time academic school		Enrolled in academic regular school		Enrolled in academic private school		Enrolled in federal school	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Above the cutoff	0.4759***	0.4047***	-0.1466***	-0.1166***	-0.1539***	-0.1233***	-0.1862***	-0.1606***	-0.0214***	-0.0249***	-0.0050	-0.0157***
	(0.0147)	(0.0216)	(0.0113)	(0.0149)	(0.0101)	(0.0134)	(0.0125)	(0.0175)	(0.0049)	(0.0072)	(0.0035)	(0.0055)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	4,119	8,119	3,465	6,789	4,119	8,119	4,119	8,119	4,119	8,119	4,119	8,119
R-squared	0.2441	0.3969	0.1022	0.1108	0.1095	0.1173	0.0788	0.1132	0.0285	0.0247	0.0335	0.0310
Adjusted R-squared	0.2380	0.3943	0.0935	0.1061	0.1023	0.1135	0.0714	0.1094	0.0206	0.0205	0.0257	0.0268
Control mean in bandwidth	0.2874	0.1980	0.2185	0.2436	0.2057	0.2324	0.3008	0.3406	0.0396	0.0460	0.0166	0.0163
IK Bandwidth	1.5473	3	1.6670	3	1.5049	3	1.5625	3	1.2787	3	1.1678	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff.

Figure 2: Change in academic outcomes for students above the admission exam score cutoff



Notes: The graph above shows the proportion of students within each bin of admission exam score distance to cutoff that repeat at least a grade during high school (Panel A), that drop out (Panel B) and average normalized Math (Panel C) and Portuguese (Panel D) test scores in a standardized test that takes place in 3rd grade of high school. Admission exam cutoff is computed as the score of the first student who was not eligible to enroll in the program even though he/she had passed the admission exam. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff. Additionally, the graph above excludes students at the cutoff, since some of these students are administratively classified as above the cutoff.

Table 7: Changes in outcomes for students above the admission exam score cutoff.

	Probability of repeating		Probability of dropping out		Normalized Math 3rd grade of HS test score		Normalized Portuguese 3rd grade of HS test score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Above the cutoff	-0.0340***	-0.0312***	-0.0652***	-0.0609***	0.2462***	0.1194**	0.2334***	0.1194**
	(0.0073)	(0.0106)	(0.0083)	(0.0116)	(0.0376)	(0.0556)	(0.0349)	(0.0514)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	3,342	6,628	4,119	8,119	2,855	5,611	2,855	5,611
R-squared	0.0276	0.0268	0.0266	0.0319	0.0881	0.1057	0.0504	0.0665
Adjusted R-squared	0.0179	0.0216	0.0187	0.0277	0.0774	0.1001	0.0393	0.0606
Control mean in bandwidth	0.0623	0.0677	0.1096	0.1281	0.3900	0.3150	0.4472	0.4129
IK Bandwidth	1.4101	3	1.4273	3	1.9897	3	1.6938	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff.

Table 8 (Continued on next page): Potential mechanisms of the effect of technical integrated high school (TIHS): School, teacher and student characteristics

	Per pupil spending		School has a laboratory		Principal reported the school has good environment		% Teachers graduated in non exact science and teach math		% Teachers have more than 5 years of experience	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Above the cutoff	125.5429***	142.0750**	0.0848***	0.0846***	-0.0085	-0.0584	-0.0758***	-0.0645***	-0.0155***	-0.0202***
	(38.4797)	(67.0818)	(0.0129)	(0.0187)	(0.0224)	(0.0370)	(0.0074)	(0.0106)	(0.0042)	(0.0062)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	6,038	7,704	3,929	7,716	1,818	2,310	3,924	7,704	4,119	8,119
R-squared	0.2871	0.2866	0.1734	0.1643	0.2259	0.2281	0.2030	0.2198	0.3165	0.3136
Adjusted R-squared	0.2832	0.2833	0.1664	0.1605	0.2116	0.2162	0.1962	0.2162	0.3110	0.3107
Control mean in bandwidth	3836.4784	3823.68	0.6991	0.6796	2.5730	2.5582	0.3842	0.4041	0.9489	0.9524
IK Bandwidth	2.0298	3	1.6938	3	2.1429	3	1.3966	3	1.2203	3

Table 8 (Continued from previous page): Potential mechanisms of the effect of technical integrated high school (TIHS): School, teacher and student characteristics

	Hourly teacher salary		% Teachers graduated in a Federal University		Proportion of mothers with university at baseline (9th grade) in school in 2014		Average Math normalized test score at baseline (9th grade) in school in 2014	
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Above the cutoff	2.7119***	2.1360***	0.0229***	0.0202***	0.0377***	0.0301***	0.3381***	0.2733***
	(0.1974)	(0.2701)	(0.0029)	(0.0041)	(0.0020)	(0.0029)	(0.0123)	(0.0178)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	1,436	2,760	3,929	7,716	4,114	8,108	4,110	8,096
R-squared	0.2846	0.3392	0.5931	0.5803	0.2116	0.2170	0.2707	0.3624
Adjusted R-squared	0.2683	0.3307	0.5897	0.5784	0.2052	0.2136	0.2648	0.3596
Control mean in bandwidth	17.6145	17.0206	0.2026	0.2083	0.1219	0.1175	0.2687	0.2122
IK Bandwidth	1.6486	3	1.2282	3	1.0271	3	1.1907	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff. For the purposes of this table, the information at baseline is the information gathered during the SAEPE standardized 9th grade for students who enrolled in 1st of high school in that school in 2014.

Table 9: Changes in outcomes for students above the admission exam score cutoff comparing technical integrated high school (TIHS) to full-time academic schools.

	Probability of repeating		Probability of dropping out		Normalized Math 3rd grade of HS test score		Normalized Portuguese 3rd grade of HS test score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Above the cutoff	-0.0213***	-0.0127	-0.0464***	-0.0365***	0.0682	-0.0202	0.0771*	-0.0163
	(0.0074)	(0.0094)	(0.0089)	(0.0109)	(0.0458)	(0.0639)	(0.0414)	(0.0579)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	1,842	3,560	2,271	4,333	1,665	3,169	1,665	3,169
R-squared	0.0457	0.0373	0.0393	0.0506	0.1041	0.0977	0.0662	0.0697
Adjusted R-squared	0.0283	0.0278	0.0251	0.0428	0.0859	0.0876	0.0473	0.0593
Control mean in bandwidth	0.0367	0.0410	0.0672	0.0867	0.6618	0.6140	0.6619	0.6488
IK Bandwidth	1.4071	3	1.4070	3	1.8969	3	1.8985	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff. These regressions include only students enrolled in technical integrated high schools (TIHS) and full-time academic high schools.

Appendix A

Table 10: Change in the probability of attriting for students above the admission exam cutoff.

	In 3rd grade of high school but without standardized test information
	(1)
Above the cutoff	-0.0479***
	(0.0117)
Above the cutoff x distance to score	0.0064*
	(0.0038)
Distance to score	0.0000
	(0.0021)
Admission exam year FE	Yes
School FE	Yes
TVET track FE	Yes
Total observations	9,471
R-squared	0.0546
Adjusted R-squared	0.0508

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. The regressions above include the full sample. Additionally, the specification includes application school, TVET track and application year fixed effect.

Table 11: Differences in characteristics for students who attrited in our sample.

	Male	Age	Mother completed high school	Student lives in a paved street
	(1)	(2)	(3)	(4)
Attrited from the sample from 3rd grade to standardized test in 3rd grade of high school	0.0175	-0.0620	-0.0440**	-0.0466***
	(0.0129)	(0.1184)	(0.0172)	(0.0157)
Total observations	12,514	12,514	11,163	11,574
R-squared	0.0001	0.0000	0.0006	0.0008
Adjusted R-squared	0.0001	-0.0001	0.0005	0.0007

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above include the full sample.

Table 12: Balance of student characteristics within students who attrit from 3rd grade of high school to standardized test in 3rd grade of high school.

	Male		Age		Mother completed high school		Mother has some university education		Normalized Math 9th test score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Above the cutoff	0.0344	0.0375	-0.4783**	-0.1516	0.0992*	-0.0487	0.0483	-0.0655	0.4405***	0.2385
	(0.0412)	(0.0831)	(0.2243)	(0.4722)	(0.0543)	(0.1207)	(0.0452)	(0.0930)	(0.1134)	(0.2170)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	632	830	830	830	444	444	353	444	370	469
R-squared	0.1845	0.1791	0.0697	0.0709	0.0926	0.1028	0.0847	0.0812	0.1903	0.2127
Adjusted R-squared	0.1423	0.1440	0.0323	0.0311	0.0244	0.0306	-0.0006	0.0073	0.1187	0.1529
Control mean in bandwidth	0.4365	0.4361	15.5657	15.5657	0.5220	0.5220	0.1440	0.1322	0.5624	0.5888
Bandwidth	2.0050	3	3.0087	3	3.0725	3	2.9459	3	2.6137	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. They exclude students who were in private schools in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff.

Table 13: Change in the probability that students have a given socioeconomic characteristic for students above the cutoff

	Took standardized test in 9th grade		Male		Age		Mother completed high school		Mother has university education		Normalized Math 9th test score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Above the cutoff	-0.0141	-0.0015	0.0191	0.0227	-0.1365*	0.0171	-0.0256	-0.0646**	-0.0032	-0.0182	0.2773***	0.0381
	(0.0150)	(0.0221)	(0.0161)	(0.0238)	(0.0761)	(0.1588)	(0.0215)	(0.0318)	(0.0151)	(0.0227)	(0.0313)	(0.0584)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	4,119	8,119	4,119	8,119	6,336	8,119	2,568	4,976	2,568	4,976	4,094	5,230
R-squared	0.0415	0.0460	0.1176	0.1203	0.0118	0.0121	0.0335	0.0308	0.0188	0.0120	0.1129	0.1269
Adjusted R-squared	0.0335	0.0418	0.1105	0.1165	0.0066	0.0078	0.0209	0.0239	0.0061	0.0050	0.1057	0.1210
Control mean in bandwidth	0.7275	0.7182	0.4475	0.4495	15.6535	15.6357	0.5257	0.5229	0.1462	0.1440	0.4028	0.3943
Bandwidth	1.7460	3	1.7961	3	2.1922	3	1.8055	3	1.7872	3	2.2358	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff.

Table 14: Change in the density of students above the admission exam score cutoff

	log(share of observations)
Above the cutoff	-0.0066
	(0.0104)
Above the cutoff x distance to score	-0.0762***
	(0.0120)
Distance to score	-0.0195***
	(0.0027)
(Above the cutoff x distance to score)^2	-0.0182***
	(0.0033)
Distance to score^2	-0.0363***
	(0.0009)
(Above the cutoff x distance to score)^3	0.0026***
	(0.0002)
Distance to score^3	-0.0006***
	(0.0001)
Admission exam year FE	Yes
School FE	Yes
TVET track FE	Yes
Total observations	11,468
R-squared	0.9963
Adjusted R-squared	0.9963

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. The regression above includes the full sample. Additionally, the specification includes application school, TVET track and application year fixed effect. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff.

Table 15: Differences in characteristics for students who drop out during high school.

	Male	Age	Mother completed high school	Mother has some university education	Student lives in a paved street
	(1)	(2)	(3)	(4)	(5)
Dropped out between 1st and 3rd grades of high school	0.0816***	0.5017***	-0.0297**	0.0030	0.0055
	(0.0095)	(0.1085)	(0.0127)	(0.0089)	(0.0115)
Total observations	15,269	15,269	9,376	9,376	10,648
R-squared	0.0048	0.0006	0.0006	0.0000	0.0000
Adjusted R-squared	0.0048	0.0005	0.0005	-0.0001	-0.0001

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above include the full sample.

Table 16: Change in the probability that students have a given socioeconomic characteristic for students above the cutoff. Comparing students in technical integrated high school (TIHS) and academic full-time high schools.

	Took standardized test in 9th grade		Male		Age		Mother completed high school		Mother has university education		Normalized Math 9th test score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Above the cutoff	-0.0205	-0.0197	-0.0013	-0.0291	0.0880	0.2678	-0.0728**	-0.1074***	-0.0082	-0.0198	0.1596***	0.0319
	(0.0195)	(0.0273)	(0.0233)	(0.0323)	(0.1370)	(0.1924)	(0.0295)	(0.0409)	(0.0181)	(0.0261)	(0.0494)	(0.0692)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	1,768	3,371	1,768	3,371	1,768	3,371	1,205	2,287	1,205	2,287	1,413	2,700
R-squared	0.0255	0.0214	0.1282	0.1167	0.0387	0.0218	0.0467	0.0440	0.0376	0.0216	0.1333	0.1307
Adjusted R-squared	0.0069	0.0111	0.1116	0.1075	0.0204	0.0116	0.0198	0.0291	0.0105	0.0064	0.1125	0.1192
Control mean in bandwidth	0.8125	0.8171	0.4570	0.4513	15.3822	15.4064	0.6083	0.6120	0.1157	0.1216	0.5531	0.5700
Bandwidth	1.8562	3	1.8404	3	1.5458	3	1.8959	3	1.8999	3	1.8573	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff. These regressions include only students in TIHS or full-time academic high school.

Table 17: (Continued on next page): Potential mechanisms of the effect of technical integrated high school (TIHS) comparing students in technical integrated high school (TIHS) and academic full-time high schools: School, teacher and student characteristics

	Per pupil spending		School has a laboratory		Principal reported the school has good environment		% Teachers graduated in non exact science and teach math		% Teachers have more than 5 years of experience	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Above the cutoff	-608.5613***	-360.9104***	0.0296**	0.0292*	-0.0320	-0.0548	-0.0121	-0.0099	-0.0729***	-0.0539***
	(41.8161)	(58.9215)	(0.0121)	(0.0163)	(0.0286)	(0.0336)	(0.0082)	(0.0104)	(0.0099)	(0.0117)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	3,434	4,333	2,271	4,333	927	1,179	2,271	4,333	823	1,522
R-squared	0.5874	0.6002	0.4230	0.4062	0.5207	0.5421	0.4052	0.4063	0.6116	0.6469
Adjusted R-squared	0.5833	0.5970	0.4145	0.4013	0.5052	0.5289	0.3964	0.4014	0.5969	0.6388
Control mean in bandwidth	4734.85	4814.32	0.8212	0.8069	2.5817	2.5535	0.2756	0.2866	0.8707	0.8923
IK Bandwidth	2.0431	3	1.7758	3	2.2472	3	1.5678	3	1.7344	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff. These regressions include only students in TIHS or full-time academic high school.

Table 17: (Continued from next page): Potential mechanisms of the effect of technical integrated high school (TIHS) comparing students in technical integrated high school (TIHS) and academic full-time high schools: School, teacher and student characteristics

	Hourly teacher salary		% Teachers graduated in a Federal University		Proportion of mothers with university at baseline (9th grade) in school in 2014		Average Math normalized test score at baseline (9th grade) in school in 2014	
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)
Above the cutoff	-0.0523	0.0043	-0.0011	-0.0017	0.0000	0.0072***	0.1882***	0.1433***
	(0.0962)	(0.1013)	(0.0027)	(0.0033)	(.)	(0.0012)	(0.0104)	(0.0125)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	1,203	1,497	2,271	4,333	787	4,150	2,161	4,150
R-squared	0.7186	0.7174	0.8210	0.8082	0.6674	0.6410	0.4839	0.5489
Adjusted R-squared	0.7114	0.7109	0.8184	0.8067	0.6533	0.6379	0.4759	0.5451
Control mean in bandwidth	21.5563	21.4994	0.2364	0.2494	0.1429	0.1384	0.5008	0.4536
IK Bandwidth	2.3745	3	1.3006	3	0.9766	3	1.6131	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9^{th} grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff. These regressions include only students in TIHS or full-time academic high school.

Table 18: Robustness check – Changes in enrollment choices and outcomes including students in private schools in 9th grade.

	Enrolled in technical integrated high school (TIHS)		Probability of repeating		Probability of dropping out		Normalized Math 3rd grade of HS test score		Normalized Portuguese 3rd grade of HS test score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Above the cutoff	0.4452***	0.3776***	-0.0279***	-0.0224**	-0.0585***	-0.0516***	0.2323***	0.0935*	0.1999***	0.0772*
	(0.0127)	(0.0189)	(0.0065)	(0.0095)	(0.0067)	(0.0095)	(0.0326)	(0.0482)	(0.0303)	(0.0445)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	5,983	12,047	4,944	9,988	5,983	12,047	3,784	7,528	3,784	7,528
R-squared	0.2040	0.3714	0.0196	0.0206	0.0239	0.0258	0.0760	0.0978	0.0444	0.0679
Adjusted R-squared	0.1996	0.3696	0.0130	0.0171	0.0185	0.0230	0.0678	0.0936	0.0360	0.0635
Control mean in bandwidth	0.2696	0.1787	0.0647	0.0679	0.1044	0.1162	0.4921	0.4208	0.5433	0.4966
IK Bandwidth	1.3123	3	1.8171	3	1.8487	3	1.9741	3	1.8596	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) for the first regression of each outcome and the double of this bandwidth for the second regression of each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. These regressions include the full sample.

Table 19: Robustness check – Alternative bandwidths (double the IK bandwidth and bandwidth equal to 2).

	Enrolled in Technical Integrated High School (TIHS)		Probability of repeating		Probability of dropping out		Normalized Math 3rd grade of HS test score		Normalized Portuguese 3rd grade of HS test score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Above the cutoff	0.5739***	0.3458***	-0.0406***	-0.0204	-0.0747***	-0.0577***	0.3544***	0.1650**	0.3044***	0.1937***
	(0.0097)	(0.0293)	(0.0061)	(0.0137)	(0.0068)	(0.0151)	(0.0264)	(0.0754)	(0.0245)	(0.0697)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	8,119	6,336	5,185	5,185	6,336	6,336	5,611	4,405	5,611	4,405
R-squared	0.3507	0.3680	0.0272	0.0308	0.0269	0.0303	0.0932	0.0917	0.0592	0.0566
Adjusted R-squared	0.3480	0.3645	0.0209	0.0242	0.0218	0.0249	0.0878	0.0844	0.0536	0.0490
Control mean in bandwidth	0.1980	0.2289	0.0676	0.0676	0.1211	0.1211	0.3150	0.3550	0.4129	0.4317
Bandwidth	3.0946	2	2.8202	2	2.8546	2	3.9794	2	3.3876	2

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the double of the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) in the first column for each outcome and bandwidth 2 (larger than the IK bandwidth but narrower than double the IK bandwidth) in the second column for each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. The sample excludes students who were in private school in 9th grade and students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff.

Table 20: Robustness check – Excluding students at the cutoff

	Enrolled in Technical Integrated High School (TIHS)		Probability of repeating		Probability of dropping out		Normalized Math 3rd grade of HS test score		Normalized Portuguese 3rd grade of HS test score	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Above the cutoff	0.6411***	0.6127***	-0.0576***	-0.0652***	-0.0774***	-0.0699***	0.3433***	0.1793***	0.3258***	0.2041***
	(0.0150)	(0.0230)	(0.0098)	(0.0156)	(0.0107)	(0.0172)	(0.0434)	(0.0683)	(0.0406)	(0.0646)
Flexible linear spline	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Total observations	2,641	6,641	2,142	5,428	2,641	6,641	1,855	4,611	1,855	4,611
R-squared	0.4479	0.4956	0.0443	0.0319	0.0384	0.0372	0.1050	0.1116	0.0765	0.0760
Adjusted R-squared	0.4409	0.4929	0.0293	0.0256	0.0262	0.0321	0.0888	0.1048	0.0598	0.0689
Control mean in bandwidth	0.1251	0.0988	0.0831	0.0779	0.1236	0.1411	0.2922	0.2457	0.3629	0.3656
Bandwidth	1.5473	3	1.4101	3	1.4273	3	1.9897	3	1.6938	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the double of the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012) in the first column for each outcome and bandwidth 2 (larger than the IK bandwidth but narrower than double the IK bandwidth) in the second column for each outcome. Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. They exclude students who were in private school in 9th grade, students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff and students with scores at the cutoff.

Table 21: Robustness check – Using an alternative cutoff.

	Enrolled in Technical Integrated High School (TIHS)	Probability of repeating	Probability of dropping out	Normalized Math 3rd grade of HS test score	Normalized Portuguese 3rd grade of HS test score
	(1)	(2)	(3)	(4)	(5)
Above the cutoff	-0.0273*	-0.0036	-0.0152	0.0062	-0.0383
	(0.0140)	(0.0116)	(0.0137)	(0.0460)	(0.0437)
Flexible linear spline	Yes	Yes	Yes	Yes	Yes
Admission exam year FE, School FE and TVET track FE	Yes	Yes	Yes	Yes	Yes
Total observations	8,119	6,628	8,119	5,611	5,611
R-squared	0.3731	0.0264	0.0298	0.1044	0.0657
Adjusted R-squared	0.3703	0.0212	0.0256	0.0988	0.0599
Cutoff at	-2	-2	-2	-2	-2
Control mean in bandwidth	0.0826	0.0747	0.1519	0.2153	0.3673
Bandwidth	3	3	3	3	3

Notes: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Each column represents a separate regression. The regressions above use the double of the bandwidth suggested by the procedure in Imbens and Kalyanaraman (2012). Additionally, they include application school, TVET track and application year fixed effect. Test scores are normalized within year and grade and have mean zero and standard deviation 1. They exclude students who were in private school in 9th grade, students who apply to technical courses and schools that are not oversubscribed and where there is no cutoff and students with scores at the cutoff. These regressions use an alternative cutoff for the TIHS admission exam score that is two points to the left of the actual cutoff.

Appendix B

Matching the data

In order to merge the school census, standardized test scores and TIHS applicant lists, we use the following variables: student name, student date of birth, student Brazilian ID number (CPF), school code, student grade and year. We then merge students' data in school census with SAEPE's test scores and socioeconomic information using students' full names conditional on students in both databases attending the same school and the same grade. Using this procedure, we match over 73% of students in the SAEPE database to school census.[33]

Then, we combine the resulting dataset with the lists of students applying to technical integrated high school (TIHS). To merge this information, we use three variables: student names, date of birth and student's Brazilian ID number (CPF). Our preferred method is to match students using student name and Brazilian ID number. Almost 55% of students matched with applicant lists are matched using these two pieces of information. However, around 64% of students do not have Brazilian ID numbers in the school census database. Therefore, around 40% of students in the applicant lists matched to our sample are matched using student name and date of birth. The remaining matches are students matched using student name only. Using this procedure, we match just over 85% of students in the TIHS applicant lists to the school census and SAEPE datasets.

[33] The reason why we cannot match all student names is because students in Brazil have usually more than one first name and at least 2 surnames. Thus, a student whose name is, for example, Maria Clara da Silva Soares, could be recorded as Maria da Silva in one database and as Maria Clara in another database. In these cases, we could not match these students, as we cannot make sure that Maria da Silva and Maria Clara are the same student.