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Abstract

This paper explores the effects of university quality in STEM education by examining the consequences of admission to Finland's most competitive engineering school for students' performance in their studies and the labor market. Using data from the centralized admission system for engineering degree programs, we estimate these effects for marginally admitted elite school applicants who also applied to and had the opportunity to be admitted to a less competitive engineering school. Our results show that being accepted by the elite engineering school leads to a more advantaged initial peer group and a sharply higher probability of eventually graduating from that elite school but does not, on average, result in significantly better early-career labor market outcomes. However, we find that admission to the elite school significantly increases the earnings of students whose parents are not highly educated.

Key words: return to school quality, higher education, STEM, regression discontinuity design

JEL classes: I23, I26, J24

1 Introduction

Recent literature has demonstrated that the choice of field of study can significantly affect the monetary return to higher education (Altonji et al., 2016). Given the high demand for technical skills in the labor market, STEM fields (Science, Technology, Engineering and Mathematics) are generally ranked among the most lucrative field-of-study choices. Besides high private returns, STEM education has the potential of wider societal returns, particularly through its impact on innovation (Toivanen and Väänänen, 2016). In contrast to the potential benefits, STEM fields suffer from many problems, including lack of attractiveness (particularly among women), low completion rates and relatively high per-student instructional costs (Altonji et al., 2016; Altonji and Zimmerman, 2018).

Due to the high expected benefits and costs of STEM education, and the consequently elevated need to direct investments efficiently, it is important to understand what factors affect students' outcomes within these fields of study. Our paper focuses on the question of whether assigning STEM students to a higher-quality institution makes a difference in terms of their performance in their studies and the labor market. While there is a large amount of previous research on the causal effects of choice of higher education institution on students' future outcomes (e.g. Behrman et al., 1996; Brewer et al., 1999; Dale and Krueger, 2002; Hoekstra, 2009; Suhonen, 2013; Zimmerman, 2019; Anelli, forthcoming), there appears to be very little evidence of whether the outcomes differ between students who choose the same field of study and who are quasi-randomly assigned to different institutions of varying quality. Hence, the effects of institution quality in STEM education are also largely unknown.

To shed light on the importance of institution quality, we use a regression discontinuity design (RDD) to investigate the effects of gaining admission to Finland's most competitive institution in the engineering field, Aalto University, versus a less competitive engineering school. The benefits of attending this elite engineering school are expected to arise, in particular, from its higher selectivity, and the resulting potential peer group effects, as well as from its favorable location next to Finland's largest cluster of hi-tech engineering jobs. Our analysis exploits data from the centralized admission system for Finnish M.Sc. engineering programs and a sample of applicants who applied to both the elite engineering school and another engineering school. We identify the effects of admission to the elite school by comparing applicants who were narrowly admitted to the elite school to those who remained just below the school's admission cutoff and were assigned to their next best institution.

We find that being accepted to the most competitive engineering school in one's first application year leads to having a substantially more advantaged peer group in the beginning of one's studies and makes one over three times as likely to eventually graduate from the elite school. While admission to the elite engineering school does not, on average, appear to increase one's earnings or employment 11 years after admission, we find significant elite school returns for certain subgroups and, in particular, for applicants originating from low-educated families.

Our analysis relates to a growing literature that investigates the outcomes of applicants marginally accepted or rejected by educational institutions to draw conclusions on the causal effects of individuals' educational choices on their future outcomes (Hoekstra, 2009; Öckert, 2010; Abdulkadiroglu et al., 2014; Zimmerman, 2014; 2019; Kirkeboen et al., 2016; Anelli, forthcoming). These papers have found significant effects from being quasi-randomly assigned to different types of institutions and programs, providing evidence e.g. of positive returns on higher education (Zimmerman, 2014), institution quality (Hoekstra, 2009; Zimmerman, 2019; Anelli, forthcoming) and particular field-of-study choices (Kirkeboen et al., 2016).

The main novelty of our paper is to use an RDD to examine the effects of institution quality within engineering degree programs. Our analysis bears closest resemblance to that of Zimmerman (2019), who investigated the consequences of admission to elite business-focused college programs in Chile. Like Zimmerman, we are able to estimate the effects of assignment to a selective institution separately for applicants who would have, in a counterfactual case, been assigned to a less selective institution within the same broad field of study. We demonstrate that this approach allows us to disentangle reasonably well the effect of attending the elite engineering school from that of participation in M.Sc. engineering studies, as applicants marginally above and below the elite engineering school admission cutoff are highly comparable with respect to their subsequent engineering-field-specific educational attainment.

The rest of the paper is organized as follows. In the next section, we discuss the institutional background and centralized admission system for engineering degree programs in Finland. Section 3 describes the details of our empirical approach, including the data, sample restrictions and model used in the regression discontinuity analysis. Section 4 presents the results, and the conclusions are given in Section 5.

2 Institutional background

2.1 Finnish institutions in engineering education

In Finland, higher education in the field of engineering is provided by two types of institutions: universities and universities of applied sciences. Our study focuses on universities, which provide the highest-level education leading to M.Sc. and D.Sc.

engineering degrees.[1] University education is free of charge, and students are entitled to welfare benefits, which enable full-time studies. The study requirements follow the Bologna system, i.e. 180 ECTS points (3 academic years) are required for a bachelor's degree and an additional 120 ECTS points (2 academic years) for a master's degree. Although university students are directly admitted to both bachelor's and master's studies, it has been mandatory, since 2005, for students to obtain an intermediate bachelor's degree.

The Finnish M.Sc. engineering degree program can be completed in various majors, including mechanical engineering, energy engineering, electrical engineering, automation engineering, information technology, telecommunications technology, process engineering, materials engineering, building construction, surveying technology and industrial management. The expected career earnings for engineering majors are generally high. The average middle-career earnings are highest for graduates from industrial management, which is, besides medicine, dentistry and law, among the highest-earning university majors (Suhonen and Jokinen, 2018).

In the engineering field, Aalto University stands out as the most prestigious Finnish institution for several reasons.[2] First, the remaining six university-level engineering schools existing today have been less selective, compared to Aalto University, in terms of the average program-specific minimum admission points required in the centralized admission system for M.Sc. engineering programs (see Table A1 in the Appendix). Second, Aalto University is internationally the most recognized and highly ranked (e.g. by QS World, ARWU and US News) technical institution in Finland. Third, the location of Aalto University's engineering school is particularly favorable in terms of engineering students' labor market opportunities: it is the only university-level engineering school located in the Helsinki-Uusimaa region, where nearly half of the R&D sector jobs in Finland are concentrated (Statistics Finland, 2017), and one of Northern Europe's largest technology and innovation clusters, including e.g. the headquarters of

[1] Universities of applied sciences focus on bachelor's-level education, while these institutions, to some extent, also award work-life-oriented master's degrees.

[2] The engineering and architecture schools at Aalto University are based on Finland's first technical college, founded in Helsinki in 1849. This institution was later transformed into the University of Technology and, until the end of the 1950s, it was Finland's only major university-level institution specialized in engineering (see Toivanen and Väänänen, 2016). In 2010, this institution became part of the new Aalto University. A small Swedish-speaking faculty of chemistry and technology was founded at the Åbo Academy University in 1923, making it the second oldest university-level institution specialized in engineering. During the geographical expansion of the Finnish university system, new institutions were founded in Oulu in 1959, in Tampere in 1965 and in Lappeenranta in 1969. Later on, in 2004, the University of Turku and University of Vaasa were granted permission to award engineering degrees.

many Finnish hi-tech companies, has developed in the vicinity of the university's main campus in Otaniemi. In view of all these facts, one can expect the engineering students at the Aalto University to have an advantaged study environment compared to other Finnish engineering students, which motivates our analysis of the consequences of admission to this institution and justifies referring to it as the 'elite engineering school'.

2.2 DIA joint admission

Finnish universities have selected their engineering and architecture students via a centralized admission system, known as the DIA joint admission, since 1968. While admissions to engineering and architecture programs are conducted simultaneously in the DIA system, we only focus on engineering program admissions, which cover around 97 percent of the total annual student intake via the system. In recent decades, the basic features of the application and admission process have remained the same.[3] At the application stage, applicants can list up to five program options (i.e. combinations of institution and major) out of a large number of alternatives available in the system.[4] Applicants submit their choices in a binding preference order and receive no more than one offer for either an engineering or architecture program after the admission process.

The engineering program admissions are conducted in three rounds with different admission criteria being applied in each round. Within the admission rounds, the assignment process follows the deferred acceptance principle, i.e. applicants to a specific major at a specific institution are ranked based on a round-specific admission index, and a limited number of best applicants are accepted by a step-wise elimination of those eligible for a higher-ranked choice. In the first admission round, covering around 30% of the admission quotas, applicants having just finished general upper secondary school are ranked for their first and second choices according to an index of matriculation examination grades and additional points given for the first choice. Applicants not admitted in the first round are obliged to participate in at least two entrance examinations, which in most cases include a test in math and a test either in chemistry or physics. In the second admission round, applicants having completed the matriculation examination in any year are ranked according to an index of entrance examination points, matriculation examination grades and first preference points. Commonly, around 60% of the student places available after the first round are filled in the second round. In the third round, the remaining student places are filled

[3] The description of the application and admission process relies on the selection guides published annually by the Joint Admission Committee of Engineering and Architecture Education (2000–2004).

[4] In 2000–2004, when the individuals in our estimation sample applied for the first time, there were 47 to 58 program alternatives available.

by ranking the thus far unassigned applicants based on their entrance examination points and first preference points.

3 Empirical approach

3.1 Data and variables

Our data set includes all applicants who participated in the DIA joint admission between 2000 and 2014. The data contain applicants' information specific to the application year, round and program applied to, including matriculation examination points, entrance examination points and overall admission score as well as an indicator for whether the applicant was admitted. To obtain a sufficiently long follow-up period for examining applicants' early-career educational and labor market outcomes, we focus on the DIA applicants who applied for the first time between 2000 and 2004. For these applicant cohorts, we observe outcomes at least eleven years after the first application year. Our main focus is on individuals' outcomes at the end of the 11-year observation period, and we also analyze the evolution of some of the outcomes throughout the observation period.

To study the effects on applicants' subsequent educational outcomes, we utilize Statistics Finland's yearly updated student and educational degree registers, which are fully representative of individuals attending Finnish secondary- and tertiary-level educational institutions. From these data, we are able to observe which institutions and programs applicants enrolled to and graduated from after the date of application. Furthermore, to examine subsequent labor market outcomes, we merge the admissions data with the Finnish Longitudinal Employer-Employee Data (FLEED) containing register-based information e.g. on applicants' income, employment and residential location up to 2015. Our main measure for applicants' labor market performance, annual earnings, combines annual salary and entrepreneurial income originating from the registers of the Finnish Tax Administration. Additionally, we use daily earnings obtained by dividing annual earnings by the number of days worked, which are based on full-population employee registers maintained by Statistics Finland.

For the regression discontinuity design (RDD), we create a centralized running variable based on each applicant's application-round-by-program-specific admission score by subtracting from this score that of the last person admitted to the given program[5] in the given round as follows:

$$r_{ijkt} = s_{ijkt} - \tau_{jkt}, \tag{1}$$

[5] Here a program refers to a major-specific degree program in a specific university institution.

where s_{ijkt} is applicant i's admission score for round j and program k in year t, and τ_{jkt} is the admission score for the last admitted applicant. When r_{ijkt} is negative, the applicant's admission score is not sufficient for admission to program k in round j in year t, whereas applicants with non-negative centralized admission scores qualify for admission.

3.2 Estimation sample

In total, our data include 22,350 engineering program applicants and 154,186 applicant-by-year-by-round-by-program observations for application years 2000–2004.[6] However, by imposing a number of necessary restrictions on the estimation sample, we end up using only a small fraction of these observations. First, we base our estimation approach only on each applicant's application and admission information in the first year they appear in the DIA admission data. Second, as our goal is to compare admittees to the elite engineering school and other engineering schools, we restrict the sample to applicants who applied to both types of schools and who were admitted to at least one engineering program in their first application year.[7] Third, we concentrate on admission cutoffs that are the most relevant regarding applicants' chances of being ultimately selected to the elite school. Namely, we base our analysis on the second and third admission rounds, as very few applicants narrowly rejected in the first and most competitive round are ultimately rejected admission to their preferred program. Furthermore, we focus on each elite school applicant's least competitive round-by-program cutoff, i.e. the one with the highest centralized admission score.

To make the RDD sharp with respect to one's probability of being admitted to the elite school versus another engineering school, we impose two additional restrictions on the sample. First, we exclude applicants who did not have an engineering program as a fallback option in the case of not exceeding the least competitive elite school admission cutoff. Second, we exclude applicants who, having crossed the admission cutoff, were or would have been admitted to another engineering school due to having ranked a less competitive program in that institution higher. In the resulting sample, each applicant only appears once. After excluding admission cutoffs for which there are no observations on both sides of the cutoff, we are left with a final sample of 1,691

[6]An applicant can rank up to 5 programs and be considered for admission in three admission rounds. As only the two highest-ranked choices are accounted for in the first round, a person can be observed in the data up to 12 times in a specific year.

[7]Excluding non-admitted candidates ensures that the estimated effects of elite school admission are not driven by differences in individuals' chances of being admitted to any engineering program in the first application year. However, the inclusion of these non-admitted candidates in the sample does not significantly alter our main results.

elite school applicants used in the analysis.[8]

Table 1: Summary statistics for the sample of elite engineering school applicants used in the regression discontinuity analysis.

	Mean		
	All	Elite school admittees	Next best school admittees
Variable	(1)	(2)	(3)
Male	0.817	0.832	0.785
	(0.009)	(0.011)	(0.017)
Age in application year	19.766	19.645	20.007
	(0.049)	(0.054)	(0.099)
Finnish speaker	0.919	0.934	0.890
	(0.007)	(0.007)	(0.013)
Originating from Uusimaa region	0.334	0.342	0.317
	(0.012)	(0.014)	(0.02)
General upper secondary graduate	0.976	0.984	0.959
	(0.004)	(0.004)	(0.008)
First language grade	3.539	3.588	3.618
	(0.028)	(0.034)	(0.056)
Advanced math grade	4.052	4.255	3.618
	(0.03)	(0.034)	(0.056)
General studies grade	3.985	4.149	3.645
	(0.033)	(0.039)	(0.061)
Mother has bachelor's degree or higher	0.375	0.387	0.353
	(0.012)	(0.015)	(0.021)
Father has bachelor's degree or higher	0.565	0.594	0.503
	(0.013)	(0.016)	(0.023)
Sum of parental income	98 046	102 820	88 524
	(4 034)	(5 888)	(2 802)
Earnings 11 years after application year	40 518	41 103	39 345
	(109)	(127)	(198)
N	1 691	1128	563

Standard deviations in parentheses. The grades are from the Finnish matriculation examination and vary from 1 to 6.

The summary statistics for the total estimation sample and sub-samples above and below the elite engineering school admission cutoff in Table 1 demonstrate that the

[8]In total, there were 140 second- and third-round admission cutoffs for Aalto University engineering programs in 2000-2004. All these cutoffs were relevant, i.e. there were rejected candidates below each cutoff. However, in our restricted sample, there are 56 cutoffs with missing observations either above or below the cutoff.

examined group of elite school applicants, to a large extent, comprises 19–20-year-old, Finnish-speaking males, who graduated from general upper secondary school and attained relatively high average grades in first language, advanced math and general studies in the Finnish matriculation examination prior to applying for M.Sc. engineering studies. Around half of the applicants have a highly educated father and around a third have a highly educated mother. The applicants' parents are relatively high-earning citizens with an average summed annual income of 98,000 euros, whereas the applicants' own annual earnings 11 years after the application year (in most applicants' early thirties) are around 40,000 euros.

The average background characteristics of the applicants above and below the elite engineering school admission cutoff are somewhat different. In particular, those above the cutoff are more likely to be male, originate from the Uusimaa region, have higher matriculation examination grades and more highly educated and high-earning parents, which logically suggests that more able or economically advantaged applicants more likely gain admission to the elite school in their first application year. Perhaps consequently, we see that the elite school admittees earn around 1,800 euros more 11 years after the application year, while it is unclear, based on this raw earnings difference, whether admission to the elite school truly affects earnings.

3.3 Model specification

Given the data and sample restrictions introduced above, we estimate the causal effect of gaining admission to the elite engineering school (i.e. an engineering program at Aalto University) in the first application year on individual i's outcome of interest y_{ijkt} using the following regression discontinuity model specification:

$$y_{ijkt} = \delta_{jkt} + \alpha_1 r_{ijkt} + \alpha_2 d_{ijkt} + \alpha_3 d_{ijkt} r_{ijkt} + \epsilon_{ijkt}. \tag{2}$$

Subscripts j, k and t denote i's applicant group, i.e. the least competitive elite school round-program combination where i was considered for admission in his or her first application year. δ_{jkt} controls for the applicant group fixed effects; r_{ijkt} is the centered running variable; d_{ijkt} is an indicator taking a value of 1 if the applicant was admitted to the elite engineering school, and 0 otherwise; the interaction term $r_{ijkt}d_{ijkt}$ accounts for the possible change in the slope of the running variable at the admission cutoff;[9] and ϵ_{ijkt} is the error term.

To estimate the discontinuity at the elite school admission cutoff α_2 in a robust manner, we limit the estimation sample to observations in the vicinity of the cutoff and

[9]We also estimated models that allow for the slopes of the running variable to differ across the applicant groups. However, due to the small sample size, this approach resulted in imprecise estimates.

weight the observations according to their distance to the cutoff. To find an optimal bandwidth for the estimation, we follow Calanico et al. (2014) and choose the one that is MSE-optimal for the estimation of the local average treatment effect (LATE).[10] For weighting the sample, we employ the following commonly used triangular kernel function, which attaches the highest weight to observations near the cutoff and linearly shrinks towards the edges of the bandwidth established:

$$K_h(r_{ijkt}) = 1\{|\frac{r_{ijkt}}{h}| \leq 1\} * (1 - |r_{ijkt}/h|), \tag{3}$$

where r_{ijkt} is the running variable, and h is the chosen optimal bandwidth. We estimate the bandwidths and weights separately for each outcome used in the analysis, and therefore the size of the estimation sample varies across outcomes in Section 4.[11] For the interpretation of effect sizes, we also estimate counterfactual mean outcomes at the admission cutoff by computing predictions of model 2 for $r_{ijkt} \rightarrow 0-$ using STATA's margins command.

3.4 Validity of the design

The first sub-figure of Figure A1 in the Appendix demonstrates that, for our restricted sample of elite school applicants, there is a sharp discontinuity in the probability of being admitted to the elite engineering school in the first application year at the admission cutoff. To interpret the estimated changes in other outcomes to result from this sharp discontinuity, we need to assume that the narrowly accepted or rejected applicants were unable to completely manipulate their chances of being admitted to the elite school. Two types of arguments support the validity of the design. First, our setting contains random elements, which prevent one from perfectly manipulating the assignment near the admission cutoff and theoretically validate the RDD (Lee, 2008). Namely, although applicants may apply strategically by ranking their choices based on their expected admission outcome, the final admission score is unknown at the stage of applying: applicants eligible for the first admission round, i.e. fresh upper secondary graduates, only learn their matriculation examination grades after the date of application, and entrance examinations taken after the first round generate additional uncertainty about the second- and third-round admission outcomes. Second,

[10] In practice, we use the STATA command rdrobust to estimate the optimal bandwidth.

[11] We also estimated the effects for our main outcomes using different bandwidths. Figure A2 in the Appendix shows that the RD estimates are imprecise and partly volatile with very small bandwidths but, in most cases, stabilize reasonably well when increasing the bandwidth. A natural explanation for this inefficiency is that, given the complex admission process of the engineering schools, we have to fit the RD models using a large number of heterogeneous admission cutoffs with relatively few observations per cutoff.

Table 2: Discontinuities in applicants' background characteristics, expected earnings index and density of observations at the elite engineering school admission cutoff.

Variable	Discontinuity
Male	0.050
	(0.051)
Age in application year	0.044
	(0.374)
Finnish speaker	-0.035
	(0.042)
Originating from Uusimaa region	-0.117
	(0.071)
General upper secondary graduate	0.018
	(0.019)
First language grade	-0.002
	(0.150)
Advanced math grade	-0.222
	(0.177)
General studies grade	-0.232
	(0.186)
Mother has bachelor's degree or higher	-0.066
	(0.086)
Father has bachelor's degree or higher	0.044
	(0.096)
Sum of parental income	4 594
	(10 611)
Expected earnings index	0.003
	(0.016)
Density of observations	-0.013
	(0.013)

*The expected earnings index is a prediction from a regression of applicants' 11th-year logarithmic annual earnings on the background characteristics listed above. The grades are from the Finnish matriculation examination and vary from 1 to 6. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

our empirical results shown in Table 2 and Table A5 in the Appendix indicate no systematic differences in observable characteristics between the marginally admitted and rejected candidates at the elite school admission cutoff.[12] According to the results of the McCrary's (2008) test reported in the bottom of Table 2, there is no significant

[12]We also conducted estimations while adding the applicants' background characteristics to our model as covariates. As one would expect in the case of a valid design, the results from these estimations are similar to the baseline results (see Table A6 in the Appendix).

discontinuity either in the density of observations at the cutoff, which further supports the validity of the design.

A shortcoming of our design is that applicants apply and are admitted to major-specific degree programs at engineering schools, and therefore the narrowly rejected elite school applicants could be admitted to a different major in their next best institution. Thus, differences between engineering majors could drive our estimated effects of elite school admission. To address this problem, we also employed an alternative sample of applicants for whom the major of the least competitive elite engineering school program option and the next best program option were the same. The results for this sub-sample, reported in the Appendix (Table A4), are qualitatively very similar to our baseline results but less precise due to the smaller sample size.

4 Regression discontinuity results

4.1 Peer group composition

A prominent way in which admission to a more selective university may affect students is through peer group composition, i.e. by providing an opportunity to study in the company of academically more able or otherwise more advantaged peers. Therefore, we begin our analysis by shedding light on the initial study environment differences between those marginally admitted to the elite engineering school and those marginally rejected and admitted to their next best engineering school. To this end, we estimate discontinuities in the mean characteristics of applicants' expected initial peer group, comprising students admitted to the same institution and degree program in the same year.[13] We measure the peer group's academic skills by its average matriculation examination grades and entry exam score in math, the peer group's labor market skills by its average total income 11 years after admission, and the peers group's socioeconomic status using the admittees' parental education and income.

The results reported in Table 3 do suggest that admission to the elite engineering school leads to a markedly more advantaged peer group in the beginning of one's studies. The elite school admittees' peer group has over a half a grade higher average matriculation examination grades in mathematics and general studies and a 0.3 grade higher average grade in first language compared to the peer group of the next best school admittees. Elite school admission further results in having a peer group with a 32% higher average entry exam score in math. Additionally, columns (5) and (6) of Table 3 indicate considerable socioeconomic differences between the elite school and

[13] Alternatively, we approximated the peer group composition based on students enrolled in the same institutions and degree programs, which provided similar results.

Table 3: Regression discontinuity results. The effects of elite engineering school admission in the first application year on the average characteristics of the initial peer group.

	Matriculation exam grades in						
	First language	Advanced math	General studies	Entry exam score in math	Highly educated parents	Parental income	11^{th}-year earnings
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Elite admission	0.292***	0.528***	0.595***	4.521***	0.198***	34 344***	2 369***
	(0.032)	(0.040)	(0.039)	(0.302)	(0.0011)	(2 494)	(555.3)
Counterfactual mean	3.560	3.907	3.819	13.951	0.446	77 713	39 120
N	719	860	914	969	913	700	841

Peer group refers to a group of applicants admitted to the same institution and degree program in the same year. Parents are defined as highly educated if at least one of them has a bachelor's degree or higher. Robust standard errors in parentheses.
**** p<0.01, ** p<0.05, * p<0.1.*

other engineering schools: the parents of the elite school admittees' peer group are 44% more likely to be highly educated and have a 44% higher income compared to the parents of the counterfactual peer group. The elite school admittees' peers also earn 2369 euros more, on average, 11 years after admission. These results provide a reason to suspect that there are significant peer group effects involved in elite school admission, which may translate e.g. into higher human capital accumulation and better networks for elite school admittees in their subsequent careers.

4.2 Educational choices and attainment

We begin analyzing the consequences of elite engineering school admission for applicants' own outcomes by examining their subsequent educational choices and attainment. Table 4 describes the effects of elite school admission on individuals' later participation in the DIA joint admission, their decisions to discontinue studies in the program initially admitted to, as well as enrolment in and completion of engineering studies. The large baseline probabilities of reapplying for engineering studies (0.37) or to the elite school (0.26) and of discontinuing the initial program (0.52) in columns (1)–(3) suggest that it is fairly common, among the studied group of Finnish engineering students, to reconsider one's educational choices. However, the estimated large negative discontinuities in these outcomes at the elite school admission cutoff suggest that exceeding the cutoff significantly reduces one's need for reconsideration. Admission to the elite school logically diminishes the probability of reapplying to the elite school to close to zero, while the probabilities of reapplying for engineering studies and discontinuing the initial program are also reduced by 60% and 40%, respectively. Furthermore, the estimates in columns (4) and (5) indicate that the negative effect of elite school admission on discontinuing is highly driven by students changing engineering

Table 4: Regression discontinuity results. The effects of elite engineering school admission in the first application year on educational choices and attainment.

	Reapplied for engineering studies (1)	Reapplied to elite school (2)	Discontinued initial program (3)	Changed field of study (4)
Elite admission	-0.230***	-0.242***	-0.209**	-0.0363
	(0.059)	(0.048)	(0.085)	(0.063)
Counterfactual mean	0.367	0.257	0.521	0.166
N	1056	1101	676	675
	Changed engineering school (5)	**Eventually admitted to elite school (6)**	**Enrolled in engineering studies (7)**	**Enrolled at elite school (8)**
Elite admission	-0.272***	0.742***	0.0828	0.630***
	(0.050)	(0.046)	(0.051)	(0.052)
Counterfactual mean	0.251	0.224	0.864	0.267
N	916	926	700	941
	Completed engineering degree (9)	**Graduated from elite school (10)**	**Engineering ECTS points (11)**	**Engineering degree completion time (years) (12)**
Elite admission	0.030	0.390***	-13.50	0.964**
	(0.086)	(0.063)	(13.38)	(0.375)
Counterfactual mean	0.545	0.162	236.166	6.651
N	721	922	977	356

*When measuring enrolment and degree completion, only university-level engineering studies are accounted for. A student is defined as having discontinued the initial program in the case of not enrolling for two years or more. Enrolment in engineering studies and elite school measured within 11 years from the first application year. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

school, whereas the estimated effect on changing the field of study from engineering to something else is small and statistically insignificant.

Based on the finding that many of the rejected applicants discontinue their initial program and reapply to the elite school, the examined applicants appear to highly appreciate the elite school and be more satisfied with the elite school study programs compared to their fallback options. Consequently, we see in column (6) of Table 4 that 22% of the marginally rejected candidates eventually gain admission to the elite school. This result highlights a problem involved in identifying the effect of attending one's preferred higher education institution: when individuals can apply several times, a sharp discontinuity in the probability of gaining admission to the preferred school in the first application year does not imply as sharp a change in the probability of ultimately attending the school.[14]

As further shown in column (8) of Table 4, even with the significant number of students switching institutions after the initial admission decision, admission to the elite engineering school in the first application year increases one's probability of ultimately enrolling at the elite school by 63 percentage points. According to column (10), admission also increases the probability of graduating from the elite school over the next 11 years by 39 percentage points, i.e. it more than triples the baseline probability (0.16). Meanwhile, columns (7) and (9) show that the marginal elite school admittees are slightly more likely, compared to the marginally rejected candidates, to enrol in engineering studies (by 8 percentage points) and to complete an engineering degree (by 3 percentage points), but these differences are not statistically significant.[15] Altogether, these findings suggest that, among the studied group of applicants, admission to the elite school primarily affects the choice of institution and not completion of M.Sc. engineering studies. Consequently, differences in engineering-field-specific educational attainment are unlikely to significantly contribute to differences in other outcomes between applicants marginally admitted and rejected by the elite engineering school.

The small and statistically insignificant estimate regarding the effect of elite engineering school admission on the accumulated engineering-field-specific ECTS points in column (11) of Table 4 also supports the view that admission to the elite school does not significantly impact eventual educational attainment.[16] However, the estimate in column (12) indicates that admission leads to a year longer average time to complete the first engineering degree among those graduated from at least one degree program during the 11-year period. Thus, those initially admitted to the next best institution have the advantage of entering the graduate labor market earlier, which may impact our results regarding the early-career labor market outcomes.

[14]Due to the fuzzy discontinuity in the probability of enrolling in the elite engineering school, we also estimated fuzzy RD models, the results of which are presented in Appendix A, Table A2.

[15]Here both B.Sc. and M.Sc. degrees are accounted for when defining graduates. However, all students are initially admitted to an M.Sc. engineering program, and the share of master's degrees of the completed degrees is over 96%.

[16]As applicants for M.Sc. engineering programs can also participate in other types of degree programs, we also examined the effects of elite engineering school admission on the probability of completing any higher education and the total amount of ECTS points completed, finding insignificant results.

4.3 Labour market outcomes

So far we have established that admission to the elite engineering school in the first application year is associated with a more advantaged peer group and a higher probability of completing a degree at that school. However, it appears that admission does not to make a large difference in terms of average early-career labor market performance, as indicated by Table 5. While the coefficient estimate for the effect of elite school admission on the 11^{th}-year logarithmic annual earnings in column (1) is positive, indicating an 8% increase in earnings, this estimate is imprecise and statistically insignificant. The estimated effects on average daily earnings and days worked are also close to zero and insignificant. The final column of Table 5 demonstrates that marginally accepted and rejected elite school candidates have an approximately similar 65% chance of residing in the Uusimaa region, where the elite engineering school is located, in the 11^{th} year. Therefore, eventual access to the Helsinki metropolitan labor market area is approximately the same for the two groups and is unlikely to generate differences in labor market outcomes.

According to the full year-by-year results presented in Figures 1a–1d, the income effects of elite school admission remain close to zero during the entire 11-year period following the first application year. While elite school admittees appear to accumulate less days worked than rejected applicants during the first five years after the first application year, the later differences between the groups are systematically close to zero. Furthermore, we see, logically, that admission to the elite engineering school initially increases one's probability of residing in the Uusimaa region by 32 percentage points, whereas after the second year this difference begins to diminish due to interregional migration and becomes approximately zero in the 9^{th} year.

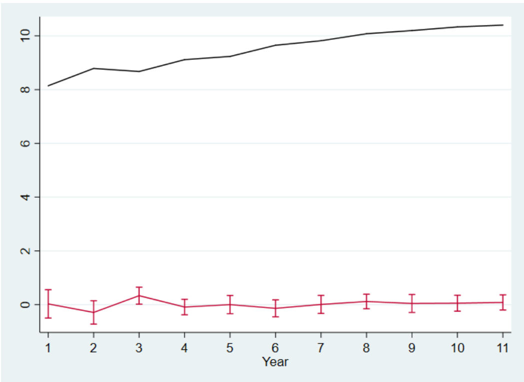
Naturally, the insignificant estimates obtained regarding the average effects of elite school admission on early-career labor market outcomes do not rule out the possibility

Table 5: Regression discontinuity results. The effects of elite engineering school admission in the first application year on 11^{th}-year labor market outcomes.

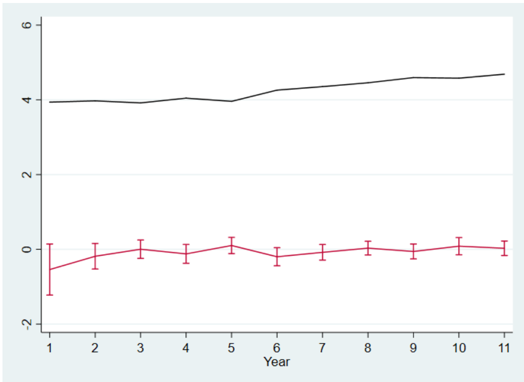
	Log annual earnings (1)	Log daily earnings (2)	Days worked (3)	Residing in Uusimaa region (4)
Elite admission	0.0805	0.0276	-0.818	0.0167
	(0.144)	(0.098)	(10.73)	(0.076)
Counterfactual mean	10.402	4.687	343.188	0.645
N	803	628	811	728

*Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

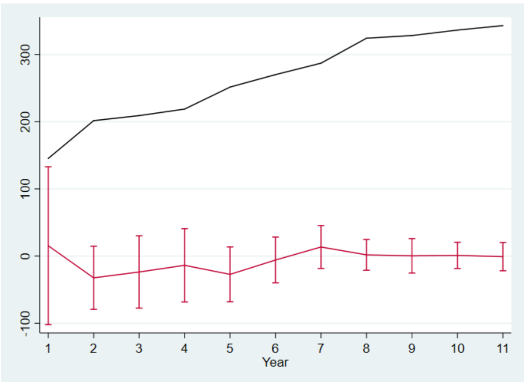
that there are significant effects for certain subgroups of elite school applicants. The sub-sample results in Table 6 indeed suggest that the effects of elite school admission are somewhat heterogeneous with respect to the prior educational achievement of applicants and their parents. For applicants originating from low-educated families, in which neither parent has a higher education degree, we find a positive and statistically significant effect of 0.37 on logarithmic annual earnings and a slightly smaller



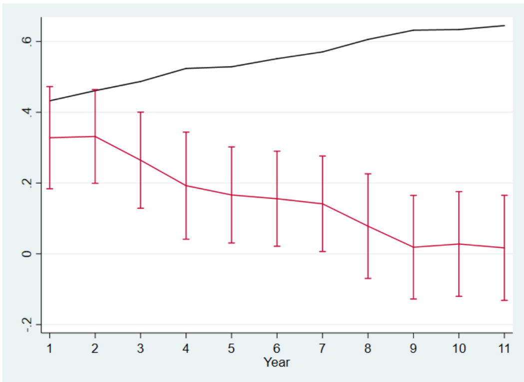
a. Log annual earnings



b. Log daily earnings



c. Days Worked



d. Residing in Uusimaa region

Figure 1: Regression discontinuity results year by year within 11 years from the first application year.

The red lines describe the RD estimates and their 95% confidence intervals, while the black line depicts the counterfactual mean outcomes.

Table 6: Regression discontinuity results. The effects of elite engineering school admission in the first application year on 11th-year labor market outcomes for sub-groups.

	Log annual earnings (1)	Log daily earnings (2)	Days worked (3)	Residing in Uusimaa region (4)
A. By parental education				
Neither parent has bachelor's degree or higher				
Elite admission	0.369**	0.250*	14.91	0.145
	(0.144)	(0.128)	(13.40)	(0.121)
Counterfactual mean	10.294	4.545	340.455	0.521
N	301	269	298	315
At least one parent has bachelor's degree or higher				
Elite admission	-0.215	-0.155	-24.33	-0.086
	(0.241)	(0.144)	(18.56)	(0.097)
Counterfactual mean	10.512	4.792	350.292	0.747
N	370	280	405	437
B. By matriculation examination grades				
First language grade M (4/6) or higher				
Elite admission	0.304*	0.141	8.585	0.1278
	(0.158)	(0.151)	(12.22)	(0.110)
Counterfactual mean	10.334	4.625	343.097	0.587
N	294	244	382	333
First language grade below M (4/6)				
Elite admission	-0.124	-0.116	-8.944	0.002
	(0.264)	(0.141)	(18.89)	(0.102)
Counterfactual mean	10.459	4.741	343.326	0.641
N	399	373	406	451
Advanced math grade M (4/6) or higher				
Elite admission	-0.048	0.075	-8.769	0.060
	(0.240)	(0.133)	(21.07)	(0.104)
Counterfactual mean	10.486	4.709	343.648	0.592
N	375	343	400	426
Advanced math grade below M (4/6)				
Elite admission	0.030	-0.087	12.12	0.025
	(0.255)	(0.207)	(16.52)	(0.137)
Counterfactual mean	10.415	4.673	347.554	0.641
N	194	206	177	224

*Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

effect of 0.25 on logarithmic daily earnings 11 years after the first application year. For this applicant group, the estimated effects on days worked and the probability of residing in the Uusimaa region are likewise positive but not statistically significant given the large standard errors. Nevertheless, it is conceivable that higher access to the metropolitan labor market area partly explains the large earnings effect from elite school admission observed for this sub-sample. For applicants with at least one highly educated parent, none of the estimated effects on labor market outcomes or residential location is statistically different from zero due to imprecision in the estimates. The fairly large negative point estimates regarding the effects on earnings nevertheless point towards the conclusion that applicants originating from educationally advantaged families may be better off if assigned to their next best institution in terms of early-career labor market performance.

The lower part of Table 6 further examines the effects of elite engineering school admission for applicants with relatively high and low matriculation examination grades in first language and advanced math, using grade M (4/6) as the high-grade threshold. These effects are imprecisely estimated and mainly too small to be statistically distinguishable from zero. However, for applicants with a high first language grade, we find a positive and weakly significant effect of 0.30 on logarithmic annual earnings. Therefore, apart from the children of low-educated parents, those with relatively good language skills appear to benefit from going to the elite school.

5 Conclusions

The admission score cutoffs in the centralized admission system for Finland's M.Sc. engineering programs generate a credible quasi-experimental research design for investigating whether being assigned to an elite engineering school versus a less competitive engineering institution matters in terms of one's early-career educational and labor market outcomes. By exploiting this design, we show that applicants marginally admitted to the elite school in their first application year begin their studies in the company of more academically and socioeconomically advantaged peers and have a 39 percentage point higher probability of eventually graduating from the elite school compared to their marginally rejected counterparts. While admission to the elite school does not appear to affect one's probability of completing an engineering degree among the studied group of applicants, admission is associated with a longer average completion time and, consequently, postponed transition to the labor market.

Despite these significant effects on the type of engineering institution attended and the length of studies, our results suggest that admission to the elite engineering school does not, on average, matter in terms of early-career labor market outcomes. However, the mean effects appear to mask significant heterogeneity, and we find that applicants from low-educated families, in particular, benefit from elite school admission. This finding is consistent with the previous results of Dale and Krueger (2002), which suggest that only students with disadvantaged backgrounds significantly gain from higher college selectivity.

Our insignificant results regarding the average labor market returns to elite school admission are again in contrast with the previous regression discontinuity results of Hoekstra (2009), Zimmerman (2019) and Anelli (forthcoming), which point towards substantial average returns to attending selective higher education institutions. However, certain differences in study contexts may explain the differences between our and previous evidence. In particular, unlike in previous studies, our results reflect the returns to elite school assignment within the engineering field among students whose subsequent engineering-field-specific educational attainment is highly similar. Therefore, reconciling our findings with previous evidence, it is possible that attending an elite institution conditional on choosing the engineering field matters less than attending an elite institution in general. An alternative explanation for the relatively low elite school returns is that, in Finland, the overall income dispersion and therefore the expected labor market returns to education are generally lower compared with the countries studied previously (U.S., Chile and Italy). A shortcoming of our analysis, which is also present in most of the previous studies, is that we can only examine early-career labor market outcomes. Therefore, our results do not rule out the possibility that higher benefits from attending a selective engineering institution appear in students' later careers.

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A Additional tables and figures

Table A1: Summary statistics. Engineering program admission score cutoffs by university and admission round in the DIA joint admission, 2000-2004.

University	Round 1 admission cutoffs			Round 2 admission cutoffs			Round 3 admission cutoffs		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
Aalto University (f.k.a. University of Technology)	11	31.2	105	6.3	36.1	58.8	7.2	18.7	37.4
Tampere University of Technology	8	27.2	99	10.2	31.1	51.5	5	16.3	31.9
Lappeenranta University of Technology	4	23.3	100	9.9	19	29.9	5	8.3	15.2
University of Oulu	8	21.7	91	7	22.4	46.9	1.1	10.2	27.4
Åbo Akademi University	11	21.8	56	14	19.5	25	2.8	5	11.9
University of Turku	12	14.3	19	14	18.7	21.7	1.7	4.2	7.4
University of Vaasa	11	14.5	18	10	12	14	5	13.2	21.3

Round 1 admission score is based on matriculation exam grades and preference points. Round 2 admission score is based on matriculation exam grades, entrance exam points and preference points. Round 3 admission score is based on entrance exam points and preference points.

Table A2: Fuzzy regression discontinuity results. The effects of elite engineering school enrolment.

	Completed engineering degree (1)	Graduated from elite school (2)	Engineering ECTS points (3)	Engineering degree completion time (years) (4)
Elite enrolment	0.064	0.626***	-21.12	1.363***
	(0.119)	(0.087)	(19.67)	(0.470)
N	823	860	1 007	871
	Log annual earnings (5)	Log daily earnings (6)	Days worked (7)	Residing in Uusimaa region (8)
Elite enrolment	0.183	0.041	-1.108	0.073
	(0.197)	(0.145)	(15.65)	(0.102)
N	1007	630	811	893

*The fuzzy RD estimates were obtained by using admission to the elite school in the first application year as an instrument for enrolment at the elite school. Robust standard errors in parentheses.*** p<0.01, ** p<0.05, * p<0.1.*

Table A3: Fuzzy regression discontinuity results. The effects of elite engineering school enrolment for sub-groups.

	Log annual earnings (1)	Log daily earnings (2)	Days worked (3)	Residing in Uusimaa region (4)
A. By parental education				
Neither parent has bachelor's degree or higher				
Elite enrolment	0.509***	0.329*	20.97	0.249*
	(0.191)	(0.147)	(16.46)	(0.142)
N	327	349	320	351
At least one parent has bachelor's degree of higher				
Elite enrolment	-0.342	-0.292	-41.43	-0.176
	(0.394)	(0.225)	(29.01)	(0.181)
N	393	317	461	404
B. By matriculation examination grades				
First language grade M (4/6) or higher				
Elite enrolment	0.615**	0.270*	18.02	0.232
	(0.250)	(0.221)	(21.25)	(0.181)
N	373	269	311	326
First language grade below M (4/6)				
Elite enrolment	-0.253	-0.112	-14.34	-0.0478
	(0.361)	(0.161)	(25.39)	(0.154)
N	355	444	370	395
Advanced math grade M (4/6) or higher				
Elite enrolment	-0.988	0.061	-16.47	0.156
	(0.409)	(0.221)	(36.71)	(0.158)
N	376	385	390	502
Advanced math grade below M (4/6)				
Elite enrolment	0.323	-0.107	23.00*	0.020
	(0.263)	(0.242)	(13.94)	(0.171)
N	300	217	260	237

*The fuzzy RD estimates were obtained by using admission to the elite school in the first application year as an instrument for enrolment at the elite school. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

Table A4: Regression discontinuity results using applicants who were or would have been admitted to the same major if not admitted to the elite school.

	Reapplied for engineering studies (1)	Reapplied to elite school (2)	Discontinued initial program (3)	Changed field of study (4)
Elite admission	-0.221***	-0.202***	-0.047	0.089
	(0.059)	(0.048)	(0.043)	(0.063)
Counterfactual mean	0.367	0.257	0.158	0.166
N	285	347	242	234
	Changed engineering school (5)	**Eventually admitted to elite school (6)**	**Enrolled in engineering studies (7)**	**Enrolled at elite school (8)**
Elite admission	-0.330***	0.740***	0.170*	0.638***
	(0.071)	(0.070)	(0.099)	(0.088)
Counterfactual mean	0.251	0.224	0.864	0.267
N	260	353	262	338
	Completed engineering degree (9)	**Graduated from elite school (10)**	**Engineering ECTS points (11)**	**Engineering degree completion time (years) (12)**
Elite admission	0.177	0.522***	-4.076	0.320
	(0.126)	(0.095)	(13.38)	(0.561)
Counterfactual mean	0.545	0.162	236.166	6.651
N	314	346	283	148
	Log annual earnings (13)	**Log daily earnings (14)**	**Days worked (15)**	**Residing in Uusimaa region (16)**
Elite admission	0.328	0.052	-4.171	0.165
	(0.238)	(0.142)	(17.13)	(0.118)
Counterfactual mean	0.545	0.162	236.166	6.651
N	312	302	280	292

The employed sample includes applicants for whom the major of the least competitive elite engineering school program option and next best program option were the same. A student is defined as having discontinued the initial program in the case of not enrolling for two years or more. Robust standard errors in parentheses.
**** p<0.01, ** p<0.05, * p<0.1.*

Table A5: Sub-sample-specific discontinuities in expected earnings index at the elite engineering institution admission cutoff.

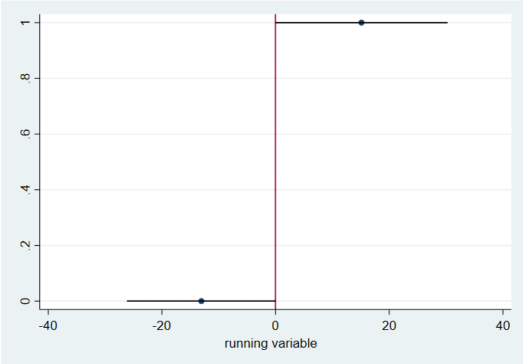
	Expected earnings index	
A. By parental education		
	Neither parent has bachelor's degree or higher	At least one parent has bachelor's degree or higher
Elite admission	0.016	0.005
	(0.021)	(0.023)
N	281	436
B. By matriculation examination grades		
	First language grade below M	First language grade M or higher
Elite admission	0.001	-0.046
	(0.019)	(0.031)
N	332	311
	Advanced math grade below M	Advanced math grade M or higher
Elite admission	-0.047	-0.026
	(0.037)	(0.024)
N	225	480

*The expected earnings index is a prediction from a regression of applicants' 11th-year logarithmic annual earnings on the background characteristics listed in Table 1. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*

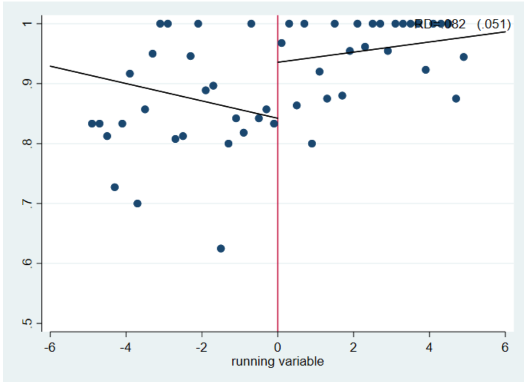
Table A6: Regression discontinuity results controlling for applicants' background characteristics.

	Enrolled in engineering studies (1)	Enrolled in elite school (2)
Elite admission	0.076	0.633***
	(0.051)	(0.053)
Counterfactual mean	0.864	0.267
N	700	941
	Completed engineering degree (3)	Graduated from elite school (4)
Elite admission	0.023	0.399***
	(0.087)	(0.064)
Counterfactual mean	0.548	0.160
N	721	922
	Engineering ECTS points (5)	Degree completion time (years) (6)
Elite admission	-13.71	0.807**
	(12.39)	(0.390)
Counterfactual mean	236.920	6.755
N	977	346
	Log annual earnings (7)	Log daily earnings (8)
Elite admission	0.100	0.053
	(0.142)	(0.095)
Counterfactual mean	10.397	4.674
N	803	628
Variable	Days worked (9)	Residing in Uusimaa region (10)
Elite admission	-0.809	0.069
	(10.52)	(0.071)
Counterfactual mean	343.736	0.620
N	811	728

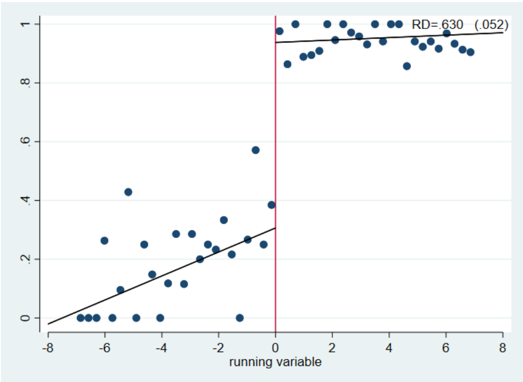
*The additional control variables include the background characteristics listed in Table 1. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.*



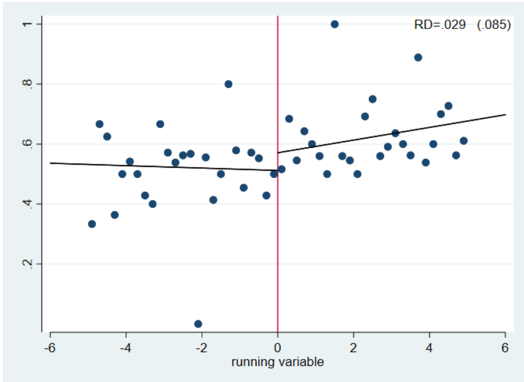
a. Admitted to elite school



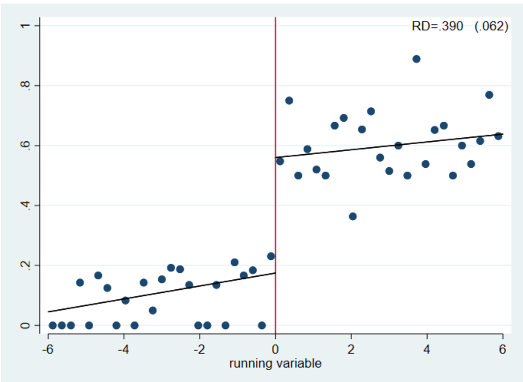
b. Enrolled in engineering studies



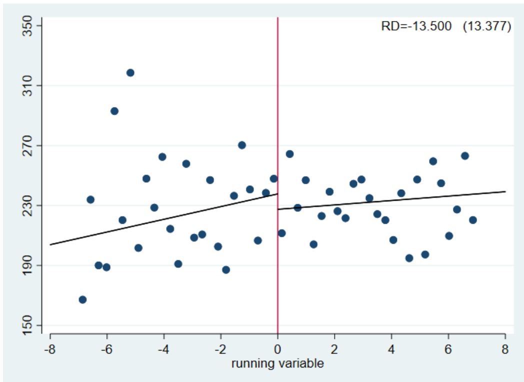
c. Enrolled at elite school



d. Completed engineering degree



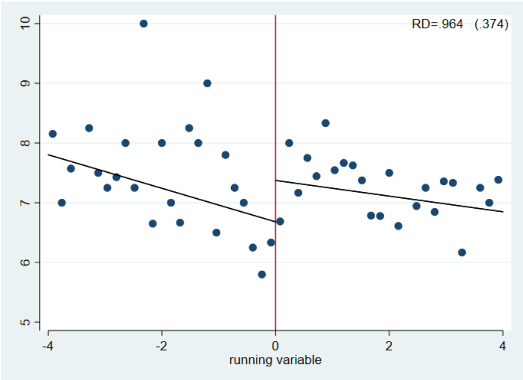
e. Graduated from elite school



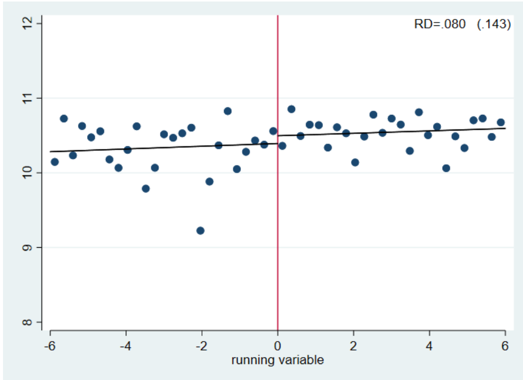
f. Engineering ECTS points

Figure A.1: Graphical illustration of discontinuities at the elite engineering school admission cutoff.

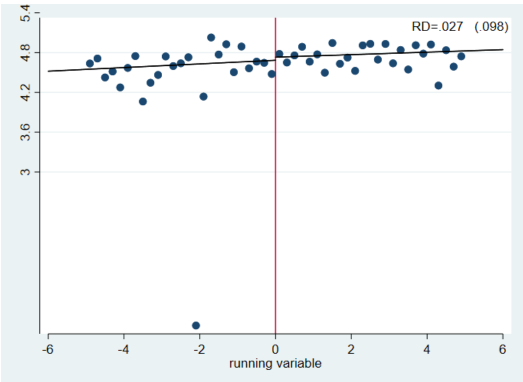
The red vertical line represents the elite engineering school's admission cutoff, while the dots depict bin-specific averages of the outcome. There are 25 bins on either side of the cutoff. The estimated discontinuity at the cutoff is reported in the top-right corner of each graph.



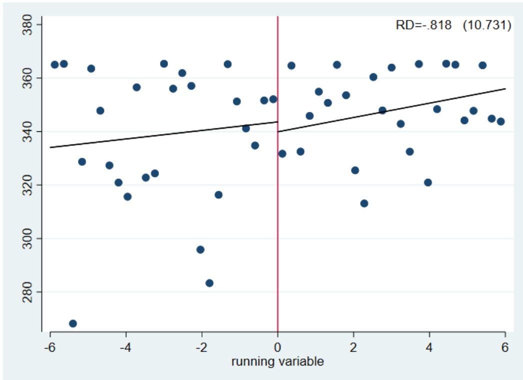
g. Engineering degree completion time (years)



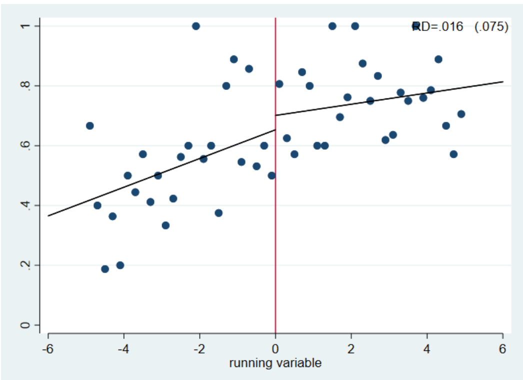
h. Log annual earnings



i. Log daily earnings



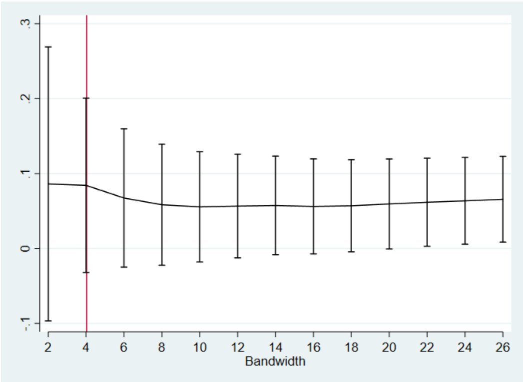
j. Days worked



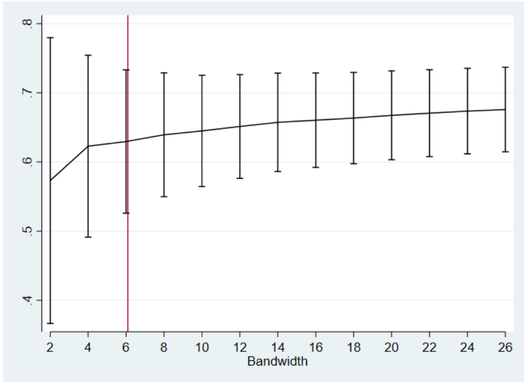
k. Residing in Uusimaa region

Figure A.1: Continued.

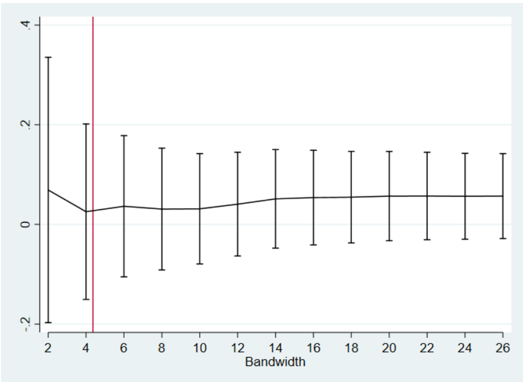
The red vertical line represents the elite engineering school's admission cutoff, while the dots depict bin-specific averages of the outcome. There are 25 bins on either side of the cutoff. The estimated discontinuity at the cutoff is reported in the top-right corner of each graph.



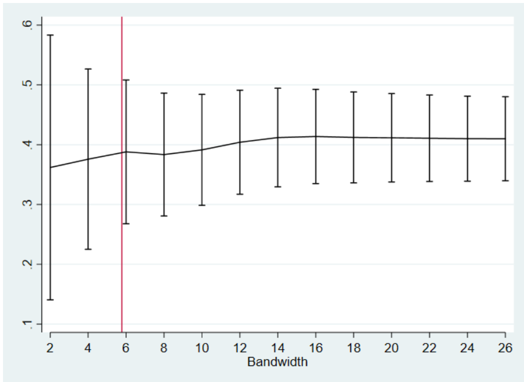
a. Enrolled in engineering studies



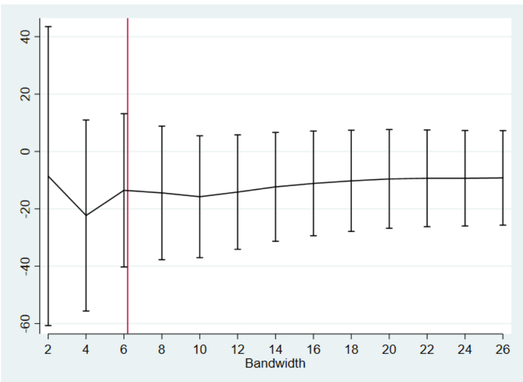
b. Enrolled at elite school



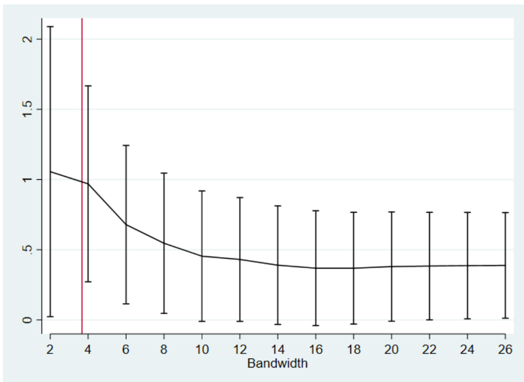
c. Completed engineering degree



d. Graduated from elite school



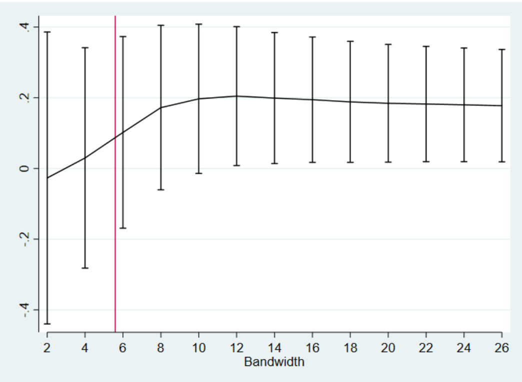
e. Engineering ECTS points



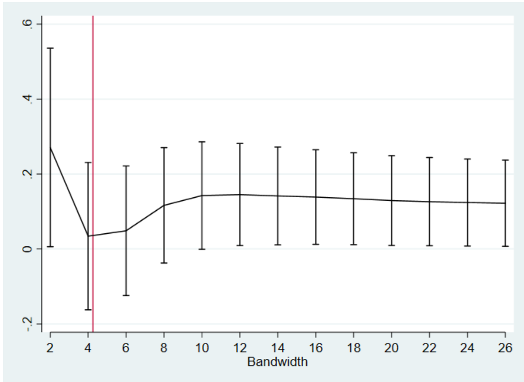
f. Engineering degree completion time (years)

Figure A.2: Sensitivity of regression discontinuity results to bandwidth selection.

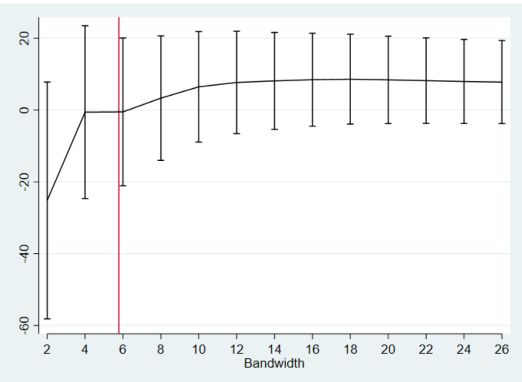
The red vertical line depicts the optimal bandwidth used in the estimation, while the black lines represent RD estimates and their 95% confidence intervals using alternative bandwidths.



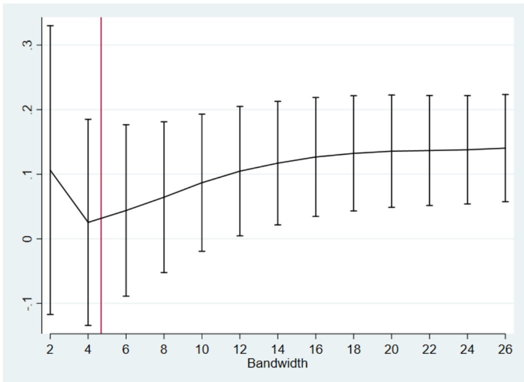
g. Log annual earnings



h. Log daily earnings



i. Days worked



j. Residing Uusimaa region

Figure A.2: Continued.

The red vertical line depicts the optimal bandwidth used in the estimation, while the black lines represent RD estimates and their 95% confidence intervals using alternative bandwidths.