Essays in the Economics of Education

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Abstract

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The thesis explores two main topics, Catholic schools in a school choice setting and decentralization of education decision making. The first chapter uses Chilean data to assess the impact of Catholic versus secular voucher or public school attendance on student outcomes. I address admission selection bias by leveraging exogenous variation from school admission lotteries and controls for students' probability of securing a seat in each type of school. My causal estimates reveal that students attending Catholic schools have a 17 percent higher probability of taking the college entry exam (CEE) than those who attend secular public schools. Additionally, Catholic school attendance raises students' chances of scoring above the national mean by 33 percent in math and 45 percent in reading. Catholic school attendance also increases students' probability of applying and being accepted to college. Nevertheless, attending Catholic schools raises dropout rates for boys with low baseline ability. Notably, the positive CEE effects are driven by girl students; however, attending a Catholic school appears to dissuade girls from pursuing STEM majors. Survey evidence reveals that Catholic schools have stricter disciplinary measures and foster higher levels of parent involvement than other public and secular institutions—characteristics commonly associated with high-achieving charter schools. The second chapters explore how student selection changed in terms of socioeconomic characteristics and baseline ability after a centralized school admission system (CAS) was mandated to all publicly funded schools in Chile. That includes private Catholic and secular runned institutions as well as public schools. Estimating a difference in difference model with multiple time periods,

leveraging the regional staggered implementation of the CAS. Results indicate that after the centralized admission system (CAS) started, private Catholic schools enrolled a higher proportion of lower-income and lower-ability students than before, this effect is also positive for private-secular and public-schools, but in a lower magnitude. Finally, the third chapter evaluates the effects of the administrative decentralization of education on teacher quality and student outcomes in Colombia. In 2001, the government established an arbitrary rule that granted municipalities with a 2002 population greater than 100,000 almost complete autonomy to provide education services (certification). This analysis takes advantage of this rule to evaluate, using difference-in-differences and regression discontinuity methodologies, the effect of municipal autonomy on teacher quality and student outcomes, including achievement and enrollment. The control group is made up of municipalities for which the provision of education was centralized and managed by the departmental authorities. The results indicate that administrative decentralization (being certified) improves both school enrollment and student achievement as well as the quality of teachers, as measured by teachers' education level and scores on teachers' entry competency exams. Using a mediation analysis, the paper finds that higher-quality teachers hired by the certified municipalities partially explained the improvement in student achievement. This analysis also shows that "certified" municipalities invest more local resources in education which also contributes to explain to a much lesser extent their superior educational outcomes. Finally, the results suggest that achieving better student outcomes is less related to the amount of resources that decentralized municipalities managed and more associated with the fact that those resources seem to have been better allocated, generating significant efficiency gains. These gains may be the consequence of lower transaction costs of matching local preferences with local educational interventions.

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Dedication

To my beloved parents and grandmother, thank you for always being my rock and safe harbor. Knowing that I can count on you, no matter what, gives me the courage and freedom to pursue my dreams. Your unwavering support and love mean everything to me, and I am endlessly grateful for all that you do.

To my dear brother, your courage and strength have been a constant source of inspiration for me. You remind me of what truly matters in life and encourage me to face challenges head-on. Thank you for always being there as a pillar of strength and wisdom.

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Chapter 1: Catholic schools and student performance: Evidence from Chile's school-admission lottery

1.1 Introduction

Catholic schools are the largest nongovernmental school network in the world; they serve 62.2 million students globally, and their enrollments are surpassed in many countries only by those of state-run institutions[1]. Although Catholic schools are commonly viewed as privately administered and financed establishments, they can also access public funding through school choice programs in many countries. While Catholic schools are often recognized for consistently outperforming their public-school counterparts, the evidence regarding whether their education model truly excels in producing superior academic outcomes remains inconclusive. Furthermore, the distinctive factors that set Catholic schools apart from other educational institutions are not yet clearly defined. In this paper, I provide evidence on the effects of Catholic school attendance on student outcomes and pinpoint how the schools' similarities to high-performing charter schools may be the key mechanisms driving the results.

This study employs data from Chile to evaluate the impact of attendance of Catholic relative to both public and other voucher schools on student outcomes. To address concerns related to potential admission selection bias within Catholic schools, I use exogenous variation stemming from school admission lotteries and control for students' probability of securing a seat in schools of different types. This method enables me to control for factors that cannot be observed and that are linked to parental and student preferences for specific school models, effectively mitigating any potential bias arising from student selection during the admission process.

The paper estimates Catholic schools' academic value-added with experimental variation, en-

[1] Wodon, 2020

abling the disentanglement of Catholic-run institutions' value-added from that of secular voucher and public schools. I accomplish this by comprehensively identifying all publicly funded schools, comprising both privately administered religious and secular institutions—financed through vouchers—and public schools. This paper also seeks to enhance our comprehension of the diverse educational models adopted by various types of schools. This analysis relies on comprehensive administrative data on school characteristics and integrates surveys conducted among students, parents, and teachers.

The Chilean context provides an ideal setting for studying the impact of attending a Catholic school. More than 90 percent of schools in Chile admit students through lotteries; both secular and religious institutions privately administer approximately 50% of these schools and receive financing through public school vouchers. This admissions model can be attributed to a 2016 governmental mandate that required all publicly funded schools to adopt a centralized admission system (CAS). The CAS employs a lottery-based mechanism to break ties in oversubscribed schools. The lottery system operates using a deferred acceptance algorithm and ensures that applicants with the same preferences and priorities for school assignments have equal probabilities of securing seats.

Within the collective pool of voucher schools, Catholic-run institutions account for over 14 percent of student enrollment, constituting 15 percent of national primary and secondary enrollment. Over the years, these schools have consistently exhibited superior standardized test performance relative to their public and privately administered counterparts.

The impact of attending Catholic schools has been extensively examined in the United States. Previous studies, including Evans and Schwab, 1995, Neal, 1997, Jepsen, 2003, and Altonji et al., 2005, have reported mostly positive effects on various academic outcomes. However, these studies often rely on strong identifying assumptions because of the challenges posed by selection into those schools. Factors such as parental preferences or selective admissions processes complicate the estimation. To address these concerns, this paper leverages the CAS and exploits the exogenous variation resulting from the school admission lottery. This methodology is similar to those used to evaluate privately administered charter schools in the United States (Abdulkadiroglu et al., 2017;

Dobbie and Fryer, 2011; Clark et al., 2015;Angrist et al., 2016 ; Dobbie and Fryer, 2015). In this way, this study overcomes the validity issues associated with selection biases, providing more reliable estimates. Furthermore, I not only focus on Catholic schools as representatives of privately administered institutions but also explore the distinctions between Catholic schools, secular private institutions, and public schools.

This paper utilizes anonymized national-level public data sources. I primarily draw on microdata originating from the Chilean CAS ninth-grade lottery applications for 2018 and data on student outcomes. Additionally, I incorporate prior standardized test results and student sociodemographic characteristics. The outcome measures are obtained from the Department of Evaluation, Measurement, and Educational Registry (DEMRE) and encompass indicators such as school retention, college entry exam results, and college application and admission records for the year 2022.

To estimate the causal effect of attending a Catholic school in 2018, I instrument enrollment with the offer of a seat obtained through the lottery process, while also accounting for the student's likelihood of securing a seat at a voucher Catholic or voucher secular school. After I control for this probability, I find no significant baseline differences between students who are offered and not offered a seat in a Catholic school.

My estimations indicate positive causal impacts of attending a Catholic school on college-entry exam participation and academic performance, particularly in math and reading. Additionally, the results show a positive effect of attending these schools on college application and acceptance rates. Furthermore, attending Catholic schools appears to influence students' preferences, notably leading to a higher likelihood of their choosing health-related majors, potentially reflecting the influence of religiosity in promoting prosociality, a trait commonly associated with health workers.

A gender-based analysis reveals that the positive effect of attending a Catholic school on test results is driven entirely by girls. However, only male students appear to benefit from attending Catholic schools with regard to college acceptance rates. Female students attending Catholic schools appear to shy away from applying to STEM majors and are instead inclined toward health-

related disciplines. This pattern is notably absent among male students.

While neither female nor male students in Catholic schools exhibit significant effects on dropout rates compared to their respective public school peers, it is noteworthy that male students in Catholic schools demonstrate a substantive increase in dropout rates (this increase lacks statistical significance). Furthermore, I observe positive and significant dropout effects for boys with low baseline math ability when I stratify by baseline math ability and gender.

Survey evidence reveals that, before the CAS was mandated and student selection was banned, Catholic schools employed more selective admissions processes. Furthermore, Catholic institutions appear to maintain stricter disciplinary measures and foster higher levels of parent involvement. Students attending Catholic schools also demonstrate better overall behavior than voucher secular and public school students; these characteristics resemble those commonly associated with high-achieving charter schools that follow the Knowledge Is Power Program (KIPP) and no-excuses models in the United States. On the other hand, public school students perceive a stronger sense of support and appreciation from their teachers than do Catholic school students.

This paper makes significant contributions to the related literature across several dimensions. First, it adds to the literature discussing Catholic schools by presenting rigorous lottery-based evidence that sheds light on the impacts of attending Catholic schools. Previous papers, including Evans and Schwab, 1995, Neal, 1997, Jepsen, 2003, and Altonji et al., 2005, have relied on very strong assumptions for identification. Mine is the first investigation to study Catholic schools in a lottery context, which simulates random assignment to schools while I control for student preferences.

Second, this work expands our comprehension of how Catholic schools, in comparison to other private educational institutions, influence academic outcomes. In doing so, it contributes significantly to the broader literature investigating the causal effects associated with enrollment in privately managed educational establishments. While charter schools in the United States have received extensive scrutiny (Abdulkadiroglu et al., 2017; Dobbie and Fryer, 2011; Clark et al., 2015; Angrist et al., 2016; Dobbie and Fryer, 2015; Cohodes and Feigenbaum, 2021), they primarily

operate as secular institutions. Catholic schools, conversely, introduce a religious component into the educational landscape, offering potential insights into how distinct educational models shape student outcomes. Furthermore, it is noteworthy that Catholic schools represent a widely replicated model in the majority of countries worldwide Wodon, 2020.

Third, this study enriches our understanding of the variations in school models by harnessing comprehensive data that encapsulate the perspectives of students, teachers, and parents regarding their school experiences. It delves into essential elements such as parental engagement, academic rigor, and other school characteristics and highlights the parallels between Catholic schools and high-achieving charter schools in the US.

Fourth, this study conducts a comprehensive analysis of the disparate effects of attending Catholic schools on both male and female students; it extends the body of literature that suggests that high-performing schools tend to predominantly benefit girls (Deming et al., 2014, Cohodes and Feigenbaum, 2021, Hastings et al., 2006). This investigation further contributes to the broader literature on heterogeneous effects by gender of educational interventions, which consistently reveals advantages accruing primarily to girls rather than to boys (Anderson, 2008, Kling et al., 2007, Angrist and Lavy, 2009, Angrist et al., 2009).

Last, this study contributes to the field of gender economics by offering evidence suggesting that religious schools may play a role in the gender gap observed in STEM major choice. This finding offers fresh insight into the multifaceted factors influencing gender disparities in STEM fields, as exemplified by Speer, 2017; Mcnally, 2020; Jiang, 2021; Bordóna et al., 2020; Landaud et al., 2020; and Delaney and Devereux, 2021. It is worth noting that this study's findings do not conclusively disentangle whether the negative effects on female students' applications to STEM majors are driven primarily by their graduating from high-performing schools, as observed in the research by Landaud (2020), or if religious affiliation also plays a significant role.

The rest of this paper is organized as follows: Section 1.2 provides a concise overview of the Chilean education system and recent educational reforms, with specific attention to the Centralized Admission System. Section 1.3 describes the data sources and sample composition, while Section

1.4 expounds upon the chosen identification strategy. Section 1.5 presents the empirical results related to academic outcomes, and Section 1.6 further dissects these findings and considers gender and baseline academic aptitude. In Section 1.7, the paper delves into potential mechanisms and elucidates distinctions in school model characteristics among different types of schools. Finally, Section 1.8 concludes the study and discusses the findings and implications for policy.

1.2 Context and Setting

1.2.1 Chilean school system

The Chilean educational system is primarily organized into three distinct categories. The first comprises public schools managed by governmental authorities, the second includes privately managed schools that receive public funding through vouchers, and the third consists of entirely private schools. As of 2017, Chile was home to a total of 11,749 schools. Among these, 45% were classified as public institutions, 50% fell under the category of private institutions subsidized through vouchers, and the remaining 5% were fully private establishments.

Within the realm of publicly funded and privately managed schools, a notable subset is operated by religious organizations. Specifically, among the 5,866 voucher-receiving schools with available data on religious affiliation, 12.4% are administered by Catholic organizations, 2.2% by other religious groups (primarily Christian organizations), and the remainder are overseen by private secular entities.

1.2.2 Publicly financed schools

Table 1.1 provides an overview of the descriptive characteristics of publicly funded schools, categorized by their mode of administration. In Panel A, notable disparities emerge, where publicly managed schools demonstrate a higher prevalence of rural locations. At the same time, Catholic institutions exhibit a pronounced tendency towards single-sex education as a distinctive feature of their traditional pedagogical model. Nevertheless, it is worth noting that recent trends have seen a shift in several formerly single-sex schools toward coeducation. Regarding the student–teacher

ratio, Catholic, and Christian schools manifest similar classroom sizes, of around 19 to 21 students per teacher. On the other hand, secular voucher institutions exhibit a significantly higher student–teacher ratio, averaging 26 students per teacher. In contrast, public schools demonstrate a notably lower student–teacher ratio of 14 students per teacher. This difference may be attributed to the greater prevalence of public schools in less populated rural areas.

Panel B presents teacher-related characteristics by school type, revealing that private educational establishments feature a more substantial representation of female and tenured educators, with the contrast being particularly conspicuous between secular and publicly managed schools. The mean years of teaching experience across all institution types range from 11 to 14 years, with Christian schools employing teachers with comparatively less experience.

Turning to the composition of the student body in 2017, as depicted in Panel C, discernible disparities emerge, particularly in Catholic and other privately administered schools. These institutions display a higher enrollment of economically advantaged students, characterized by a reduced percentage of students of low-income backgrounds and a more significant proportion of students with mothers possessing higher educational attainment. Additionally, the prevalence of immigrant students is notably lower in these schools. These differences may be attributable to either selective admissions processes or, prior to the 2016 reform, privately managed schools' practice of soliciting or accepting parental contributions in exchange for admission, even while receiving public funding through vouchers.

1.2.3 Religious education

Religious education has constituted an integral element of Chile's national curriculum since 1983 and is mandated for all public schools nationwide. The curriculum prescribes a standard allocation of two hours per week for religious instruction. Nevertheless, parents retain the prerogative to request an exemption on behalf of their child, allowing the substitution of religious instruction with an alternative school activity. Notably, this opt-out option is more frequently exercised during the middle and high school years. In most public schools, the time allocated for these

classes is utilized to impart humanitarian values and provide life orientation. Importantly, these thematic areas are typically presented from the perspective of Catholic or Christian values and beliefs, as affirmed by the United Nations Development Program in Chile (PNUD) and Ministry of Education (MINEDUC) in 2017.

Conversely, the inclusion of religious education in privately managed schools varies significantly and is contingent upon the specific religious orientation of each institution. Panel D of Table 1.1 presents administrative records detailing classes offered by grade and whether attendance of them is mandatory, making evident that a substantial proportion of Catholic schools incorporate some form of religious education. Notably, religious education is mandatory in 62% of primary schools and 57% of secondary schools affiliated with the Catholic tradition. In this regard, private Christian schools exhibit patterns similar to those in Catholic schools, albeit with somewhat less stringency regarding the compulsory nature of religious classes. As expected, most public and secular private schools either allow students to abstain from religious instruction or, in some cases (particularly secondary-public institutions), do not offer such classes at all.

1.2.4 Student performance

Panel E in Table 1.1 examines student performance prior to the implementation of the Centralized Admission System. The academic performance of Catholic schools was consistently superior to that of publicly funded and privately managed educational institutions, with the former demonstrating a substantial advantage of at least one standard deviation or more. This performance differential is particularly conspicuous when Catholic schools are contrasted with public schools, with the disparity persisting at a relatively consistent level over time, at approximately 1.5 standard deviations (see Figures A.1, A.2, A.3, and A.4, in Appendix for detailed graphical representations).

Another noteworthy aspect of the data is the disparity in student performance between primary (4th-grade standardized test results) and secondary (8th-grade standardized test results) education based on school type. It is notable how the performance gap between public schools and voucher schools widens, with public school students appearing to perform worse, while voucher school

students perform better. Two possibilities could explain this trend: either public school students are experiencing a decline in performance compared to voucher school students, or low-performing students are leaving voucher schools and enrolling in public schools.

1.2.5 Reforms

Over the past decade, Chile's educational system has undergone substantial transformations aimed at addressing persistent challenges arising from the school choice framework, particularly educational disparities and segregation. In approximately 2010, the government introduced targeted subsidies for economically disadvantaged students across all publicly funded schools. This reform played a pivotal role in elevating students' test scores and reducing income-based disparities by approximately one-third within five years of its enactment, as documented by Murnane et al. (2017).

Another significant transformation followed the student movement of 2011, leading to the most comprehensive overhaul of the school system since the restoration of democracy in 1991. Implemented progressively, this reform mandated that all educational institutions benefiting from public funds refrain from activities such as profit generation, student selection based on academic or socioeconomic criteria, solicitation or acceptance of parental contributions, and the use of selective admissions criteria.

In addressing the issue of student selection, the Chilean government introduced the CAS.

1.2.6 Centralized Admission System

Under the current system, parents seeking to enroll their children in a new school or transition between schools are required to participate in the CAS. The application process involves providing basic demographic information about the students and listing their preferred schools and grade levels in order of priority. Concurrently, schools indicate the number of available vacancies for each grade level.

Then, students are assigned a priority level for each selected school. The highest priority is

Table 1.1: Publicly financed schools in Chile

	Public	**Private-Catholic**	**Private-Christians**	**Private-Secular**
A. School Characteristics				
% Single sex	1.4%	12.4%	0.0%	0.4%
% Rural	24.3%	1.1%	0.2%	6.1%
Student-teacher ratio	20	21	19	44
B. Teachers Characteristics				
% Female	69.5%	71.8%	73.4%	79.4%
% Tenured	39.4%	63.7%	57.0%	64.1%
Years of experience	*13.0*	*13.7*	*11.2*	*13.9*
C. Student Characteristics				
% Female	46.4%	53.5%	48.1%	44.9%
% Low-income	71.2%	48.5%	53.1%	53.2%
% Have Wifii	82.3%	89.5%	89.4%	89.3%
% Mother high-school	47.2%	22.6%	27.9%	27.5%
% immigrant	3.2%	1.3%	2.9%	1.8%
D. Religious education				
Primary religious class	75.5%	90.8%	91.6%	73.5%
Mandatory for primary	11.6%	62.0%	52.9%	18.4%
Secondary religious class	14.8%	64.9%	49.6%	30.4%
Mandatory for secondary	4.6%	56.8%	42.9%	12.0%
E. Standardized tests				
4th grade math	-0.17	0.36	0.42	0.17
4th grade reading	-0.15	0.31	0.36	0.16
8th grade math	-0.35	0.68	0.42	0.30
8th grade reading	-0.25	0.58	0.48	0.18
N Schools	5266	726	131	5009
% of total schools	47%	7%	1%	45%
N Students	1,317,995	490,622	58,144	1,394,646
% of total students	40%	15%	2%	43%

Source: Author's calculations using 2017 public school census data from the Chilean Ministry of Education. Note: Table 1 presents descriptive statistics of all publicly funded schools in Chile. Panel A displays the percentage of single-sex and rural schools by type, along with the student-teacher ratio. Panel B illustrates the average characteristics of teachers in each school type. Panel C outlines the average characteristics of students enrolled in each school type. Panel D indicates the percentage of schools offering religious classes at primary or secondary grade levels, along with their mandatory status. Lastly, Panel E shows the average school performance by type in 4th and 8th-grade standardized tests, measured in standard deviation units. Privately funded schools are not included in these analyses.

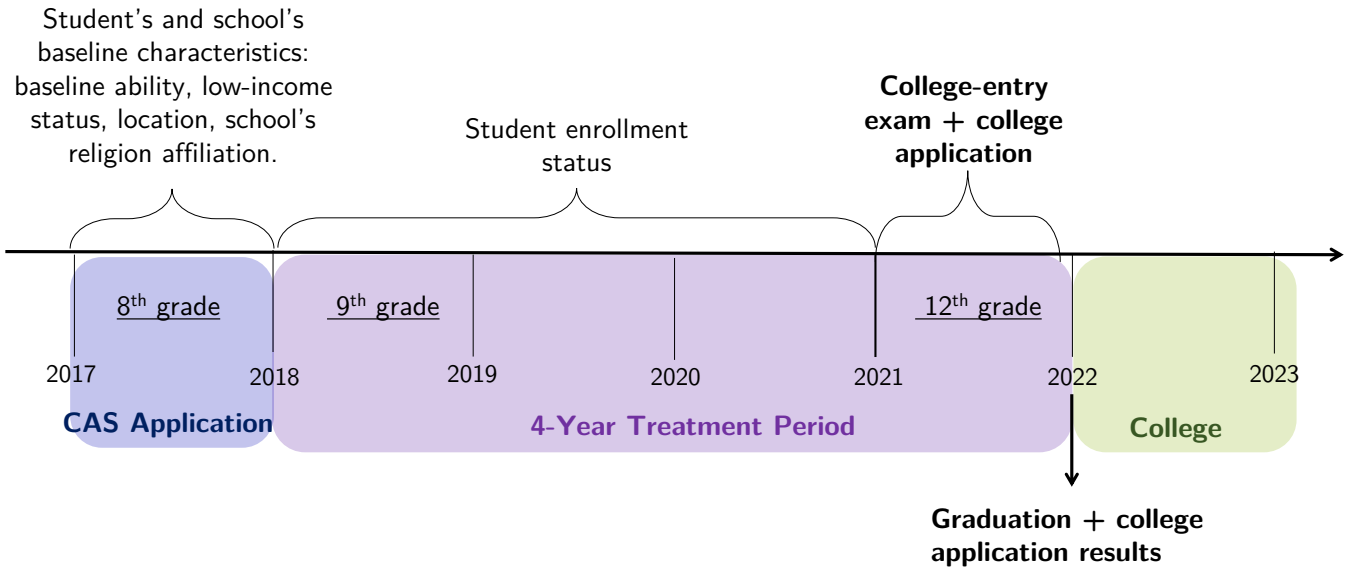
given to students who were previously enrolled in the school during the preceding academic year. The second level of priority is reserved for students with siblings already attending the same school. The third level of priority is allocated to students from low-income backgrounds, while the fourth pertains to students whose parents are employed by the school. Students who have previously attended the school are assigned the fifth priority. Next, a random lottery number is assigned to each student for every school she has applied to, which assists in breaking ties among students with equal priority status.

The entire process is managed through the deferred acceptance algorithm with multiple tie-breaking rules (DAMR algorithm) (Abdulkadiroğlu and Sönmez, 2003). The term "multiple tie-breaking rules" signifies that each student is assigned a distinct random number for each school she has applied to. Once the DAMR results are determined, a subsequent algorithm comes into play, specifically for students not assigned a school through the DAMR process. This supplementary algorithm allocates these students to the nearest available school.

The steps comprising the DAMR algorithm are as follows:

(i) A separate and uniformly distributed random lottery number is generated for each applicant–school pairing. (ii) Initially, only the most preferred school of each student is considered. Each school ranks the applicants based on priority and then by their random number within each priority group. The school provisionally admits applicants in descending order of their ranking until the school reaches its capacity. Other applicants are rejected. (iii) Subsequently, the second most preferred school for each student is considered. This school ranks the rejected applicants from the first round along with the applicants it has provisionally accepted. The school then provisionally admits the highest-ranked applicants in accordance with their ranking order and capacity. The rest are rejected. (iv) The algorithm concludes when no new applications remain. (v) Unassigned applicants are then allocated to the nearest available school.

Figure 1.1: Timeline and data



Note: Figure 1.1 depicts a timeline illustrating the time-frame of the data used for estimation, as well as the periods observed for students before and after being assigned to schools via the Centralized Admission System (CAS).

1.3 Data

The primary data sources used for estimation purposes are publicly available and include data from the Chilean CAS, student socioeconomic characteristics gathered from the national education census, and school-level data extracted from the school census. These datasets, meticulously administered and published annually by the Ministry of Education, pertain to the pre-2018 period. For the outcome variables, I draw upon data from the year 2021, sourced from the DEMRE. Access to the DEMRE data for research purposes is granted upon request.

The study focuses its analysis on students who applied to the CAS in 2017 for a seat in 9th grade in 2018. The reason for selecting this specific cohort is that, for those set to graduate in 2021, I can observe standardized test results before their participation in the CAS (2017 8th-grade standardized test results) and four years after they were assigned a school through the CAS—this is when they graduate and present the college entry exam. It also allows me to track their college application and enrollment. Because the CAS only began in 2017, selecting a cohort for analytical

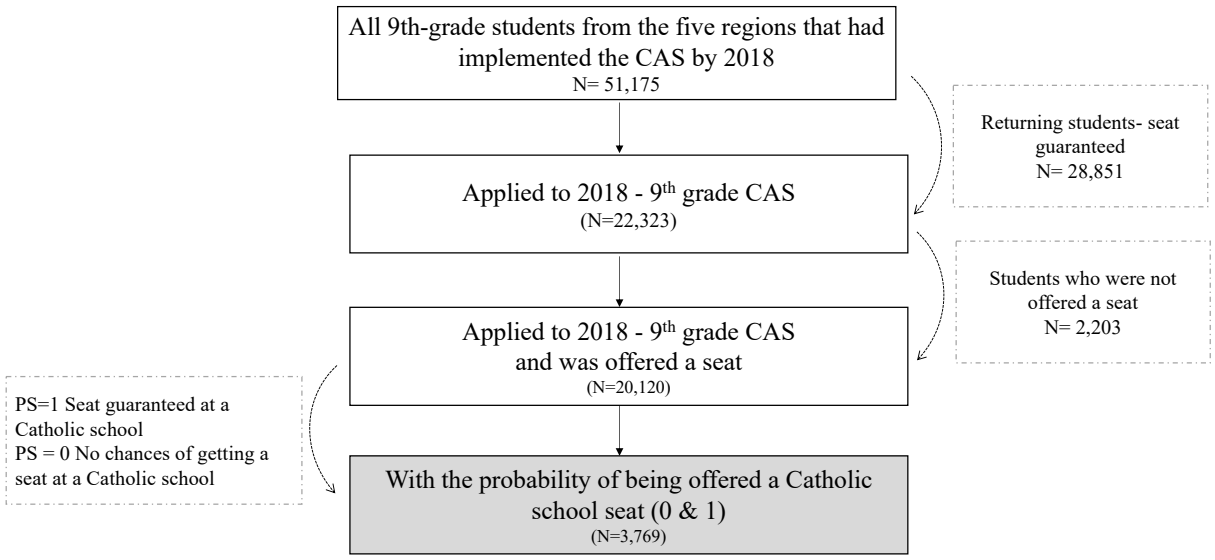
purposes requires consideration of data availability given the COVID-19 pandemic in the middle, the limited years the CAS has been in place, and providing students with sufficient exposure to the school they were assigned.

Figure 1.1 illustrates the timeline of the period the study draws upon, showcasing when students apply, are "treated" (i.e., attend the school assigned through the CAS), their graduation date, and the data used from each period.

Figure 1.6 presents a data flow diagram illustrating the process of constructing the final dataset. The dataset comprises students who applied to the CAS in 2017 for a seat in 9th grade in 2018. Not all students participated in the CAS, either because they had a guaranteed seat in their current school as continuing students or because they planned to attend a privately financed school. This is depicted in Figure 1.6, moving from the top box to the one below. From the second box to the third, of the 22,323 students, only 20,120 were assigned a seat. The 2,203 students dropped from the sample were not assigned a school through the CAS and were instead given a seat at the nearest school with available seats. From the third to the fourth and last box, only 3,769 students remain. This will be explained in more detail below, but the main idea is that I only consider students who have variation in the probability of securing a seat at a Catholic school; students who are certain to be assigned or not assigned a seat at a Catholic school do not contribute to identifying the parameter of interest.

Next, this section offers an overview of the data employed, categorizing it into two distinct groups: data collected before and data collected after 2018, with the latter serving as the outcome data. Subsequently, the section outlines the criteria used to define the treatment variable, specifically, how schools are classified as Catholic schools. Last, the study delves into the composition of the final estimation sample, highlighting any differences or similarities that it may have with the national sample of schools by school type.

Figure 1.2: Estimation sample and outcomes



Note: Figure 1.2 illustrates the sample selection process, starting from all 9th-grade students in the five regions of Chile and narrowing down to the sample of students with a probability between 0 and 1 of attending a Catholic school. The five regions that had implemented the CAS by 2018 were Magallanes, Tarapacá, Coquimbo, O'Higgins, and Los Lagos.

1.3.1 Data before 2018

To explore student performance following enrollment through the Chilean CAS across various school types, this study relies primarily on publicly available data published annually by the Chilean Ministry of Education. Specifically, the analysis draws from the CAS dataset for 9th-grade enrollment in the year 2018. Focusing on 9th-grade students is particularly valuable as it enables a comprehensive four-year examination tracking their progress through graduation and college application.

The CAS dataset comprises both student-level and school-level data. At the student level, it includes information such as the student's school ranking, the targeted grade level for enrollment, priority status, assigned lottery numbers for each ranked school, demographic characteristics, CAS outcomes related to seat offers, and the student's decisions regarding offer acceptance or refusal.

The school-level data encompass fundamental details such as location, name, and grade-level vacancies. Lottery results can be reproduced based on the algorithmic rules outlined earlier.

Furthermore, data on additional sociodemographic characteristics of students and their prior education records (e.g., previous schools attended and standardized test scores from previous years) are obtained from census data provided by the Ministry of Education. To account for students with missing baseline ability information, I employ a regression model utilizing older standardized test scores (i.e., 4th- and 6th-grade reading and math) and sociodemographic characteristics to predict their 8th-grade performance.[2]

Last, school census data are utilized to gather information about the schools. Specifically, I identify single-sex schools and distinguish publicly and privately financed institutions, also determining whether they were publicly or privately administered. The process of acquiring information regarding religious affiliation is elaborated upon in the subsection 1.3.3.

1.3.2 Data after 2018

All data for years after 2018 correspond to the outcome variables. These include dropout rates as of 2021, determined by whether a student is present in any grade in the 2021 student-census dataset. I conclude that students not appearing in the dataset were not formally enrolled in any school in Chile, whether public or private, by 2021. Subsequent outcomes include measures related to college applications: whether students took the college entry exam; their performance in math, reading, science, and history; their college application in the same year (2021, for enrollment in 2022); the type of major applied for (e.g., STEM, health, arts and humanities); and whether the students were accepted for any of their chosen university–major combinations.

Due to differential attrition across school types and stages, students who dropped out are imputed the minimum possible score for all remaining outcomes. For CEE scores, I introduce a binary variable indicating whether students scored above or below the national mean score in each subject, assuming that dropouts would have scored below the national average if tested.

[2]Further details on approximating baseline ability for students with missing information can be found in the Annex X.

1.3.3 Defining Catholic schools

Classifications of Catholic schools may vary. In this study, I rely primarily on the dataset constructed by Gregory Elacqua and Humberto Santos in 2010, which draws on a Catholic school census conducted by the Catholic Church. From the 2017 school census data, I successfully identify the religious affiliation of 81% of my sample (9,259 schools) using the Elacqua and Santos (2010) dataset. For the remaining 2,089 schools, I calculate their probability of being a Catholic school based on information provided in their school mission documents, which are accessible through a public school web-search tool from the Chilean Ministry of Education.

I use text analysis to identify religious keywords such as "Catholic," "religion," "church," "sacraments," "Bible," and "Jesus Christ" in the schools' mission documents. Subsequently, I regress a binary variable indicating religious affiliation against the frequency of these words in the mission documents and predict the probability of a school's being Catholic. The presence of Catholic-related words helps explain 33% of the variation in whether a school is classified as Catholic.

Table 1.2: Religious affiliation imputations

	Public	Private-Catholic	Private-Secular
Predicted probability of beeing Catholic			
5th percentile	0.019	0.019	0.019
25th percentile	0.019	0.055	0.019
50th percentile	0.019	0.249	0.019
75th percentile	0.021	0.830	0.021
95th percentile	0.031	0.999	0.051
Imputations			
N schools with religious affiliation	5,266	700	2,995
Imputations using 0.2 as threshold*	0	26	2,014
Christian schools regrouped	0	131	0
Total schools after imputations	5,266	857	5,009

Table 2 displays percentiles by school type of the predicted probability of a school being classified as Catholic. These probabilities were derived from a regression model, where a binary variable denoting Catholic religious affiliation was regressed against the frequency of religious-related words found in the schools' mission documents. Source: Author's calculations

I then examine the distribution of predicted probabilities across school types to determine the threshold for classifying a school with missing information as likely Catholic. As depicted in Table 1.2, 95 percent of private secular and public schools have probabilities below 0.05 and 0.031, respectively, of being Catholic. In contrast, half of Catholic schools have probabilities exceeding 0.24. I set the minimum probability threshold for imputing a Catholic school affiliation to 0.2 to minimize classification errors. Only 3% of private secular schools and 1% of public schools exceed this threshold. Importantly, my results remain robust to variations in this threshold.

To the group of Catholic schools, I add schools marked as Christian evangelical in the Elacqua and Santos (2010) dataset. This is because both evangelical and Catholic denominations share similar beliefs and have Christian roots. However, Protestant schools make up a very small proportion of schools, as seen in Table 1.2. In the final estimation sample, only 6 (8 percent) of the 74 Protestant schools, which represent 6 percent of the student sample, are classified as Catholic.

1.3.4 Estimation sample

The estimation sample in this study is not an exhaustive representation of all students who applied to the Chilean CAS in 2017 for 9th-grade enrollment in 2018. Instead, it comprises students whose chances of securing a seat at a Catholic school were contingent upon the outcomes of a lottery drawing. Furthermore, the sample is restricted to students who received offers from one of three types of schools: public, voucher Catholic, or voucher secular. Students who did not receive offers are excluded from the analyses, as their subsequent school choices are nonrandom.

The subset of schools used for the estimations somewhat reflects the average characteristics of the national sample of schools categorized by type, as presented in Table 1.1. Characteristics specific to secondary education are assessed for the schools utilized in the estimation sample and detailed in Table 1.3, based on data from 2017, which predate the implementation of the CAS. Given that the estimation sample pertains to 9th-grade students and beyond, Table 1.6 primarily presents characteristics relevant to secondary education. Notably, the schools in this subsample exhibit lower average 8th-grade standardized test scores than the national average scores for their

respective school types. This suggests that they are, on average, lower-performing schools relative to the national average for their school type. Additionally, Catholic schools within the subsample tend to place a greater emphasis on religious instruction, with all of them offering religious classes at the secondary level, and in 84% of the schools, such classes are mandatory. In terms of class sizes, public schools in the subsample tend to have smaller class sizes than private Catholic and private secular schools, a contrast that is not as pronounced in the national sample.

For a deeper understanding of the disparities within the estimation subsample, Table 1.4 (columns 1 to 4) compares the characteristics of the 2018 9th-grade students across different categories: those enrolled in publicly financed schools in Chile (column 1), lottery participants (column 2), and those eligible for Catholic school offers who did not receive one and those who did.

1.4 Identification Strategy

To determine the causal effect of attending a private Catholic school, I estimate a two-stage least squares (2SLS) regression in which a private Catholic school seat offer serves as an instrument for enrollment at that school. For the estimation, I compare two groups of students: those potentially eligible to attend a private Catholic school through the Chilean CAS process who did not receive an offer and those equally eligible for an offer who did receive one. To control for selection into these schools driven by the student's and family's preferences and priorities, I control for each student's probability of receiving an admission offer from a private Catholic school. This probability is known as the student's propensity score (Abdulkadiroglu et al., 2017).

I calculate the propensity score utilizing the CAS assignment algorithm provided by the Chilean Ministry of Education. The algorithm is simulated 1,000 times, and in each round, a random lottery number is introduced for each applicant and the seat allocation of all participants recorded. After the 1,000 simulations, I add the number of times each student is assigned to each of her ranked schools and divide it by the number of simulations (i.e., 1,000). The ratio of times a student receives a seat offer at a specific school to the total number of simulations (1,000) equals the propensity score for that student–school combination. I calculate a student's propensity score for

Table 1.3: Estimation sample: School characteristics

	Public	**Private-Catholic**	**Private-Secular**
A. School Characteristics			
% Single sex	1%	7%	0%
% Rural	5%	8%	5%
Student-teacher ratio	15	20	19
B. Teachers Characteristics			
% Female	57%	70%	70%
% Tenured	43%	63%	50%
Years of experience	*14*	*13*	*11*
C. Student Characteristics			
% Female	49%	55%	50%
% Low-income	61%	41%	40%
D. Religious education			
Secondary religious class	83%	100%	79%
Mandatory for secondary	27%	84%	33%
E. Standarized tests			
8th grade math	-0.61	0.22	0.15
8th grade reading	-0.57	0.31	0.09
N Schools	133	74	149

Author's calculations using 2017 public school census data from the Chilean Ministry of Education. Note: Table 3 presents descriptive statistics for schools analyzed in the study to assess the impact of Catholic school attendance on student academic outcomes. Included are all lottery-participating schools with at least one available seat, where students seeking admission had a nonzero but less than one probability of being assigned to a Catholic school.

attending a private Catholic school by dividing the frequency of receiving a seat offer from such a school by the total count of random lottery draws.

In essence, the propensity score reflects the probability of a student's being assigned to a private Catholic school based on the rules of the DAMR algorithm. The primary identifying assumption is that the enrollment mechanism seats applicants with the same preferences and priorities for assignment to a school with equal probability. What is essential about the DAMR process is that available seats, student preferences, and priority status are fixed once they are provided to the system. Conditional on those fixed values, whether a student is assigned to one or another school depends entirely on the distribution of random lottery numbers.

After calculating the propensity scores, I estimate a 2SLS model:

First stage

$$PS_i^t = \alpha_0 + \alpha_1 A_i^t + \alpha_2 \hat{p}_i^c + \alpha_3 \hat{p}_i^s + \alpha_4 \hat{p}_i^x + \alpha_5 X_i + \alpha_6 SXs + \epsilon_i \tag{1.1}$$

Second stage

$$Y_i = \beta_0 + \beta_1 \hat{PS}_i^c + \beta_2 \hat{PS}_i^s + \beta_3 \hat{p}_i^c + \beta_4 \hat{p}_i^s + \beta_5 \hat{p}_i^x + \beta_6 X_i + \beta_7 SXs + \varepsilon_i \tag{1.2}$$

Equation 1 predicts whether student i enrolled in a private Catholic school or private secular school in 2018 following participation in the CAS. On the left-hand side of equation 1, PS_i^t indicates whether student i enrolled in a private Catholic (PS_i^c) or private secular school (PS_i^s). On the right-hand side, A_i^t indicates whether the algorithm assigned the student a seat in a participating private Catholic (A_i^c) or secular (A_i^s) school, X_i is a vector of student i's baseline demographics and baseline test scores, SXs is a dummy indicating whether the school to which the student was assigned was single-sex in 2017, and P_i^c represents student i's simulated propensity score for a private Catholic school assignment, P_i^s the propensity score for a secular school assignment, and P_i^x the propensity score for a single-sex school assignment. The second-stage model then uses the vector of baseline characteristics, the propensity scores, a control for assignment to a single-sex school and the first stage's prediction of private Catholic or secular school enrollment $\hat{PS}_i^t$ to predict the student's academic outcomes.

The coefficient β_1 represents the local average treatment effect of enrolling in a participating private Catholic school relative to a traditional public school and β_2 the effect of enrolling in a participating secular school relative to a traditional public school. The central assumption that must hold for β_1 and β_2 to have a causal interpretation is that the DAMR mechanism seats applicants with the same preferences and priorities for assignment to a school with equal probability. All students with a probability of private Catholic school assignment between 0 and 1 contribute to the

identification of β_1 and with a probability of private secular school assignment between 0 and 1 to the identification of β_2.

As mentioned above, Table 1.4 presents descriptive statistics for the estimation sample in comparison to the national and lottery samples. It also assesses balance within the estimation sample, distinguishing between students who received offers from Catholic schools and those who did not, while controlling for the student's probability of securing a seat in a Catholic school. Details on the calculation of this probability are further elucidated in Abdulkadiroglu et al., 2017.

As anticipated based on the study's design, when I control for the student's probability of receiving an offer from a Catholic school, there are no significant differences observed between the students offered and those not offered a seat in terms of their baseline characteristics. The only exception is the baseline math ability variable. However, since this discrepancy appears in just one out of 17 variables, it is more likely attributable to random chance than to any systematic bias. Additionally, it is worth noting that students not offered a seat tend to have higher baseline math test scores, which suggests that if there is any imbalance, the estimated results would provide a lower bound.

1.5 Lottery Results

The first-stage results, as presented in Table 1.5, reveal, that approximately 70 percent of students who receive a seat offer for a Catholic school through the CAS accept and subsequently enroll. The enrollment rate for private secular institutions stands at around 63 percent.

Moving on to the second-stage estimates, the study explores the effects of attending different types of schools on school retention and learning outcomes. Attending either a Catholic or private secular school does not significantly influence the likelihood of students dropping out of the school system.

However, in Column 2 of Table 1.6, a positive impact is observed for attending a Catholic school on the likelihood of students taking the college-entry exam (CEE), with an increase of around 9 percentage points. This represents a 17 percent increase compared to students in public

Table 1.4: Balance

			P-score between 0-1		
	(1) Chile	**(2) Lottery participant**	**(3) Not-offered**	**(4) Offered**	**(6) P-value**
Baseline math 8th grade	0.130	-0.051	0.026	-0.005	0.02
Baseline Spanish 8th grade	0.122	0.057	0.114	0.128	0.22
8th-grade GPA	0.000	0.022	0.123	0.206	0.12
Years in a Catholic school	0.605	0.253	0.355	0.467	0.74
Years in a private-secular school	1.375	0.989	1.343	1.130	0.69
Years in a public school	1.920	2.729	2.250	2.356	0.82
Female	0.477	0.476	0.491	0.639	0.68
Low-income	0.592	0.853	0.776	0.804	0.86
Age	15.0	14.4	14.4	14.345	0.18
Years in top-1 schools	0.533	0.591	0.534	0.561	0.24
Years in top-2 schools	0.726	1.032	0.888	0.928	0.86
Years in top-3 schools	0.903	1.358	1.266	1.226	0.36
Years in top-4 schools	1.395	0.965	1.231	1.205	0.08
Single-sex	0.165	0.080	0.101	0.116	0.82
Catholic-first choice		0.150	0.467	0.694	0.12
Secular-first choice		0.207	0.241	0.131	0.31
Public-first choice		0.643	0.293	0.174	0.38
N	273,176	20,120	2,534	1,235	3,769

Note: Column (1) Includes all Chilean students that were enrolled in any publicly funded school in 2018 in grade 9th. Column (2) Includes students who participated in the 2018 Chilean CAS for a seat in 9th grade. Columns (3) and (4) Includes students who participated in the 2018 lottery for a 9th grade spot and had a Catholic-school propensity scores between 0 and 1. Column (3) depict the mean of students who were not offered a seat at a Catholic school and column (4) for those who were offered one. Column (5) reports the the p-value of the Catholic assignment coefficient in a regression of Catholic assignment, Catholic-school, other private school, and public-school propensity scores on the relevant co-founder.Top-1 to top-4 school variables, refer to how many years since 2015 until 2018 the students was enrolled in a Top quarter (Top-1) to bottom quarter(top-4) school measured by a ranking made by the Ministry of Education based on the school's standardized test results.
Source: Author's calculations.

schools. Similarly, attending a secular institution shows a positive effect of 8 percentage points, roughly a 15 percent increase compared to public school students.

Columns 3 to 6 in Table 1.6 indicate positive effects of attending a Catholic school on students' performance, particularly in math and reading, above the national mean in the CEE. Notably, only the reading and math estimates achieve statistical significance. Conversely, attending a private secular institution only yields positive and significant results for reading and history.

Table 1.5: First Stage

	Enrolled at:		
Seat offered at:	Private-Catholic	Private-Other	Public
Private-Catholic	0.705***	-0.014	-0.690***
	(0.016)	(0.016)	(0.017)
Private-Secular	0.005	0.632***	-0.636***
	(0.019)	(0.018)	(0.020)
Observations	3,769	3,769	3,769
F-statitic	752.86	667.26	681.01
R-squared	0.855	0.855	0.855

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Table 2.2 shows the estimated coefficients of an OLS estimation that regresses enrollment on a private-Catholic school - Column (1)-, private-secular school - Column (2)-, or a public school - Column (3)- on being offered a seat at a Catholic school - first row - or private-secular school – second row - through the CAS. All estimation includes student location (commune) fixed effect effects, controls for the estimated probability of being offered a seat at a private-Catholic, private-secular school, or single-sex school, female indicator, and a dummy to indicate if the student was offered a seat at a single-sex school. Source: Author's calculations.

Table 1.7 presents findings related to college application, acceptance and major preference. It is noted that Catholic school students who are accepted through the lottery exhibit higher college application and acceptance rates. However, only the effect of being accepted is statistically significant. Students attending a Catholic school have a 6 percentage point higher probability of being accepted to college, representing a 40 percent increase compared to students attending a public school. On the other hand, there are significant effects for attending a private secular school on college application and acceptance.

Regarding the influence of attending Catholic schools on students' major preferences (Table 1.7, Column 2-5), the analysis reveals that the coefficient associated with the inclination to opt for a health major is positive and statistically significant. This translates to a four-percentage-point increase in the likelihood of selecting a health-related major, constituting a 50 percent increase relative to students from public schools.

In conclusion, the analysis in this section sheds light on the nuanced effects of enrolling in

Table 1.6: Academic performance

	High-School		CEE: Scored above national mean			
	Dropout	Took CEE	Math	Spanish	Science	History
Private-Catholic	0.007	0.093**	0.079**	0.091***	0.056	0.050
	(0.017)	(0.038)	(0.035)	(0.034)	(0.036)	(0.036)
Private-Secular	0.003	0.080*	0.019	0.093**	0.024	0.086*
	(0.022)	(0.048)	(0.044)	(0.043)	(0.046)	(0.045)
Observations	3,769	3,769	3,769	3,769	3,769	3,769
R-squared	0.005	0.037	0.006	0.009	0.024	0.010
Mean Pub	0.0540	0.540	0.238	0.203	0.286	0.267

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Table 3.1 portrays IV estimated coefficients of enrolling on a Catholic or private-secular school (instrumented by having been offered a seat at such school type) on various outcomes: (1) If the student dropped out from the school system by 2021, if the student presented the college-entry exam (CEE) in 2021 (2), CEE standardized test results on math (3), reading (4), science (5) and, history (6). All estimation includes location of the student in 2017 (commune) fixed effects, controls for the estimated probability of being offered a seat at a private-Catholic, private-secular, or single-sex school, dummy for female, and another that indicates if the student received an offer in a single-sex school. School drop out variable takes the value of one if the student is not observed in the school enrollment census of 2021. Also, if the student did not take the PSU, they are imputed a value of zero for all their results. Source: Author's calculations.

Catholic and private secular schools on various educational outcomes. First-stage findings show high acceptance rates for Catholic schools and private secular institutions, which reveal the instrument is strong. The second-stage estimates reveal positive impacts of attending a Catholic school on college exam participation and academic performance, particularly in math and reading. Additionally, the results underscores the significance of attending these schools in enhancing college application and acceptance rates. Furthermore, attending Catholic schools appears to influence students' preferences, notably leading to a higher likelihood of choosing health-related majors, potentially reflecting the influence of religiosity on promoting pro-social behaviors, traits commonly associated with health workers.

Table 1.7: College application

	Applied College				Accepted
	Any	STEM	Health	Arts & Humanities	
Private-Catholic	0.050	-0.001	0.042*	-0.001	0.059**
	(0.034)	(0.022)	(0.023)	(0.013)	(0.030)
Private-Secular	0.054	0.002	0.043	0.003	0.038
	(0.043)	(0.028)	(0.030)	(0.016)	(0.038)
Observations	3,769	3,769	3,769	3,769	3,769
R-squared	0.025	0.005	0.020	0.001	0.009
Mean Pub	0.225	0.0820	0.0810	0.0250	0.148

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Table 7 presents IV estimated coefficients for enrolling in either a Catholic or private-secular school (instrumented by having received an offer from such a school) on various college outcomes:(1) College application: Whether the student submitted an application to the centralized college application system.(2) STEM-major application: Whether the student indicated a STEM major in their college-major application.(3) Health-major application.(4) Arts and humanities-major application.(5) Acceptance to any major applied for. All estimations include fixed effects for the student's 2017 location (commune), controls for the estimated probability of receiving an offer from a private-Catholic, private-secular, or single-sex school, a dummy variable for female students, and another indicating if the student received an offer from a single-sex school. Source: Author's calculations.

1.6 Heterogeneity by Gender and Baseline Ability

1.6.1 Results by gender

This section delves deeper into how attending different types of schools affects students with distinct characteristics. I replicate the equations from Section 1.5 but break down the results by gender and baseline math ability.

Table 1.8 presents the results by gender, with the top panel focusing on female students and the bottom panel on male students. Notably, although the coefficient for school dropout rates remains statistically insignificant for both genders, it becomes negative for female students and positive, and notably larger, for male students. The effect on participation in the College Entrance Exam (CEE) remains positive for both genders but is not statistically significant.

The most salient observation is that only female students seem to benefit from improved CEE

Table 1.8: Results by gender: Dropout and academic performance

	High-School		CEE: Scored above national mean			
	Dropout	Took CEE	Math	Spanish	Science	History
A. Female students						
Private-Catholic	-0.013	0.065	0.124**	0.134***	0.012	0.052
	(0.021)	(0.053)	(0.052)	(0.050)	(0.056)	(0.054)
Private-Secular	-0.023	0.028	0.021	0.117**	-0.030	0.109*
	(0.025)	(0.062)	(0.060)	(0.058)	(0.065)	(0.062)
Observations	2,015	2,015	2,015	2,015	2,015	2,015
R-squared	0.003	0.011	0.007	0.010	0.004	0.008
Mean Pub	0.0390	0.627	0.262	0.212	0.365	0.284
B. Male students						
Private-Catholic	0.028	0.087	0.016	0.018	0.065	0.029
	(0.029)	(0.056)	(0.048)	(0.047)	(0.049)	(0.049)
Private-Secular	0.042	0.123	-0.006	0.027	0.057	0.048
	(0.039)	(0.077)	(0.066)	(0.064)	(0.067)	(0.067)
Observations	1,708	1,708	1,708	1,708	1,708	1,708
R-squared	-0.001	0.013	0.018	0.023	0.011	0.006
Mean Pub	0.0660	0.469	0.218	0.195	0.221	0.254

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Table 8 displays IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by gender. The results for female students are presented in Panel A, while those for male students can be found in Panel B.Source: Author's calculations

performance. Female students attending Catholic schools exhibit a 47 percent higher chance of surpassing the national average in reading and approximately a 63 percent higher chance in mathematics compared to their peers in public schools. However, these advantages do not extend to male students. Additionally, attending secular schools does not appear to significantly influence math performance for either gender. Still, it results in an approximate 12 percentage point increase in reading performance and a 10 percentage point increase in history for female students.

Table 1.9 delves into college application outcomes by gender. Both male and female students attending Catholic schools display a greater inclination for college applications, although the coefficients are not statistically significant. Female students attending Catholic schools tend to apply more to health-related majors and are less inclined towards STEM majors; however, only the nega-

Table 1.9: Results by gender: College application

	Applied College				Accepted
	Any	STEM	Health	A&H	
A. Female students					
Private-Catholic	0.029	-0.056*	0.065	-0.014	0.043
	(0.054)	(0.029)	(0.040)	(0.019)	(0.046)
Private-Secular	0.034	-0.038	0.060	-0.019	0.028
	(0.062)	(0.034)	(0.046)	(0.023)	(0.054)
Observations	2,015	2,015	2,015	2,015	2,015
R-squared	0.005	-0.004	0.001	0.000	0.004
Mean Pub	0.298	0.0690	0.126	0.0290	0.182
B. Male students					
Private-Catholic	0.055	0.039	0.011	0.014	0.075*
	(0.045)	(0.034)	(0.026)	(0.018)	(0.040)
Private-Secular	0.056	0.038	0.006	0.034	0.043
	(0.061)	(0.047)	(0.036)	(0.024)	(0.055)
Observations	1,708	1,708	1,708	1,708	1,708
R-squared	0.012	0.003	0.005	-0.005	0.010
Mean Pub	0.165	0.0930	0.0440	0.0220	0.120

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Table 8 displays IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by gender. The results for female students are presented in Panel A, while those for male students can be found in Panel B.Source: Author's calculations

tive effect on STEM-major preference is statistically significant. Male students attending Catholic schools, on the other hand, exhibit a positive effect on choosing STEM-related majors, though the coefficient does not reach statistical significance. They also demonstrate a somewhat higher likelihood of applying to college and getting accepted, with only the coefficient for college acceptance being significant.

In summary, the findings suggest that female students attending Catholic schools experience improved CEE results but seem less inclined to pursue STEM majors. Furthermore, only male students appear to benefit from attending Catholic schools in terms of college acceptance rates. Higher-performing schools in the United States tend to yield positive educational outcomes, primarily driven by female students. Deming et al., 2014 suggests that this may be because girls adapt

Table 1.10: Results by gender: College application

	Applied College				Accepted
	Any	STEM	Health	A&H	
A. Female students					
Private-Catholic	0.029	-0.056*	0.065	-0.014	0.043
	(0.054)	(0.029)	(0.040)	(0.019)	(0.046)
Private-Secular	0.034	-0.038	0.060	-0.019	0.028
	(0.062)	(0.034)	(0.046)	(0.023)	(0.054)
Observations	2,015	2,015	2,015	2,015	2,015
R-squared	0.005	-0.004	0.001	0.000	0.004
Mean Pub	0.298	0.0690	0.126	0.0290	0.182
B. Male students					
Private-Catholic	0.055	0.039	0.011	0.014	0.075*
	(0.045)	(0.034)	(0.026)	(0.018)	(0.040)
Private-Secular	0.056	0.038	0.006	0.034	0.043
	(0.061)	(0.047)	(0.036)	(0.024)	(0.055)
Observations	1,708	1,708	1,708	1,708	1,708
R-squared	0.012	0.003	0.005	-0.005	0.010
Mean Pub	0.165	0.0930	0.0440	0.0220	0.120

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Table 8 displays IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by gender. The results for female students are presented in Panel A, while those for male students can be found in Panel B.Source: Author's calculations

better to stricter learning environments, a trend that may also explain the results found for Catholic schools.

Female students attending Catholic schools appear to shy away from applying to STEM majors and are instead inclined toward health-related disciplines. This pattern, notably absent among male students, may be linked to the impartation of values through religious education. Literature in sociology has established links between religiosity and gender stereotypes, which could explain these observed effects Siordia, 2016. Another explanation could be linked to literature showing that women attending high-quality schools are less likely to apply to STEM majors Landaud et al., 2020.

To test the hypothesis that religious teachings influence female students' major preferences,

we explored results based on the probability of a school adhering to Catholic values, as inferred from schools' mission documents. While this does not definitively confirm a school's Catholic affiliation, it strongly suggests the influence of religious values. Given its high correlation with affiliation to the Catholic Church, most schools in the treatment group are likely affiliated with the church, while others may impart Catholic values without formal religious affiliation (Planning on doing this but haven't had the time- I have to calculate another PS based on schools with higher and lower scores of religiosity)

1.6.2 Results by baseline ability

Table 1.11: Results by baseline math: Dropout and academic performance

	High-School		CEE: Scored above national mean			
	Dropout	Took CEE	Math	Spanish	Science	History
A. Below math-baseline class mean						
Private-Catholic	0.032	0.093*	0.045	0.075**	0.062	0.023
	(0.027)	(0.053)	(0.039)	(0.035)	(0.046)	(0.046)
Private-Secular	0.019	0.124*	-0.007	0.074*	0.033	0.137**
	(0.032)	(0.064)	(0.046)	(0.043)	(0.056)	(0.056)
Observations	1,937	1,937	1,937	1,937	1,937	1,937
R-squared	0.003	0.042	0.009	0.014	0.032	0.019
Mean Pub	0.0650	0.433	0.112	0.0790	0.206	0.199
B. Above math-baseline class mean						
Private-Catholic	-0.032	0.155***	0.187***	0.191***	0.081	0.123**
	(0.021)	(0.052)	(0.057)	(0.056)	(0.056)	(0.055)
Private-Secular	-0.022	0.069	0.107	0.174**	0.043	0.043
	(0.029)	(0.071)	(0.078)	(0.077)	(0.077)	(0.076)
Observations	1,784	1,784	1,784	1,784	1,784	1,784
R-squared	0.014	0.045	0.003	0.011	0.029	0.007
Mean Pub	0.0440	0.642	0.358	0.321	0.361	0.332

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Table 8 presents IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by baseline math ability. Panel A shows results for students who enrolled in schools where their 8th-grade math test scores were below the class mean, while Panel B presents results for students whose math test scores were above the class mean.Source: Author's calculations

Tables 1.11 and 1.12 report second-stage results for students with baseline math scores below and above their class averages. Despite lacking statistical significance, one notable finding is the

increased dropout probability for low-performing students in Catholic schools and the negative probability for high-performing students. Students attending Catholic schools with baseline math scores below their class mean experience a 3.2 percentage point rise in the probability of dropout, representing a 50 percent increase compared to the average public school.

Regarding CEE performance, it seems more advantageous to attend a Catholic school for high-performing students relative to their peers than for low-performing students. Students with higher baseline math scores appear to have positive and significant effects on all subjects except science, which appears positive but not significant. They also exhibit a higher probability of taking the CEE than their public school counterparts. For lower-performing students, attending a Catholic school does not seem detrimental but only appears to have an effect on their probability of scoring above the national mean on the reading part of the exam. They also appear to have a higher probability of taking the CEE exam than their public school counterparts.

Regarding college applications, both high and low-performing students, as measured at baseline, attending Catholic schools seem to benefit in terms of applying and being accepted to college. Students with higher baseline math scores have a 13 percentage point higher chance of getting accepted to college, representing a 55 percent increase compared to their public school counterparts. Lower-performing students also exhibit a positive and significant effect, representing an 88 percent increase in acceptance compared to their public school counterparts.

In terms of major preference, only low-performing students appear to be affected by attending a Catholic school, increasing their propensity to choose health-related majors by 7 percentage points, more than doubling the average application rate to health majors compared to their public school counterparts.

1.6.3 Results by baseline ability interacted with gender

The results for low and high-performing girls and low and high-performing boys are presented in tables A.1-A.4in the appendix. These findings yield a central takeaway: Attending Catholic schools appears to be particularly advantageous for high-performing girls, while it may have ad-

Table 1.12: Results by baseline math: College application

	Applied College				
	Any	STEM	Health	Arts&-Humanities	Accepted
A. Below math-baseline class mean					
Private-Catholic	0.065	0.003	0.072***	0.012	0.052*
	(0.041)	(0.021)	(0.028)	(0.014)	(0.031)
Private-Secular	0.065	-0.013	0.032	0.022	0.038
	(0.050)	(0.026)	(0.033)	(0.016)	(0.038)
Observations	1,937	1,937	1,937	1,937	1,937
R-squared	0.023	0.005	0.014	0.002	0.008
Mean Pub	0.138	0.0320	0.0570	0.0100	0.0590
B. Above math-baseline class mean					
Private-Catholic	0.091*	0.011	0.023	-0.011	0.129**
	(0.055)	(0.039)	(0.039)	(0.023)	(0.051)
Private-Secular	0.085	0.049	0.066	-0.003	0.099
	(0.075)	(0.054)	(0.054)	(0.031)	(0.071)
Observations	1,784	1,784	1,784	1,784	1,784
R-squared	0.034	0.002	0.031	0.004	0.016
Mean Pub	0.307	0.131	0.104	0.0400	0.232

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Table 8 presents IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by baseline math ability. Panel A shows results for students who enrolled in schools where their 8th-grade math test scores were below the class mean, while Panel B presents results for students whose math test scores were above the class mean.Source: Author's calculations

verse effects on low-performing boys, who emerge as the primary contributors to the positive impact observed in school dropout rates.

Another significant finding emerges when examining results stratified by gender and ability. High-performing male students appear to benefit from attending a Catholic school in terms of their science performance on the CEE. On the other hand, female students benefit in terms of improving their math and reading CEE test scores.

Based on the findings related to baseline ability and gender, it appears that Catholic schools tend to experience a reduction in the presence of low-performing male students. This phenomenon

might be linked to a process wherein these students discontinue their education, potentially contributing to the observed positive effects on girls' math and reading performance. One possible explanation is that Catholic schools encourage or inadvertently lead low-performing students to leave, enabling teachers to provide higher-level instruction to the remaining students. This concentration of resources may enhance classroom efficiency and effectiveness.

Additionally, the absence of low-performing students in Catholic schools could contribute to an improved overall learning environment. This conducive atmosphere may be leveraged by female students, leading to increased learning outcomes compared to their counterparts in public schools. Ultimately, these enhanced learning outcomes may manifest in their College Entrance Examination (CEE) performance.

1.7 What Makes Catholic Schools Different?

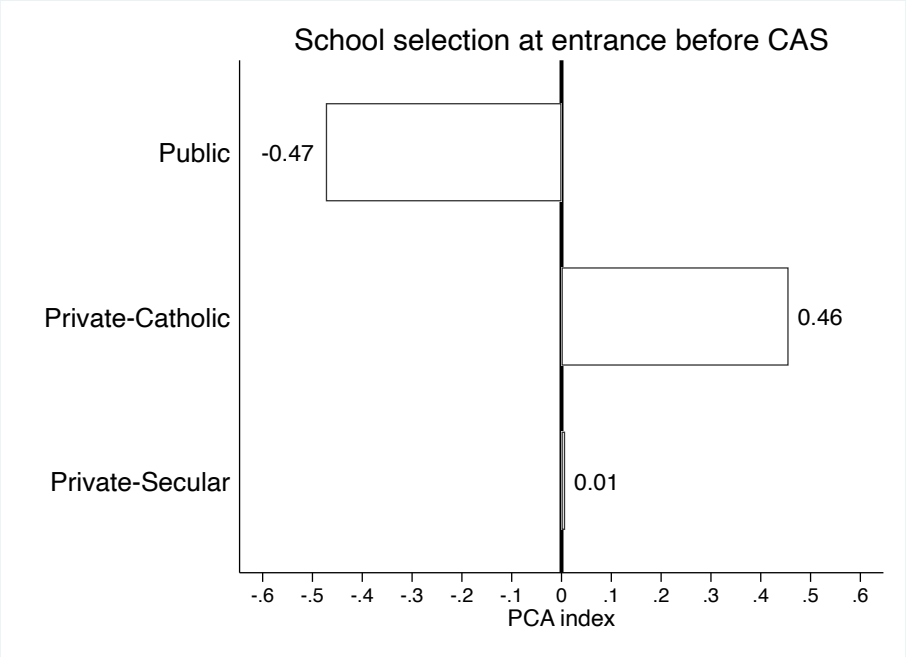
To understand what sets Catholic schools apart from private secular and public schools, the study analyzed surveys from 2017 involving parents, teachers, and students. These surveys covered various aspects of their experiences in their respective educational settings. For analytical simplicity, responses were grouped thematically, and principal components analysis was used to create summarized indices. The findings are presented in the following order: school selection criteria, parental involvement, adherence to school policies, student behavior, and students' perceptions of their schools and teachers.

1.7.1 Selection before CAS was implemented

In the realm of student selection, Catholic schools exhibit a discernible pattern, as evidenced by the descriptive statistics in Table 1.1, which portray a student body composition characterized by higher income levels. This observation gains further support from Figure 1.3, which presents parental responses concerning the prerequisites or background information sought during the student application process. These prerequisites encompassed various elements, including transcripts from prior educational institutions, income documentation, and parental interviews, among others.

Evidently, the data underscores that Catholic schools occupied the position of being the most selective educational establishments prior to the universal implementation of the CAS (Centralized Admission System) across all publicly funded schools. This selectivity trend is followed by other private secular schools. As anticipated, public schools emerge as the least selective in this context.

Figure 1.3: Schools selection at entrance



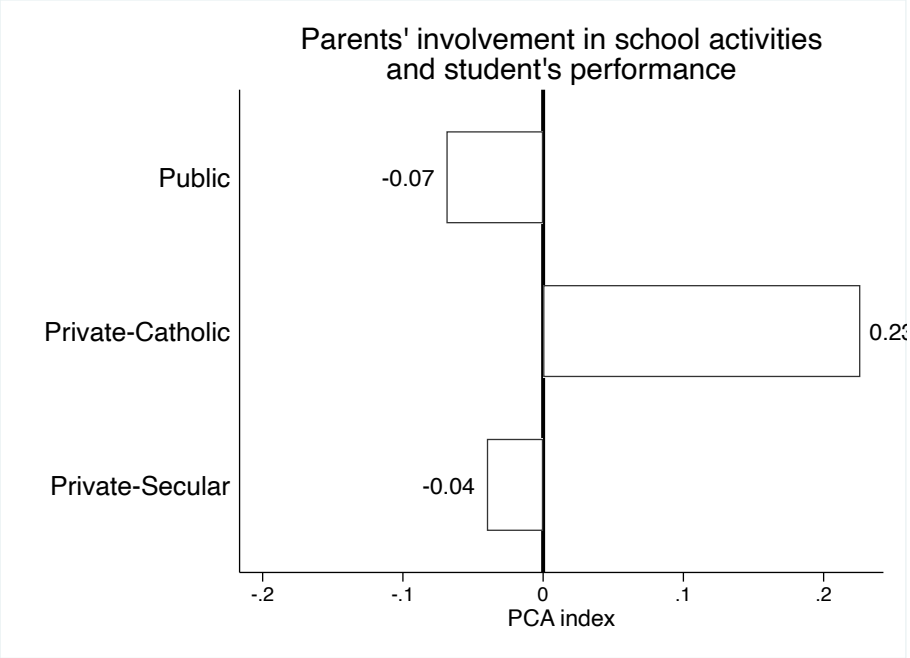
Note: Figure 1.3 illustrates the mean of the "admission selection" principal component indicator for the three types of schools. The "admission selection" indicator was generated using principal components analysis and calculated based on responses provided by parents who participated in a school survey regarding their experiences with their children's school. These responses were categorized and encompass data from all parents of 8th and 10th-grade students in the year 2017 who completed the school climate questionnaire. It's worth noting that these questionnaires were administered prior to the implementation of the CAS. For a detailed breakdown of the questions used to compute this indicator, please consult Tables A.5 and A.6 in the appendix. Source: Author's calculations.

1.7.2 Parent's involvement

Another common trait shared by high-performing schools is the degree of parental involvement in school activities, student behavior, and academic performance. Similar to the KIPP or No Excuses approach found in charter schools, Catholic schools also place a premium on parental involvement in their child's educational journey compared to other types of schools. As depicted in Figure 1.4, parental involvement appears to be more of a priority in Catholic schools than in pri-

vate secular or public schools. The principal component index for selection incorporates parental responses to questions related to the frequency of communication with parents and guardians about students' academic and personal progress, as well as the frequency with which headteachers schedule meetings with parents and guardians to discuss students, among other factors.

Figure 1.4: parental involvement in the school



Note: Figure 1.4 illustrates the mean of the "parents' involvement" principal component indicator for the three types of schools. The "parents' involvement" indicator was generated using principal components analysis and calculated based on responses provided by parents who participated in a school survey regarding their experiences with their children's school. These responses were categorized and encompass data from all parents of 8th and 10th-grade students in the year 2017 who completed the school climate questionnaire. It's worth noting that these questionnaires were administered prior to the implementation of the CAS. For a detailed breakdown of the questions used to compute this indicator, please consult Tables A.5 and A.6 in the appendix. Source: Author's calculations.

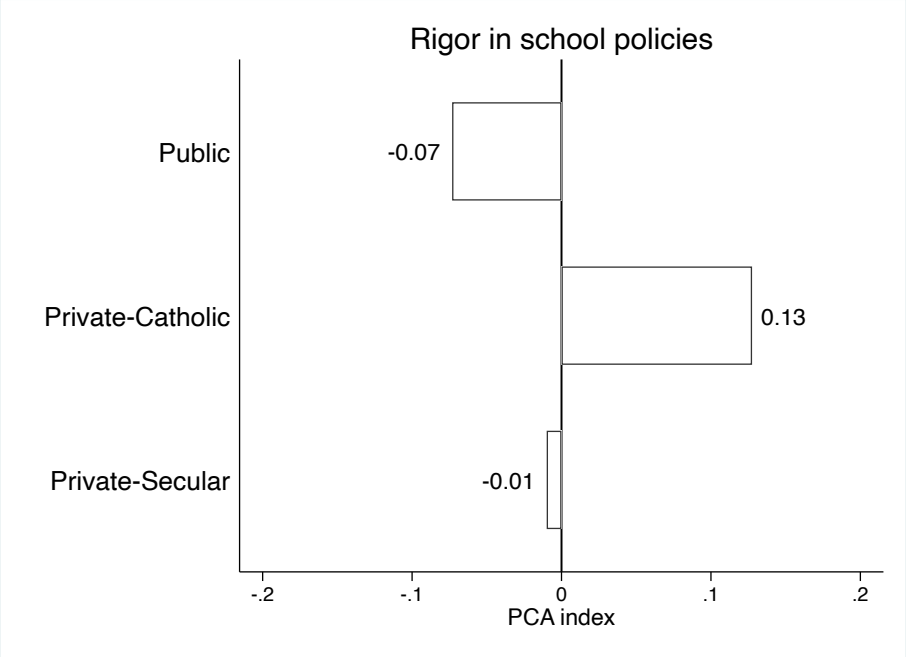
1.7.3 Rigor in school policies

Figure 1.5 delves into another aspect of high-performing schools, namely the rigor in enforcing rules and regulations outlined in the school's code of conduct. To construct this index, survey responses from both students and parents were utilized. Students were queried about their perceptions of school code adherence, the seriousness of actions such as class or school truancy, and

insulting classmates. Parents were solicited for their opinions on the institution's adherence to the code of conduct and its handling of students with behavioral issues.

Consistent with other categories, Catholic schools emerge as exhibiting the strongest inclination toward strict adherence to their school code of conduct.

Figure 1.5: Rigorous schools

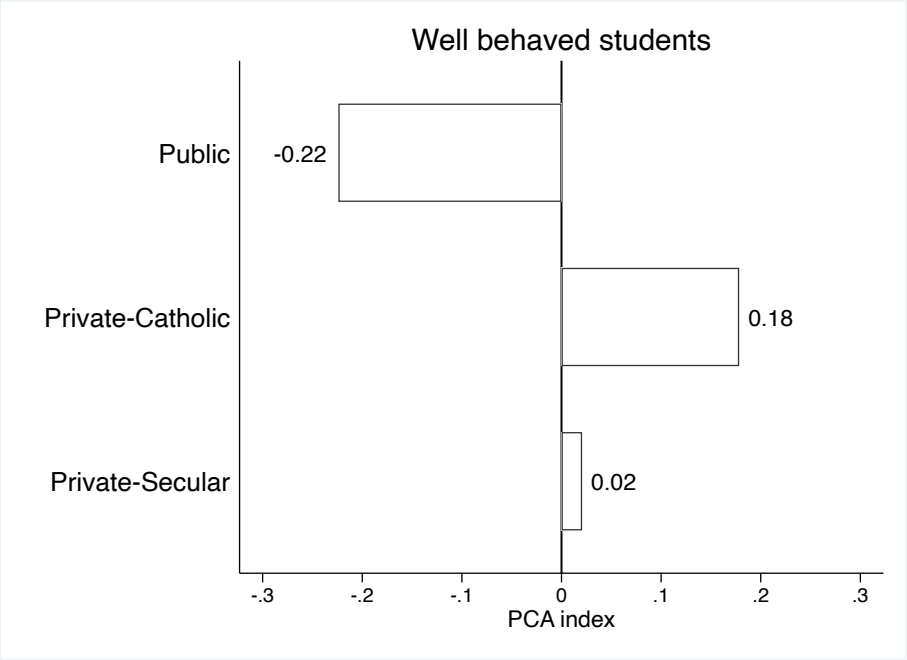


Note: Figure 1.5 illustrates the mean of the "School's rigour" principal component indicator for the three types of schools. The "School's rigour" indicator was generated using principal components analysis and calculated based on responses provided by students and parents who participated in a school survey regarding their experiences with their school. These responses were categorized and encompass data from all 8th and 10th-grade students and their parents in the year 2017 who completed the school climate questionnaire. It's worth noting that these questionnaires were administered prior to the implementation of the CAS. For a detailed breakdown of the questions used to compute this indicator, please consult Tables A.5 and A.6 in the appendix. Source: Author's calculations.

1.7.4 Student's behaviour

Figure 1.6 illustrates the results pertaining to the index evaluating student behavior. This category incorporates questions directed at teachers, mainly focused on student conduct in class and adherence to norms established by teachers. Catholic schools once again lead in this indicator, consistent with their rigor in adhering to school norms.

Figure 1.6: Good student behaviour



Note: Figure 1.6 illustrates the mean of the "Well behaved students" principal component indicator for the three types of schools. The "Well behaved students" indicator was generated using principal components analysis and calculated based on responses provided by teachers who participated in a school survey regarding their experiences in their school. These responses were categorized and encompass data from all 8th and 10th-grade teachers in the year 2017 who completed the school climate questionnaire. It's worth noting that these questionnaires were administered prior to the implementation of the CAS. For a detailed breakdown of the questions used to compute this indicator, please consult Tables A.5 and A.6 in the appendix. Source: Author's calculations.

1.7.5 Students like school and feel supported by teachers

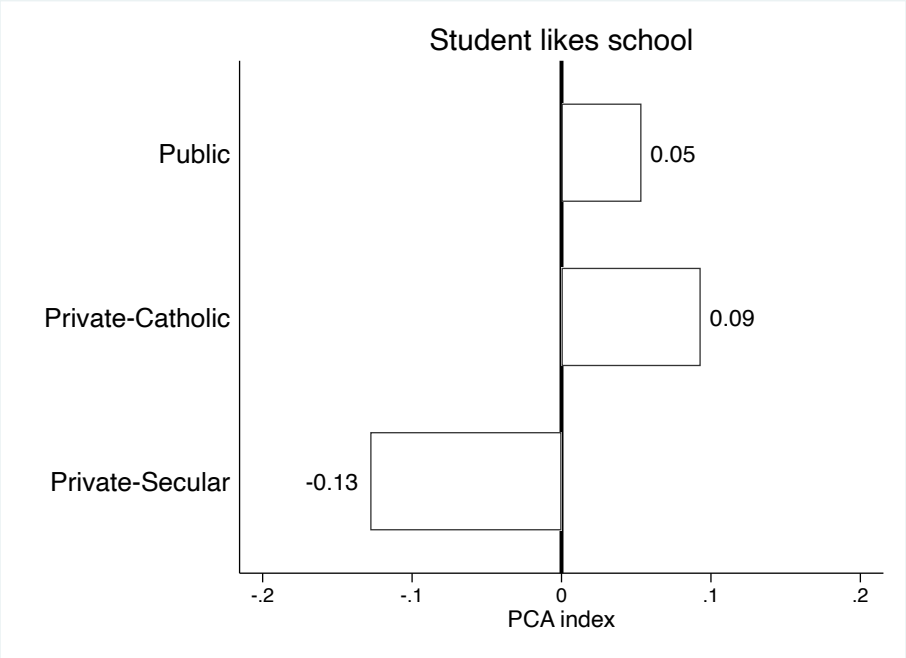
When examining student sentiments toward their schools, Catholic school students tend to express higher levels of satisfaction compared to their public school counterparts (Figure 1.8). However, public school students report a greater sense of support from their teachers (Figure 1.7).

The index measuring students' affinity for their schools was constructed from questions posed to students, addressing their enjoyment of attending school, pride in their institution, and willingness to recommend it to others.

Regarding the index gauging whether students feel supported by their teachers, the questions posed to students encompassed various affirmations such as, "My teachers tell me that I am capable of learning," "My teachers motivate me to study and make an effort," or "My teachers make me

feel that I am an important part of my institution."

Figure 1.7: Students like their school



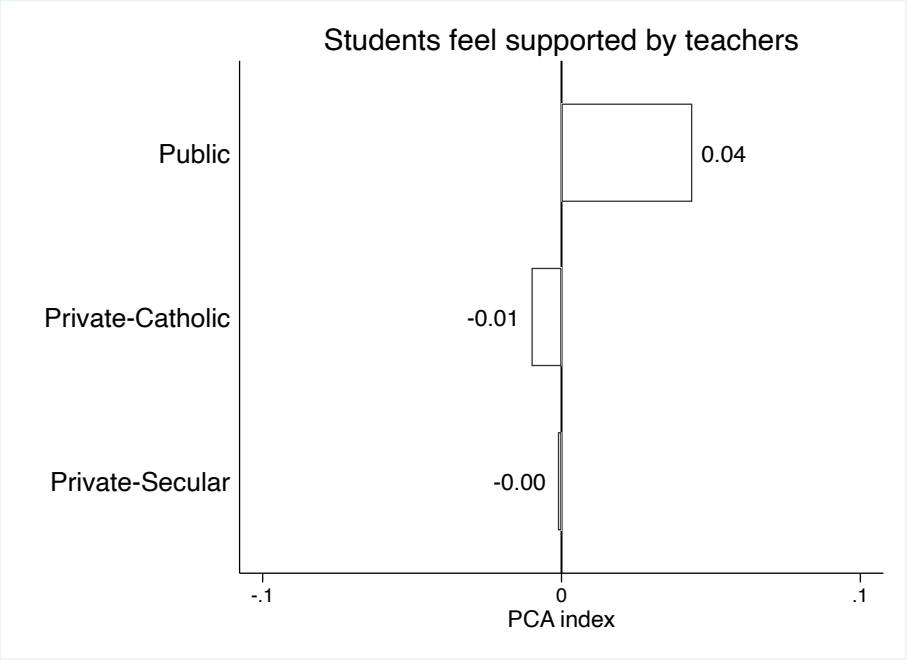
Note: Figure 1.7 illustrates the mean of the "Students like their school" principal component indicator for the three types of schools. The "Students like their school" indicator was generated using principal components analysis and calculated based on responses provided by students who participated in a school survey regarding their experiences in their school. These responses were categorized and encompass data from all 8th and 10th-grade students in the year 2017 who completed the school climate questionnaire. It's worth noting that these questionnaires were administered prior to the implementation of the CAS. For a detailed breakdown of the questions used to compute this indicator, please consult Tables A.5 and A.6 in the appendix. Source: Author's calculations.

1.8 Conclusion

In conclusion, this study has conducted an extensive examination of the educational landscape in Chile, with a specific focus on the impact of Catholic schools on student outcomes. By leveraging school admission-lotteries exogenous variation, this research advances our understanding of the educational effectiveness of Catholic schools.

Leveraging the unique Chilean context characterized by lottery-based school admissions and a centralized admission system, this study successfully mitigated concerns related to selection biases. The findings have illuminated a nuanced array of outcomes associated with attending

Figure 1.8: Students feel supported by teachers



Note: Figure 1.8 illustrates the mean of the "Students feel supported by teachers" principal component indicator for the three types of schools. The "Students feel supported by teachers" indicator was generated using principal components analysis and calculated based on responses provided by students who participated in a school survey regarding their experiences in their school. These responses were categorized and encompass data from all 8th and 10th-grade students in the year 2017 who completed the school climate questionnaire. It's worth noting that these questionnaires were administered prior to the implementation of the CAS. For a detailed breakdown of the questions used to compute this indicator, please consult Tables A.5 and A.6 in the appendix. Source: Author's calculations.

Catholic schools. Notably, such attendance has been linked to positive effects on academic performance, particularly in math and reading, as well as heightened rates of college application and acceptance. However, these benefits exhibit intriguing gender-specific variations, with female students emerging as the primary beneficiaries in terms of math and reading performance on college-entry exams, while male students primarily benefit in terms of college acceptance rates.

Furthermore, the survey data have unveiled intriguing parallels between Catholic schools and the No-Excuses and KIPP charter school models, marked by stringent disciplinary measures and heightened parental engagement. These resemblances expand our comprehension of school models and their potential influence on student achievement.

This investigation also underscores gender-specific educational disparities, challenging conventional assumptions about the uniformity of educational interventions. The dearth of low-

performing male students in Catholic schools, potentially attributable to attrition, fosters an enriched learning environment, conducive to enhanced teaching efficiency and improved academic outcomes. Particularly noteworthy is the substantial benefit accruing to female students.

The findings of this study carry several implications for both education policy and future research. Firstly, policymakers should consider the nuanced impacts of Catholic schools on student outcomes when formulating education policies. Understanding the differential effects on male and female students can inform strategies aimed at improving educational equity.

Secondly, this research opens avenues for future investigations. One possible extension is exploring the long-term effects of Catholic school attendance, including post-secondary education trajectories and career attainment. Additionally, comparative analyses across different countries and educational contexts could offer insights into how variations in educational policies influence the outcomes of Catholic schools.

Future research in this domain could delve into the mechanisms driving the varying impacts of Catholic schools on male and female students, shedding light on the complex interplay between school environment, gender, and academic outcomes. Additionally, examining the role of religious teachings in influencing students' major preferences could provide further insights into the factors shaping gender disparities in STEM fields, extending the current body of literature in this area.

Chapter 2: School Admission's Lottery and Changes in Student Selection by Type of School

2.1 Introduction

Governments worldwide are increasingly adopting centralized school admission systems to improve the efficiency and equity of student assignments. These systems aim to eliminate supply-side selection, reduce informational costs for parents, and promote diversity within educational systems. One such system, the Centralized Admission System (CAS), was implemented in Chile to replace the decentralized system and reduce school segregation.

This paper examines how the characteristics of incoming students enrolled in Catholic, public, and private secular publicly funded schools in Chile changed after the implementation of CAS. Leveraging the variation before and after the lottery started between these types of schools, the study aims to quantify the impact of CAS on student selection. The central question of this study is how the implementation of a centralized admission system with a lottery for oversubscribed schools affects student selection in Chile.

Using public anonymous microdata of all students enrolled in a public school or private-subsidized school from 2012 to 2020, the study employs a difference-in-difference model with multiple time periods following Callaway and Sant'Anna, 2021. This methodology allows for an in-depth analysis of the difference in student selection between Catholic, private secular, and public schools before and after the CAS implementation.

The results indicate that Private Catholic schools started enrolling a higher proportion of lower-income and lower-ability students after the CAS implementation compared to private secular and public schools. This suggests a change in student selection patterns following the introduction of CAS, highlighting the impact of centralized admission systems on school demographics. Because

Catholic school are known for being the most selective, it could be that this reform specifically helped selection on high selective and high achieving students.

Building upon existing literature, which has shown that CAS can improve within-school socio-economic diversity (Kutscher et al., 2023), this paper focuses exclusively on new students. This approach differentiates the study from previous work and allows for a more granular analysis of the effects by school type. Additionally, the study utilizes the latest methodologies of difference-in-difference analysis to provide a more precise measure of the impact of CAS on student selection.

Furthermore, this paper builds on the broader literature on school choice and segregation. Previous studies, such as those by Kessel and Olme, 2018 and Laverde et al., 2022, have explored the impact of different school choice policies on segregation and student welfare. By focusing on the specific case of Chile and utilizing rigorous empirical methods, this paper adds to the growing body of research on the impact of education policy on student outcomes.

This paper aims to provide valuable insights into how the implementation of a centralized admission system with a lottery for oversubscribed schools helps minimize student selection in Chile. The findings of this paper contribute to the ongoing discourse on the effectiveness of centralized admission systems in promoting diversity and equity in education.

The rest of this paper is organized as follows: Section 2.2 provides a concise overview of the Chilean education system and recent educational reforms, with specific attention to the Centralized Admission System. Section 2.3 describes the data sources and sample composition, while Section 2.4 expounds upon the chosen identification strategy. Section 2.5 presents the empirical results resulting form the difference in difference estimation. Finally, Section 2.6 concludes the study and discusses the findings.

2.2 Context and setting

The Chilean school system comprises three main categories: public schools managed by municipalities, privately managed and publicly funded schools, and entirely private schools. As of 2020, Chile had 9,085 schools, with 52.6% public, 40.7% private but publicly funded (via vouch-

ers), and 6.7% entirely private.

A significant portion of publicly funded but privately managed schools are owned and operated by religious organizations. Of the 3,292 voucher schools with known religious affiliation, 20% are managed by Catholic organizations, 4.5% by other religious groups, and the remainder by private secular entities.

Reforms in the past decade aimed to address educational inequalities and segregation caused by the school choice system. One reform introduced targeted subsidies for low-income students in all publicly funded schools, leading to improved test scores and reduced income-based gaps. Another significant reform, following the 2011 student movement, prohibited educational institutions receiving public funds from generating profits, selecting students based on academic or socioeconomic factors, charging copays, or selecting students. A Centralized Admission System (CAS) was implemented to manage student selection, gradually expanding to include all grades in all publicly funded schools by 2021.

The Centralized Admission System (CAS) in Chile works by having parents apply through a system that considers their preferences for schools and their children's details. Schools also submit their available spots. Students are then prioritized based on criteria like previous enrollment, having siblings in the school, low-income status, and parents working at the school. Each student is assigned a random number for each school they apply to, which helps break ties. An algorithm called Deferred Acceptance with Multiple Tie Breaking Rules (DAMR) is used to assign students to schools based on these factors. If a student is not assigned a school through DAMR, they are then assigned to their nearest school.

As depicted in figure 2.1, in the CAS's inaugural year of implementation in 2017, one of the country's 15 regions participated, restricting participation to students seeking admission to pre-K, kindergarten, 1st grade, 7th grade, and 9th grade, with the allocation being determined through a lottery-based mechanism. In the following year (2018), four additional regions adopted the lottery-based system. Among these regions, the lottery was limited to applicants for the specified grades, while the original region that initiated the lottery in 2017 incorporated students from all

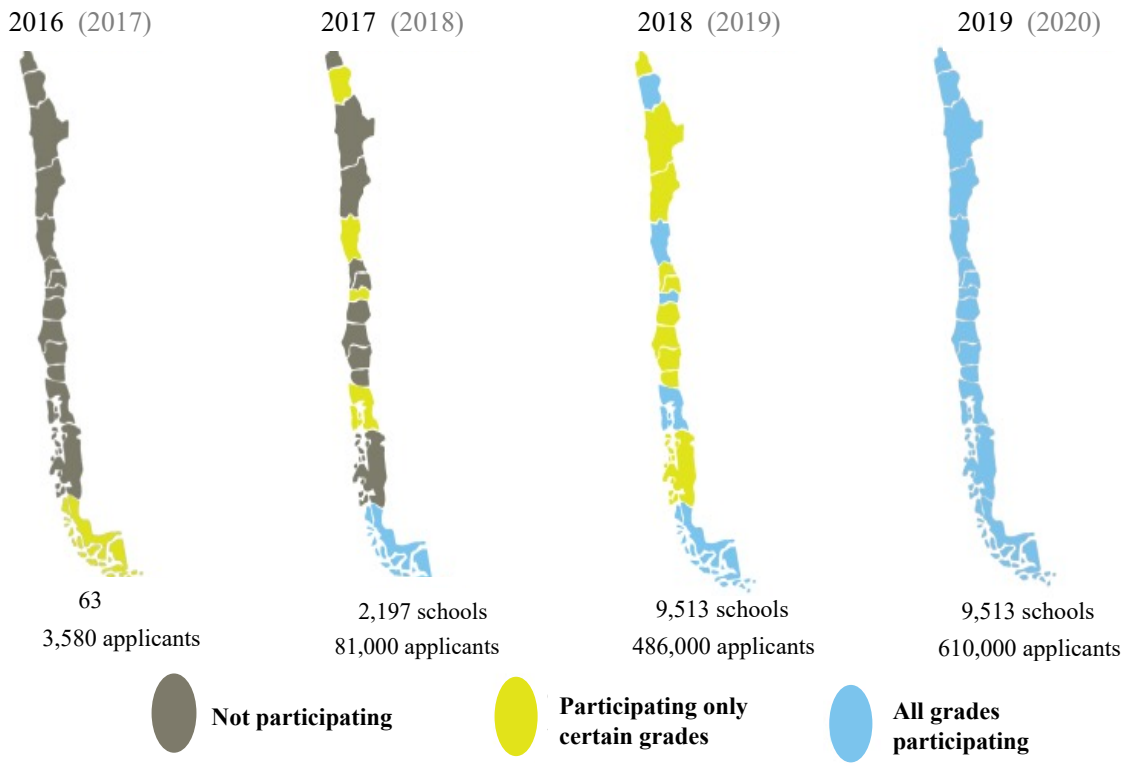
grade levels. This standardized procedure was consistently applied across all regions that adopted the CAS. In the initial year, only students seeking admission to the designated key grades were included in the CAS. In the ensuing years, this scope expanded to encompass all remaining grade levels. By 2019, eleven additional regions had embraced the admission lottery system, with the final and largest region implementing it in 2020. Consequently, by 2021, publicly funded schools in all 15 Chilean regions employed the CAS for student admissions across all grade levels.

This study aims to understand if incoming students' baseline characteristics change after the implementation of the CAS leveraging its gradual implementation, as the expectation is to see less selection at entrance due to the randomized assignment process. However, an alternative hypothesis is that the CAS may not effectively reduce selection, as parents' preferences for certain schools could still influence the application process despite the randomized lottery system. By examining the changes in student characteristics before and after the CAS implementation, this study seeks to provide insights into the effectiveness of centralized admission systems in reducing selection biases in school admissions.

2.3 Data

To analyze changes in student selection, I constructed a panel at the school-grade level from 2012 to 2020 .This information is publicly available on the Chilean Ministry of Education website. The panel includes school level characteristics and average students' socio-demographic characteristics by school-grade. To measure incoming student's baseline ability, I asked for the student-level anonymized dataset containing all standardized test results (SIMCE) from 2008 to 2019. The grades at which students were evaluated are 4th, 6th, 8th, and 10th grade, in Spanish, math, and social sciences. Because not all students took every test, and were not evaluated every year, students were assigned their most recent standardized-test grade that was previously standardized at the national level. Then, students' performance was merged to the school-level panel by reporting the average performance for each school-grade. Each aggregated student-level variable was created twice, one for continuing students and one for incoming students (i.e., students that reported

Figure 2.1: CAS roll-out



Source: Chilean Ministry of Education. March 2018.

Note: Figure 2.1 illustrates the gradual implementation of the CAS across regions in Chile. Each map includes the year of implementation, with the year in parentheses indicating when students accepted through the CAS began classes, and the year outside parentheses indicating the year prior to enrollment when parents applied to the CAS. Regions shaded in green denote those that started implementing CAS for specific grades that year, light blue represents regions where CAS was implemented for all grades, and brown signifies regions that had not yet begun implementing the CAS.

being in a different school the year before).

Each school was classified either as public, private-Catholic or private-secular. Public schools are schools publicly funded and managed by the municipalities, Private Catholic schools are schools managed or affiliated with religious organizations but publicly funded, and Private secular schools are privately managed by non-religious organizations but also publicly funded. For comparability, I discarded all privately funded and privately managed schools- as these schools were not affected by the reform. Schools that only served a special population such as adults or students with special needs and, private non-Catholic religious schools were also excluded.

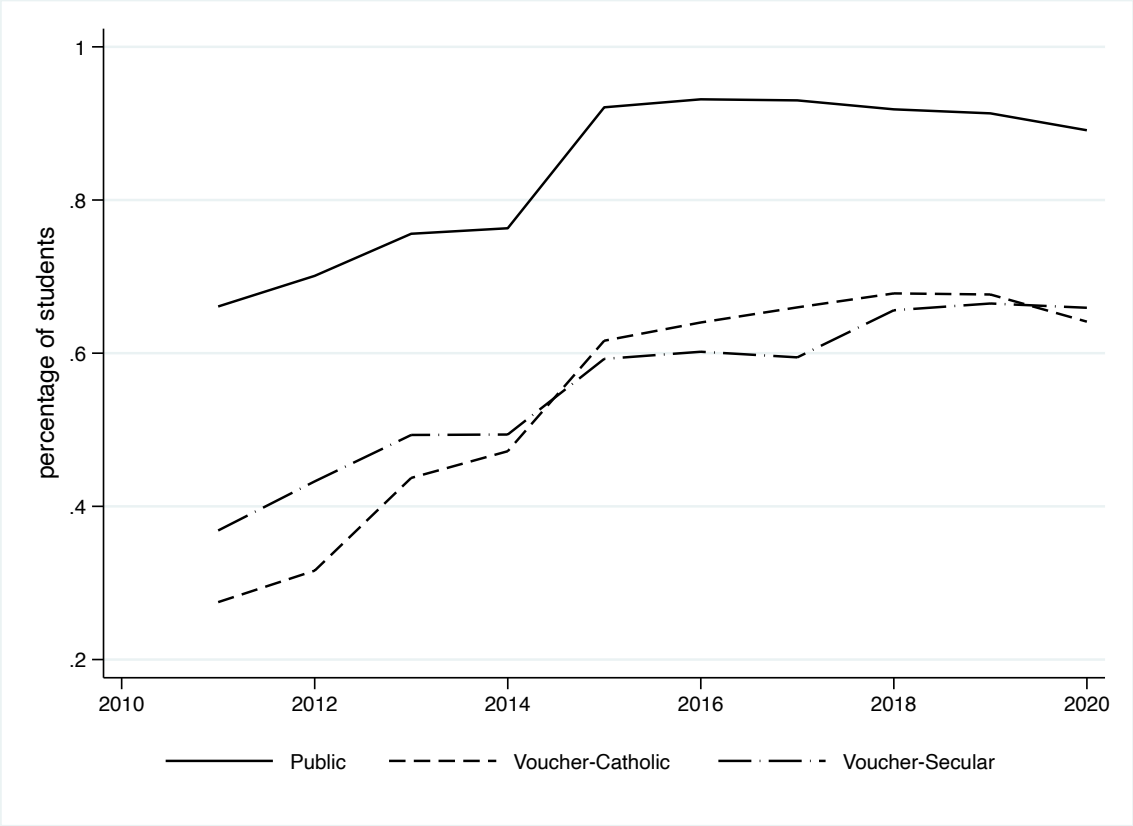
Subsidized private Catholic schools have outperformed subsidized private secular and public schools for years, as shown in Figures A.1, A.2, A.3, and A.4. Subsidized private Catholic schools score, on average, between 0.8 and 1 standard deviation more in 4th and 8th grade Spanish and math standardized tests from 2011 to 2017. It is unclear whether these results are driven by selection or something in the private Catholic school's production function that makes them more effective. As shown in Table 1.1 in Chapter 1, students attending the three types of schools differ substantially which might explain some of the differences.

Table 1.1 in Chapter 1 reveals significant differences among school types in terms of location, pedagogical approach, student-teacher ratios, and student demographics. Publicly managed schools are more prevalent in rural areas, while Catholic schools often feature single-sex education, although there's a recent trend toward coeducation. Student-teacher ratios vary, with public schools having lower ratios compared to secular voucher institutions. Private schools, including Catholic and Christian schools, tend to have more female and tenured teachers. Additionally, these schools enroll a higher percentage of economically advantaged students, with fewer students from low-income backgrounds and more students with mothers having higher education levels. Before the Centralized Admission System, Catholic schools consistently outperformed publicly funded and privately managed schools academically. However, there is a widening performance gap between public and voucher schools, suggesting a shift in student performance trends between primary and secondary education.

Table 1.1 in Chapter 1 looks at students admitted to schools before and after the CAS was implemented. To understand how the CAS changed student selection is necessary to look at the characteristics of incoming students over time.

Figure 2.2 shows how the percentage of just enrolled low-income students change over time. Discernibly, the percentage of low-income students enrolled in the three types of schools increased over time. The big jump in 2014-2015 is likely due to a policy that gave schools an extra subsidy for every low-income student enrolled, encouraging the schools to enroll a higher proportion of low-income students to increase their revenue. After 2015 there seems to be a plateau in public

Figure 2.2: Incoming student's low-income status evolution by type of school



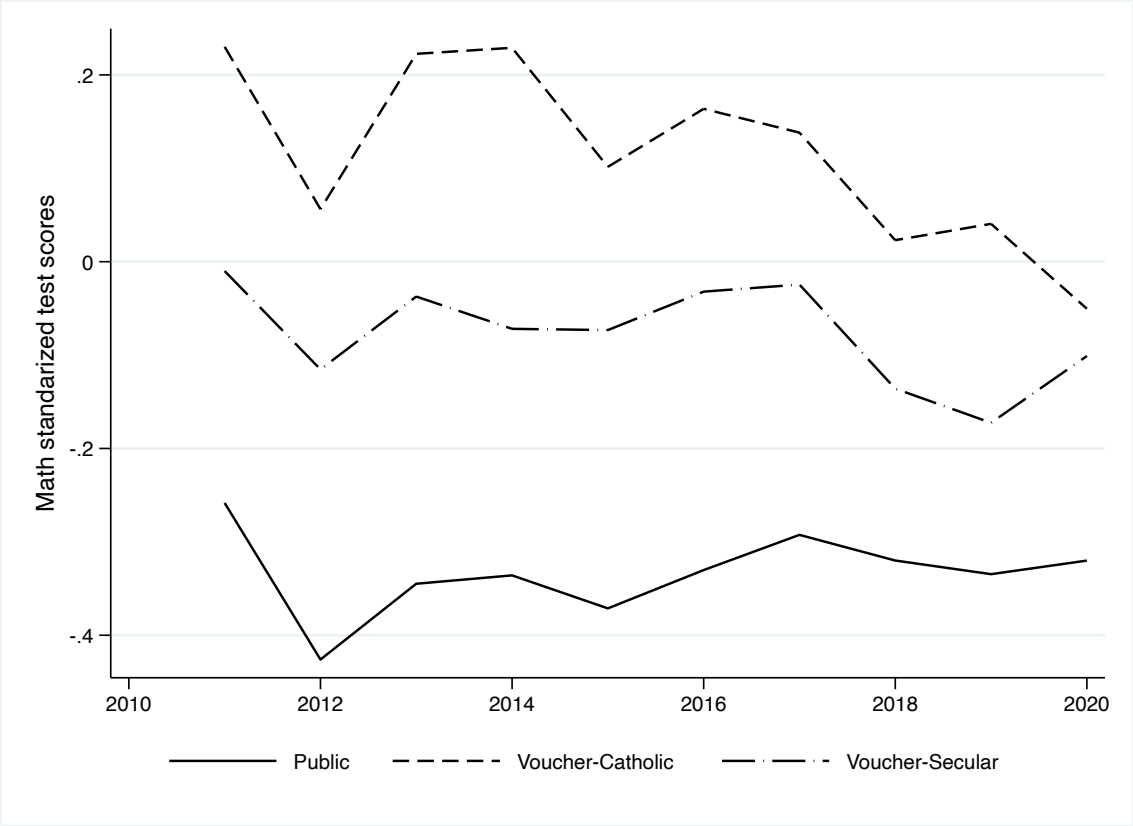
Source: Author's calculations.

Note: Figure 2.2 depict the evolution of incoming students in terms of low-income status. The Solid line represents the average incoming student to a public school from 2012 to 2020, the dashed-dotted line private-secular school incoming students, and the dashed line private-Catholic school incoming students.

and private secular schools and a minor increase in private Catholic schools. Also, the consistent increase in the proportion of low-income students in all school types is most likely due to several changes in the government's definition of a low income-student. The reforms made the definition broader with time which granted the low-income status to more families each year. After the CAS was implemented (between 2017 and 2018), a more considerable increase in the proportion of low-income students is visible in Catholic and private secular schools and a slight decline in public schools.

In terms of academic proficiency in Spanish and math (Figures 2.3 and 2.4), the gap between incoming students to the three different types of schools is shrinking. In standard deviations,

Figure 2.3: Incoming student's math proficiency evolution by type of school



Source: Author's calculations.

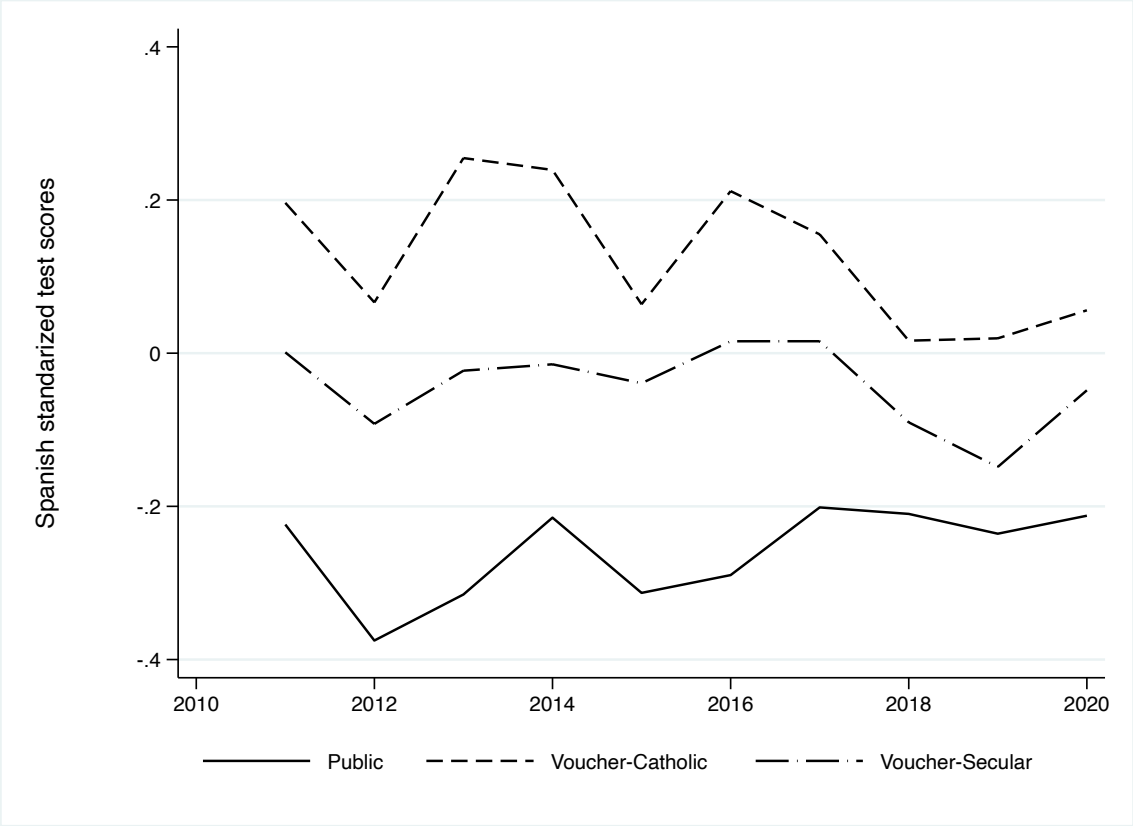
Note: Figure 2.3 depict the evolution of incoming students in terms of Math baseline proficiency in standardized test scores. The Solid line represents the average incoming student to a public school from 2012 to 2020, the dashed-dotted line private-secular school incoming students, and the dashed line private-Catholic school incoming students.

the average math and Spanish baseline test scores have slightly increased in public schools and declined in voucher-Catholic and voucher secular schools.

2.4 Identification Strategy

To understand how the characteristics of incoming students change over time after the implementation of the CAS, I employ a difference-in-difference non-parametric model following the approach outlined by Callaway and Sant'Anna, 2021. This method calculates separate treatment effects for each group of observations treated at the same point in time for each time period. It

Figure 2.4: Incoming student's reading proficiency evolution by type of school



Source: Author's calculations.

Note: Figure 2.4 depict the evolution of incoming students in terms of reading baseline proficiency in standardized test scores. The Solid line represents the average incoming student to a public school from 2012 to 2020, the dashed-dotted line private-secular school incoming students, and the dashed line private-Catholic school incoming students.

also allows for relaxing the parallel trends assumption by using a propensity score that absorbs all pre-treatment covariates information to create implicit pairings of units in the treatment and comparison group.

Using the variation in the timing of CAS implementation across regions, schools, and grades, I estimate the average treatment effect on the treated (ATT) for each cohort-year combination. All school grades located in regions that started implementing the CAS in the same year belong to the same cohort. For example, students in pre-k, kindergarten, 1st, 7th, and 9th grades enrolled in schools located in Magallanes, the first treated region, are all part of the 2017 cohort. Similarly,

pre-k, kindergarten, 1st, 7th, and 9th grade students enrolled in schools located in the four regions that started centralized admissions in 2018, are all part of the 2018 cohort, as well as Magallanes incoming students of all other grades, and so on.

The ATT for the cohort2018-time2018 is calculated as the difference in academic proficiency between incoming students in 2017 and 2018, and the difference of that difference between the treated and control groups. In this case, the treated group consists of all 2018-cohort school grades, and the control group consists of all school grades not yet treated by 2018.

The parameters of interest are as follows:

$$ATT(g,t) = E[(Y_t(g)) - Y_t(0)|X, G_g = 1], for \rightarrow t \geq g \tag{2.1}$$

Where g represents each treated cohort (i.e., 2018-2020), t every point in time (i.e., 2012-2020), X are covariates (i.e., mix-sex school dummy and percentage of female students), G_g are treated-at t cohort dummies, and Y_t the outcome at t (i.e., percentage of incoming low-income students, incoming student's Spanish, and math baseline performance). In other words, the parameters of interest are all average treatment on the treated effects for every cohort-year combinations. If looking at incoming student's baseline Spanish proficiency, the ATTs of interests are the difference in the outcome between students enrolling in year t from schools first treated in year g minus the same outcome if the same school hadn't been treated.

To recover the ATTs, I estimated equation (2) using schools from not-yet treated regions as my control group- denoted as ny in the ATT upper index. $p_{g,t}$ represent the estimated propensity score and is calculated with equation (4) using a mix-sex school dummy and the proportion of female students as explanatory variables. D_t represents a dummy that takes the value of one the year a school is treated and then onwards, and zero otherwise. Y_t is the value of the outcome variable in year t and Y_{g-1} the value of the outcome variable the year before the school was first treated. Finally, $m^{ny}_{g,t}(X)$ is calculated with equation (3) and represent the outcome average difference for the not-yet treated schools. As method of estimation, I use Sant'Anna and Zhao, 2020 doubly robust difference-in-difference estimator based on stabilized inverse probability weighting and ordinary

least squares- denoted as *dr* in the ATT lower-index.

$$ATT^{ny}_{dr}(g,t) = E[(\frac{G_g}{E[G_g]} - \frac{\frac{p_{g,t}(X)(1-D_t)}{1-p_{g,t}(X)}}{E[\frac{p_{g,t}(X)(1-D_t)}{1-p_{g,t}(X)}]})(Y_t - Y_{g-1} - m^{ny}_{g,t}(X))] \tag{2.2}$$

Where:

$$m^{ny}_{g,t}(X) = E[Y_t - Y_{g-1}|X, D_t = 0, G_g = 0] \tag{2.3}$$

And:

$$p_{g,t}(X) = P(G_g = 1|X, G_g + (1 - D_t)(1 - G_g) = 1) \leq 1 - \in a.s. \tag{2.4}$$

I estimated an ATT for every cohort-year combination, except for the schools treated after 2019 because, by then, there is no comparison group available (all schools are treated by 2020). To estimate. I then aggregate the estimated time-cohort ATTs to illustrate the results in an event-study framework.

The analysis concentrates on new students (i.e., they appear to be enrolled in a different school the year before). To understand changes in student selection across the three types of schools, I estimated the difference in characteristics of incoming students of public, subsidized private-secular, and subsidized private-Catholic schools, separately. I focus on the proportion of low-income students and the student's academic performance on standardized tests before the application.

2.5 Results

Table 2.1 depicts the aggregate ATT effects on student selection after the CAS started. Change in student selection is measured as the composition change of new students in terms of low-income status, and math and Spanish baseline performance. The effect on the three different selection measures was calculates separately for each type of school. The first row presents the aggregate ATT on student selection. Rows 2 to 5 depict the aggregate annual ATT after the CAS was implemented for

Table 2.1: Average treatment effects on the treated in student selection after the implementation of the Centralized Admission System

	% low-income			Math baseline performance			Spanish baseline performance		
ATT	Private-Catholic (1)	Private-Secular (2)	Public (3)	Private-Catholic (4)	Private-Secular (5)	Public (6)	Private-Catholic (7)	Private-Secular (8)	Public (9)
Aggregate	0.030***	0.017***	0.011***	-0.063**	-0.015	-0.017	-0.066**	-0.002	0.008
	(0.009)	(0.005)	(-0.004)	(0.026)	(0.014)	(0.014)	(0.028)	(0.014)	(0.014)
Year 2017	0.143**	-0.017	-0.083*	-0.186	-0.134	-0.078	-0.015	0.028	0.181*
	(0.064)	(0.069)	(0.049)	(0.054)	(0.307)	(0.121)	(0.149)	(0.076)	(0.100)
Year 2018	0.023	0.034***	0.016**	-0.081	-0.024	-0.023	-0.092*	-0.007	0.035
	(0.020)	(0.012)	0.007	(0.054)	(0.035)	(0.027)	(0.055)	(0.034)	(0.026)
Year 2019	0.044***	0.015**	0.012***	-0.073**	-0.017	-0.002	-0.038	0.004	0.032**
	(0.010)	(0.006)	0.004	(0.030)	(0.018)	(0.015)	(0.031)	(0.018)	(0.015)
Year 2020	0.024**	0.016**	0.011*	-0.056	-0.013	-0.023	-0.077**	-0.005	-0.010
	(0.012)	(0.006)	0.006	(0.034)	(0.018)	(0.02)	(0.038)	(0.018)	(0.021)
N	29,148	87,106	107,641	23,623	99,940	134,529	27,035	82,459	99,536

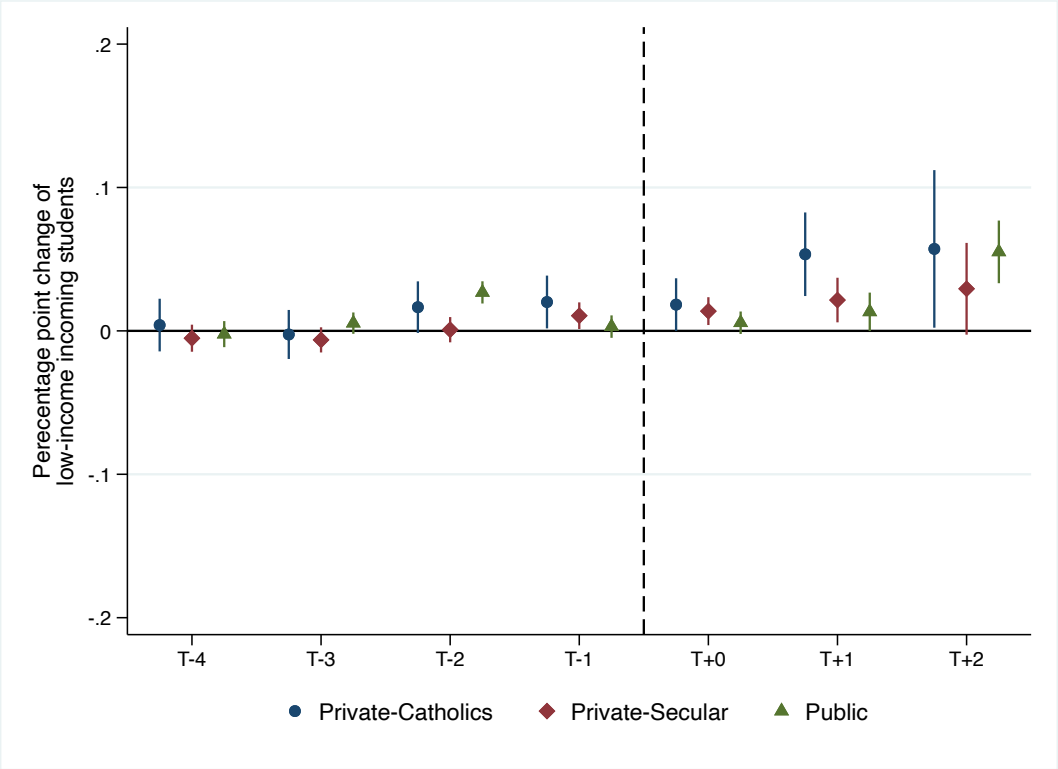
Note:Table 2.1 depicts the estimated coefficients of a difference in difference estimation following Callaway and Santana (2021). The first row shows the aggregated student-selection effect of attending a Catholic, secular, or public school after the CAS was implemented. Rows 2 to 5 depict the aggregated annual ATT after the CAS was implemented for the first time. Columns (1), (4), (7) show the estimated aggregate effects of implementing a CAS on Catholic school's student selection in terms of low-income status, math, and Spanish baseline performance, respectively. Columns (2), (5) and (8) show the same aggregate student selection effect, but for private secular schools, and (3), (6), and (9) for public schools. The comparison group are schools that haven't yet implemented the CAS of that same school type. Coefficients are estimated using Sant 'Anna and Zhao (2020) doubly robust did estimator based on stabilized inverse probability weighting and ordinary least squares and controls for a single-sex school dummy and the proportion of female students. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 Source: Author's calculations.

the first time. Catholic school appear to be the most affected by the CAS implementation. Subsidized private Catholic schools appear to enroll students with higher baseline academic proficiency in math and Spanish (i.e., the last registered standardized test results of the incoming student) in around .07 standard deviations and increased the proportion of low-income students in around 3 percentage points. Private-Secular and Public schools appear to have increased the proportion of incoming low-income students in around 1 percentage point, but not student's baseline math or Spanish baseline proficiency.

To test for parallel trends, Figures 2.5, 2.6, and 2.7 show the ATT for every period relative to the year of treatment. Pre-treatment trends assumption appears to hold for the three-outcome measure

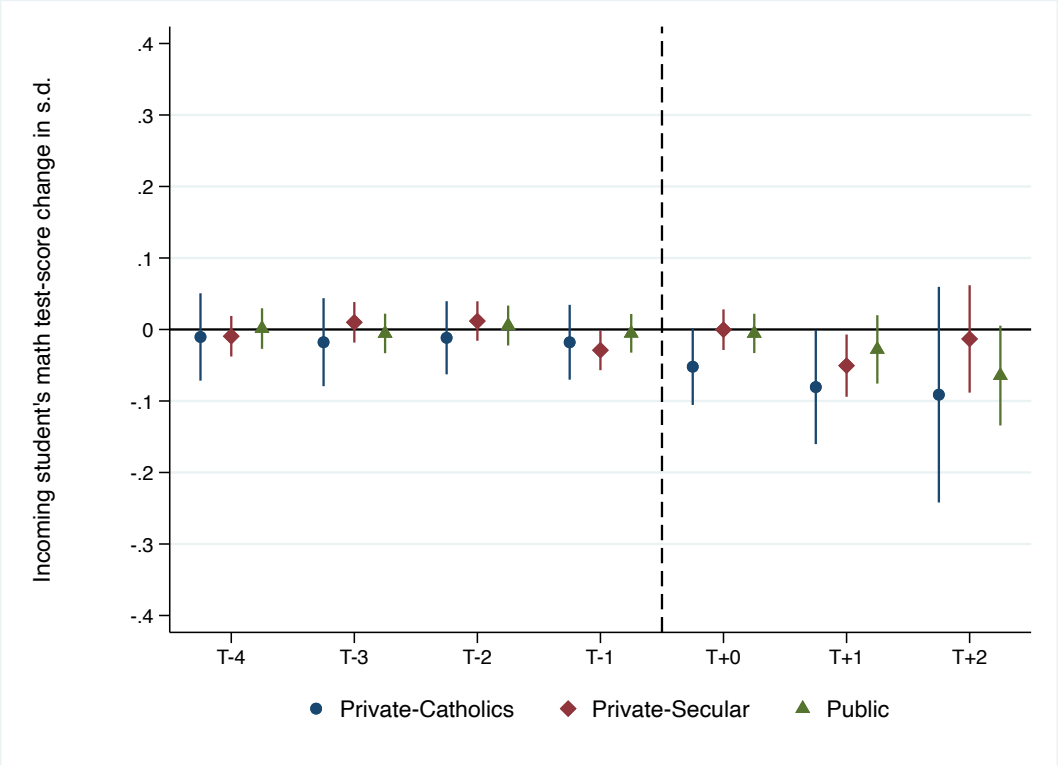
and for the three types of schools. Most Private Catholic school's ATTs for periods post-treatment don't appear significant at the 95% level on their own, but the aggregate post-treatment effect is significant for every student selection measure.

Figure 2.5: Incoming student selection. Percentage change in low-income



Note: Figure 2.5 depicts ATT estimated coefficients following Callaway and Sant'Anna, 2021 that regresses baseline incoming students' low-income status, on recent admission to a private-Catholic (blue dots), private-secular (red diamonds), or public school (green triangles) before and after the CAS system was implemented. One coefficient is estimated for each period relative to the time of CAS implementation, and then aggregated by each time relative to CAS implementation. Coefficients plotted from T+0 onwards, depict the change in student selection variables after the CAS was implemented, and from T-4 to T-1 before it was implemented. These coefficients are estimated using Sant'Anna and Zhao, 2020 doubly robust did estimator based on stabilized inverse probability weighting and ordinary least squares using a single-sex school dummy and the proportion of female students as control variables. Vertical lines above and below the estimated coefficients represent 95% confidence intervals.

Figure 2.6: Incoming student selection. Percentage change in math performance

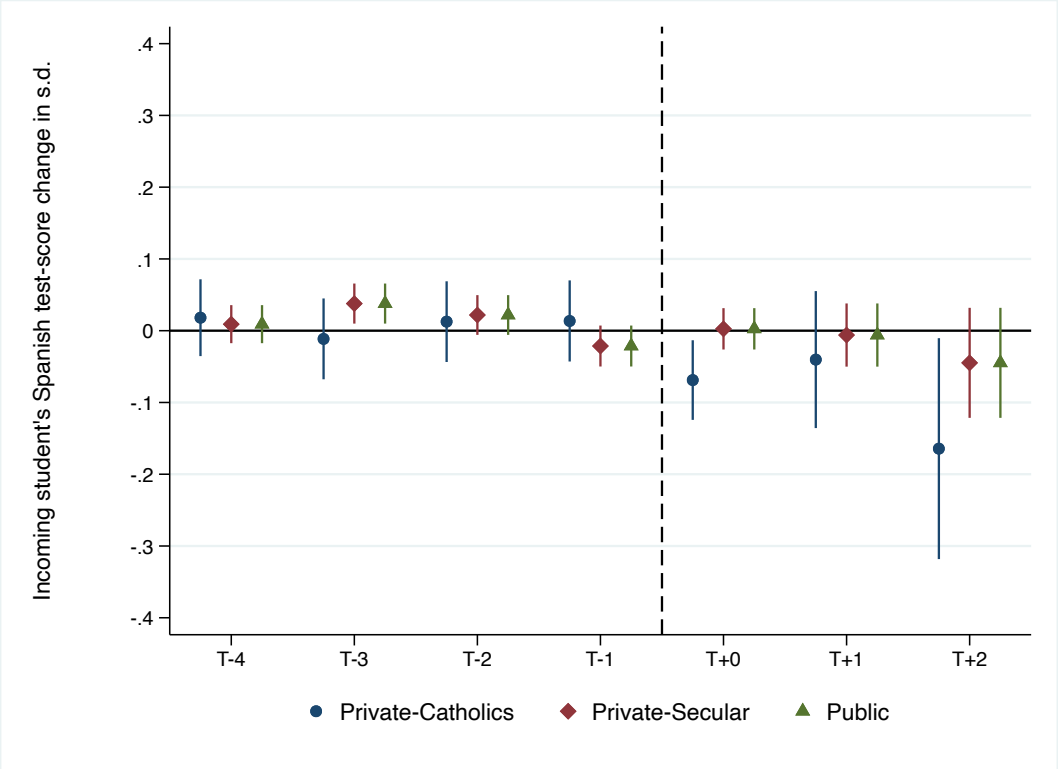


Note: Figure 2.6 depicts ATT estimated coefficients following Callaway and Sant'Anna, 2021 that regresses baseline math performance of incoming students, on recent admission to a private-Catholic (blue dots), private-secular (red diamonds), or public school (green triangles) before and after the CAS system was implemented. One coefficient is estimated for each period relative to the time of CAS implementation, and then aggregated by each time relative to CAS implementation. Coefficients plotted from T+0 onwards, depict the change in student selection variables after the CAS was implemented, and from T-4 to T-1 before it was implemented. These coefficients are estimated using Sant'Anna and Zhao, 2020 doubly robust did estimator based on stabilized inverse probability weighting and ordinary least squares using a single-sex school dummy and the proportion of female students as control variables. Vertical lines above and below the estimated coefficients represent 95% confidence intervals.

2.6 Conclusions

This study sheds light on the impact of the Centralized Admission System (CAS) on student selection. The findings reveal that the incoming student body of subsidized private secular, but specially subsidized Private Catholic schools, significantly changed after the CAS was introduced. Incoming students from lower economic backgrounds and with lower baseline academic performance now have better chances to study in a Catholic School, for example. In the long run, if these

Figure 2.7: Incoming student selection. Percentage change in reading performance



Note: Figure 2.7 depicts ATT estimated coefficients following Callaway and Sant'Anna, 2021 that regresses baseline reading performance of incoming students, on recent admission to a private-Catholic (blue dots), private-secular (red diamonds), or public school (green triangles) before and after the CAS system was implemented. One coefficient is estimated for each period relative to the time of CAS implementation, and then aggregated by each time relative to CAS implementation. Coefficients plotted from T+0 onwards, depict the change in student selection variables after the CAS was implemented, and from T-4 to T-1 before it was implemented. These coefficients are estimated using Sant'Anna and Zhao, 2020 doubly robust did estimator based on stabilized inverse probability weighting and ordinary least squares using a single-sex school dummy and the proportion of female students as control variables. Vertical lines above and below the estimated coefficients represent 95% confidence intervals.

changes persist, the CAS implementation should decrease segregation and educational inequality throughout the country. However, this will also depend on how preferences for the different types of schools correlate with students' income and baseline ability.

Additionally, it is essential to consider the possibility of cream-skimming occurring post-admission. Even though the CAS may have decreased selection at the entrance, there is a concern that schools could still push out low-performing students after enrollment. Further research

could explore this issue by examining dropout rates among students who entered before and after the lottery started. Analyzing these trends could provide insights into whether there are systemic differences in student retention and academic outcomes based on admission under the CAS.

Chapter 3: The Impact of Decentralized Decision-making on Student Outcomes and Teacher Quality: Evidence from Colombia

[1]This paper is published in the Journal of World Development, Volume 141, May 2021, and is coauthored with Gregory Elacqua, Fabio Sanchez, and Humberto Santos.

3.1 Introduction

Since the 1980s, Colombia has been undergoing a progressive decentralization process. Administrative decentralization was complemented by political decentralization that saw the enactment of the election of mayors in 1986 and of governors in the early 1990s (Falleti, 2005 Falleti, 2010). Also in the early 1990s, as a consequence of the 1991 constitution the amount of resources transferred from the central government to the departments and municipalities began to grow rapidly. However, in the late 1990s, the nation's fiscal situation became critical, which triggered a set of reforms in 2001 aimed at reducing the public deficit. Among them was a decentralization reform that, on the one hand, limited the growth of resources transferred from the central government to the departments and municipalities and, on the other hand, altered the distribution of transfers between the municipalities. The decentralized municipalities received a higher amount of transfers from the central government and were also granted greater responsibilities in the delivery of public services.

Regarding education, Law 715/2001, the core reform law, shifted the management of public education to either municipalities or departments. [2] Law 715 established that municipalities with

[2]A municipality is a territorial entity managed by the mayor, who governs along with a municipal council. Both the mayor and the council are elected by popular vote. Colombia has 1,123 municipalities. Departments are headed by a governor responsible for the autonomous administration of public resources. Departments have autonomy in the handling of matters related to their jurisdiction and operate as entities between the national government and the municipalities. In addition to the governor, they are administered by an assembly of deputies elected in popular elections. In Colombia, there are 32 departmental units.

100,000 or more inhabitants in 2002 would become "certified in education," which granted them the responsibility for the supervision, planning, and delivery of public education. These functions included financial management of the central government transfers, teacher hiring and transfers across schools, and programs to improve both enrollment rates and education quality. Municipalities with less than 100,000 inhabitants were not certified, and their public education activities remained the responsibility of the departments of their jurisdiction. From receiving a narrow share of transfers and being subject to departmental supervision, certified municipalities transitioned to having greater managerial and financial autonomy, while non-certified municipalities gave up their already limited powers to their respective department (Brutti, 2020).

These reforms in the delivery of public education in Colombia starting in 2001 created an opportunity for a natural experiment on the effects of greater administrative decentralization. By using the arbitrary rule that defines a decentralized municipality as a natural experiment, the objective of this paper is to causally evaluate the effect of the reform on educational indicators and outcomes, including the quality of teachers, student achievement, and student enrollment.

There is an ongoing discussion as to whether decentralization improves equity and efficiency in the provision of public education. On the one hand, the fiscal federalism literature has identified several mechanisms by which decentralization may lead to improved levels of efficiency in the provision of public goods and services in general (Enikolopov and Zhuravskaya, 2007, Lockwood, 2005). First, decentralization advocates maintain that sub-national governments have better knowledge of their population's preferences and needs than the central government (Faguet and Pöschl, 2015 Oates, 1999). Therefore, in the absence of economies of scale and externalities, they argue that decentralization can ensure a better match between political decisions and local preferences (preference-matching argument). In the case of education, for example, local governments have more information about teacher shortages in specific subject areas (e.g., sciences or foreign languages), for which schools need better-trained teachers to offset the disadvantages faced by students with low socioeconomic status (Bertoni et al., 2018), and in how to design better incentives to attract teachers to hard-to-staff schools (Umansky and Vegas, 2007; Salinas, 2014). For example,

Faguet, 2004 finds that following fiscal and political decentralization reform in Bolivia, investment in education increased in municipalities with higher illiteracy rates. The second argument put forth by decentralization advocates is that, since local governments are closer to the beneficiaries, authorities are held responsible for the quality of local services (accountability argument). The increase in the degree of political accountability of government could serve as an incentive for public officials to act in the best interests of their citizens and to increase the quality of education (Seabright, 1996). Recent findings using information from the Organization for Economic Co-operation and Development show that greater decentralization generally improves enrollment rates, though it also creates congestion effects that lower the quality of education. Local politicians nonetheless often focus on improving enrollment rates over boosting student achievement, since the former is more visible to citizens and quicker to achieve (Guerra and Lastra-Anadón, 2019).

In contrast to the argument that decentralization favors better delivery of education, there are those who argue that decentralization has potential negative effects on education quality and equity. First, local governments may have a higher probability of being captured by local elites and interest groups, which reduces the efficiency of spending. This result is context-specific, however, suggesting the need for empirical studies (Bardhan and Mookherjee, 2005). Some studies of decentralization reforms have found that there is favoritism and corruption in the teacher hiring process at the local level (Grauwe, 2005 Green, 2015 Khanal, 2011). Second, decentralization has the potential to increase regional inequities in education outcomes because there is significant heterogeneity in the management capacity of local governments (Leer, 2016 Parry, 1997). Several papers show that the positive effects of decentralization are concentrated among local governments with greater management capacity, resources, and economic development (Brutti, 2020; Galiani et al., 2008; Kalirajan and Otsuka, 2012).

A number of studies have attempted to evaluate the effect of decentralization on educational outcomes using different methodologies and data. First, cross-country studies, using results from international assessments, find a positive impact of decentralization, but one that is concentrated in developed and high-performing countries (Falch and Fischer, 2012 Hanushek et al., 2013). Second,

some studies within educational systems, using difference-in-differences and panel data techniques and decentralization reforms as an identification strategy, generally find positive effects of decentralization on academic results (Barankay and Lockwood, 2007 Galiani et al., 2008 Jeong et al., 2017 S and C, 2018 Diaz-Serrano and Meix-Llop, 2019). Finally, a few recent studies take advantage of arbitrary rules defining different levels of autonomy of local governments or schools to evaluate the impact of educational autonomy in a quasi-experimental setting. For example, Clark, 2009 analyzes a 1988 reform in the United Kingdom that gave public secondary schools the option to opt out of local school district control and become autonomous schools funded directly by the central government.[3] Using a regression discontinuity design, the author finds large achievement gains at schools that became autonomous. Litschig and Morrison, 2013 exploit the increase over 1982–1985 in central government transfers in Brazil at arbitrary population cutoffs. The authors find that communities that received additional funds increased years of schooling and reduced poverty, and that the incumbent mayors boosted their reelection chances. Brutti, 2020 attempts to explain the divergent path of educational indicators among the autonomous Colombian municipalities with a population greater than 100,000 subject to the country's decentralization reforms in 2002. She finds a growing test score gap between autonomous municipalities in the top socioeconomic quartile and those in the bottom quartile. She also shows that more advantaged autonomous municipalities supplemented central government transfers with local resources.[4]

This paper focuses on the effect of the 2001 decentralization reform in Colombia on student enrollment, student achievement, and teacher quality. Colombia is a unique case because the reform granted autonomy in decision-making to certain municipalities using as a sole condition an arbitrary population threshold that enabled these municipalities to become "certified." This arrangement allows for estimating the effect of the treatment in a quasi-experimental setting, as the reform affected the management of public education, including the appointment and allocation of teachers across schools, handling of programs to reduce dropout rates and increase enrollment,

[3]Schools seeking autonomy had to apply to participate in the program and win a majority of votes among parents. Almost one in three high schools voted to become autonomous between 1988 and 1997.

[4]Cortés, 2010 used the same arbitrary rule to study the impact of increased autonomy on total enrollment. Results suggest that more decentralized municipalities subsidize more students in private schools to increase enrollment.

distribution of financial resources to local schools, and evaluation of principals, among other tasks. The 2001 decentralization reform affected the distribution of the central government transfers between municipalities and departments related to the delivery of public education but did not alter decentralization in fiscal or political matters.

This paper evaluates the causal effect of the 2001 decentralization reform on the educational outcomes upon which "certified" municipalities had the autonomy to focus their efforts: student enrollment, teacher quality, and student achievement. The promotion of student enrollment and the hiring and allocation of teachers correspond to the types of government functions that advocates maintain should be decentralized (Pritchett, 2014; Pritchett and Pande, 2006). First, to be implemented successfully, both functions require discretionary actions, including need-based program design, creation of incentives, teacher hiring, and personnel transfers, as well as local knowledge regarding where there are children out of school, which schools lack teachers, etc. Second, both actions are transaction-intensive, since they entail constant interactions and negotiations with the local bureaucracy, communities, and schools. Finally, the implementation of both functions can be constantly evaluated and accordingly improved at the local level. Thus, it is expected that student enrollment, the quality of teachers, and student learning would improve when municipalities become more autonomous precisely because those functions should be managed at the local level.

In order to evaluate the effects of the decentralization reform, this analysis uses two approaches: first, a difference-in-differences model with information at the municipal level for the period 1996–2015 exploiting the quasi-experimental treatment on the "certified" municipalities after the 2001 reform; and second, a regression discontinuity design using information at the school level during 2010–2015. The difference-in-differences results show that municipalities that became autonomous in the delivery of public education after 2001 increased student enrollment, recruited a higher proportion of teachers with higher levels of education, and had students with higher achievement scores on standardized tests. Using a mediation analysis, we also examine the probable channels explaining the higher educational performance of certified municipalities and find that the higher quality of teachers explains a large part of the results. We also look into the role that

local fiscal effort as a means to mobilize additional resources for education may have played in educational outcomes, and into the likely trade-offs between student enrollment and teacher quality. Based on additional variables on student performance and teacher quality at the school level (only available from 2010 onward) the regression discontinuity results corroborate the difference-in-differences findings.

This paper contributes to the literature on decentralization in two ways. First, it utilizes a natural experiment that arbitrarily granted almost total administrative autonomy to a set of municipalities and almost totally reduced the autonomy of the other municipalities, with no changes in political or fiscal decentralization. This setup allows for a causal evaluation of the effect of administrative decentralization at the municipal level on educational outcomes. Second, it analyzes how educational municipal autonomy (certification) influences decisions on teacher hiring and how this affects educational outcomes. To the best of our knowledge, this is the first study in the decentralization literature that has explored how these mechanisms influence student achievement.

The next section provides background on educational decentralization in Colombia. Section 3.3 describes the data, Section 3.4 describes the empirical methods employed and presents the results, and Section 3.5 puts forth the paper's conclusions.

3.2 Decentralization in Colombia

3.2.1 The Pre-2001 Reform Scenario

In the mid-1980s, Colombia initiated a process of gradual decentralization that started with political decentralization in 1986 with the election of mayors and in 1991 with the election of governors by popular vote. Prior to then, mayors were appointed by the governors and the governors by the president (Cortés, 2010). In 1993, with the enactment of Law 60 the process of administrative decentralization deepened and both municipalities and departments assumed greater responsibilities in the delivery of education, health, and potable water and sewage (Faguet et al., 2009, Faguet et al., 2014). The greater administrative decentralization was accompanied by a significant increase in central government transfers to the departments (what was known as the Situado Fiscal)

and the municipalities (the Municipal Share). Law 60 specified that municipalities were to oversee the management of preschool, primary, and secondary education services. In addition, the law stated that municipalities should allocate resources to finance school construction and education programs and projects. Law 60 also determined that municipalities should oversee and evaluate the delivery of educational services. The responsibilities of departments included the same as the municipalities, which entailed a great deal of coordination between the two levels of government. The departments were also in charge of the hiring, training, and ranking of teachers as well as their assignment across municipalities. Teacher payrolls were to be paid by the departments, financed with central government transfers to the departments (Borjas and Acosta, 2000; Bonet et al., 2014).

The lack of a clear delineation of the responsibilities of each level of government generated an overlapping of functions that blurred the lines of accountability. For example, prior to the 2001 reform, teachers were in fact paid by both departments and municipalities. Estimates by Borjas and Acosta, 2000 indicate that department payrolls covered 85-90 percent of all public school teachers, while municipalities – which also assigned teachers across schools within their jurisdiction – hired and paid the remaining 10-15 percent. In addition, in many cases entities in charge of certain educational services did not have enough resources and authority to fulfill their responsibilities. For example, municipalities had a key role in the management of public schools, but they had very limited authority to appoint or dismiss staff (Borjas and Acosta, 2000). In practice, during the 1990s and until 2002, departments performed the chief role in the structure of administrative decentralization of education. They also received a higher percentage of the central government transfers earmarked for education. However, by the late 1990s the structure of administrative decentralization and the central government transfers associated with it had become fiscally unsustainable, given the increasing cost.[5] The Colombian economic and fiscal crisis in 1999 sparked a reform of the system of central government transfers to the subnational entities. However, the reform required a set of constitutional and legal changes and involved a great deal of political and tech-

[5]The 1991 constitution established that transfers to departments and municipalities were calculated as a yearly growing share of central government current revenues. Transfers grew both due to the growing share and to the growth of current revenue.

nical discussions. Law 715 was enacted in 2001, and since then, with some modifications, it has been the main regulatory framework of Colombia's administrative decentralization. The reform limited the annual growth of central government transfers and tried to fix the shortcomings of Law 60 regulations, mainly the overlapping of responsibilities between departments and municipalities (Bonet et al., 2014; Brutti, 2020).

3.2.2 The 2001 Decentralization Reform of Education

Law 715 of 2001 redefined the administrative decentralization of the Colombian education system and introduced profound changes in the distribution rules of transfers from the central government. First, administrative decentralization and the supervision, planning, and delivery of education started to be managed by Certified Territorial Entities (Entidades Territoriales Certificadas - ETCs) that could be either be departments (regional level) or municipalities (local level). The departments managed most of the supervision, planning, and delivery of the non-certified municipalities of their jurisdiction. As mentioned above, Law 715 established that certification would be granted to those municipalities with more than 100,000 inhabitants as of the end of 2002. However, Law 715 also allowed municipalities with less than 100,000 inhabitants to become "certified" if an evaluation by the department found that they had technical, administrative, and financial capacity to manage the provision of education (de Educación Nacional de Colombia, 2002).[6] Of the 63 municipalities certified in 2020, 17 obtained certification through this process.

As for teachers, Law 715 established that certified entities have the legal authority to hire principals and teachers, although due to resource constraints the Ministry of Education imposes restrictions on the number that can be hired. These limits were implemented to avoid the disorderly increase in teacher payrolls of the 1990s (de Colombia, 2000 Duarte, 2001).[7] Until 2002, the hiring

[6]Specifically, municipalities with less than 100,000 inhabitants can be certified after fulfilling the following requirements: (1) Alignment between the local educational development plan with national policies; (2) organization of schools as institutions offering all grades; (3) appointment of education staff in accordance with the national parameters of the student-teacher ratio, and subject to the administrative career trajectory; and (4) demonstrating the institutional capacity to perform the tasks and collect the information required by the educational authorities. Compliance with these requirements is determined by the departments.

[7]Teacher hiring at the local level compromised the central government's fiscal sustainability when a municipality was unable to pay the teachers' salaries. If this occurred, the central government was required to assume the payroll

of teachers and principals by the departments occurred after a determination of eligibility based on credentials of the applicants (degrees, experience) and interviews. After teachers were deemed eligible, the educational authority assigned the new teachers in the department's schools based on the number of available vacancies (Ome, 2013; Brutti and Torres, 2017). The credential-based system was replaced in 2002 by an exam-based system (which continues today) under which the candidate applies to become a teacher in a specific certified entity. Candidates are required to pass the subject exam with a minimum score (60/100), and once that requirement is met, the candidate must take a psychometric test, meet credential requirements, and be interviewed. Eligible teachers choose schools among the available vacancies. The certified entities place applicants into vacancies based on the ranking of the eligible teacher. Once in the system, the educational authority of each certified entity has the legal authority to reassign teachers within the entity. In the case of departments that encompass multiple non-certified municipalities, teachers are assigned according to their ranking and preference in any of these jurisdictions.[8] Since more advantaged and high-performing schools are often chosen first by the highest-scoring teachers, low-performing teachers are often assigned to underachieving, isolated, and disadvantaged schools.[9] Certified entities can also hire temporary teachers if they deem it necessary. A high percentage of these teachers either did not participate in the eligibility process or did not pass the mandatory exams.

Certified entities have no restrictions to use diverse sources of funding (e.g., own taxes, debt, dividends from public companies) or to distribute resources to programs or interventions aimed at improving educational outcomes. Likewise, non-certified municipalities can add their own resources for the educational inputs they consider important.[10] Such inputs cover (1) furniture, texts,

costs (de Colombia, 2000).

[8]For example, the department of Cundinamarca oversees the implementation of the teacher eligibility process for 113 non-certified municipalities.

[9]Bertoni et al., 2018 show this positive correlation between teacher characteristics and school socioeconomic status in Colombia. Additionally, teachers who apply to the vacancies in a department ETC have more uncertainty about where they will end up working – especially those who passed the entry exam but were not top performers – because remaining vacancies may only be available in remote municipalities or because there is a risk of being moved in a few years to a school with inferior working conditions or located in an isolated area within the same department. These factors likely reduce the incentive to apply to a department over a certified municipality.

[10]Similar to the pre-reform scenario, departments and municipalities, including non-certified ones, can invest their own resources in education. These revenues come from direct taxes (e.g., taxes on property, industry and commerce, and alcoholic beverages), indirect taxes, and non-tax revenues (e.g., contributions and fines). Municipalities have au-

libraries, didactic, and audiovisual materials; (2) improvement of school management; (3) construction, maintenance, and adaptation of infrastructure; (4) public services and operation; (5) improvement of working conditions of teachers; and (6) non-teaching staff. Certified entities can attract teachers to schools in their jurisdiction by improving working conditions and giving incentives to high-performing candidates. The municipalities also allocate resources for school transportation and school meals programs (de Educación Nacional de Colombia, 2002).

3.2.3 The Structure of the Central Government Transfer for Education

The distribution of the transfers to subnational entities has operated since 1993 under two legal and regulatory frameworks. The first, developed in Law 60 of 1993, established a set of rules for a type of administrative decentralization under which the responsibilities for providing primary and secondary education by departments and municipalities substantially overlapped. Despite the fact that departments had greater responsibilities – particularly in the hiring and assignment of teachers and the oversight of schools and personnel – the municipalities de facto could undertake the same departments' functions and tasks. As mentioned, Law 60 was replaced by Law 715 in 2001 in the aftermath of the economic and fiscal crisis that Colombia experienced at the end of the 20th century. Law 715 redefined the structure of administrative decentralization, clearly separating the responsibilities of "certified" and "non-certified" territorial entities. The central government transfers – known as the General System of Revenue Sharing (Sistema General de Participaciones) – were set to finance the provision of social services in general, and public education in particular, according to the assigned responsibilities. Thus, the reform sharply divided the Colombian municipalities: "certified" municipalities became autonomous and the departments lost their administrative authority over them, while "non-certified" municipalities became less autonomous and

tonomy to allocate these resources to education, but they cannot be used to fund teacher salaries (Law 715). However, they can fund infrastructure and maintenance, as well as additional services such as transportation, school meals, and extracurricular activities. In 2016, these resources represented 9 percent of total public spending. However, they are strongly concentrated in some certified territorial entities. For example, Bogotá (43 percent), Medellín (8.8 percent), and Barranquilla (4.9 percent) account for 56.4 percent of total resources invested at the national level. In some ETCs like Bogotá, Rio Negro, Barrancabermeja, and Sabaneta, own resources represent more than 30 percent of total resources (Alvarez et al., 2018).

the departments gained administrative authority over them. As the responsibilities and functions assigned to the certified municipalities are better performed at the local level, it is expected that they would exhibit better educational outcomes than non-certified municipalities.

The structure of central government transfers to the subnational entities expressed in Law 60 radically changed with the inception of Law 715. Law 60 established that 60 percent of the transfers to the departments (Situado Fiscal) were allocated to education and 20 percent to health, while 30 percent of the central government transfers to municipalities (Participación Municipal) were earmarked to education and the rest to other social services and local running costs.[11] The distribution of transfers across municipalities depended upon population, poverty rates, and many other variables. Law 715 introduced a new set of rules to distribute central government transfers under the General System of Revenue Sharing. The law established that the total amount of transfers would grow at a fixed annual rate of 2 percent and fund the provision of education, health, and water and sanitation services.[12] According to current legislation, of the total (General System of Revenue Sharing, (SGP), 58.5 percent is allocated to education, and 90 percent of that 58.5 percent is distributed across "certified" entities depending on the total number of students and their the regional costs, as well as on the national objectives for growth in enrollment.[13] These funds cover personnel costs (teachers and administrative staff) and can also be used to contract private schools when seats in public schools are in short supply. The remaining 10 percent of the central government transfers for education are distributed across municipalities and allocated to quality

[11] Law 60 established that by 1996 transfers to the departments (Situado Fiscal) would reach 24 percent of the central government's current revenues divided among the departments according to population and an array of many other variables. Central government transfers to municipalities (Participación Municipal) grew between 1993 and 2001 from 15 to 22 percent of the central government's current revenues.

[12] This rule has been modified and today the growth of transfers reflects the average growth of current revenue during the previous four years.

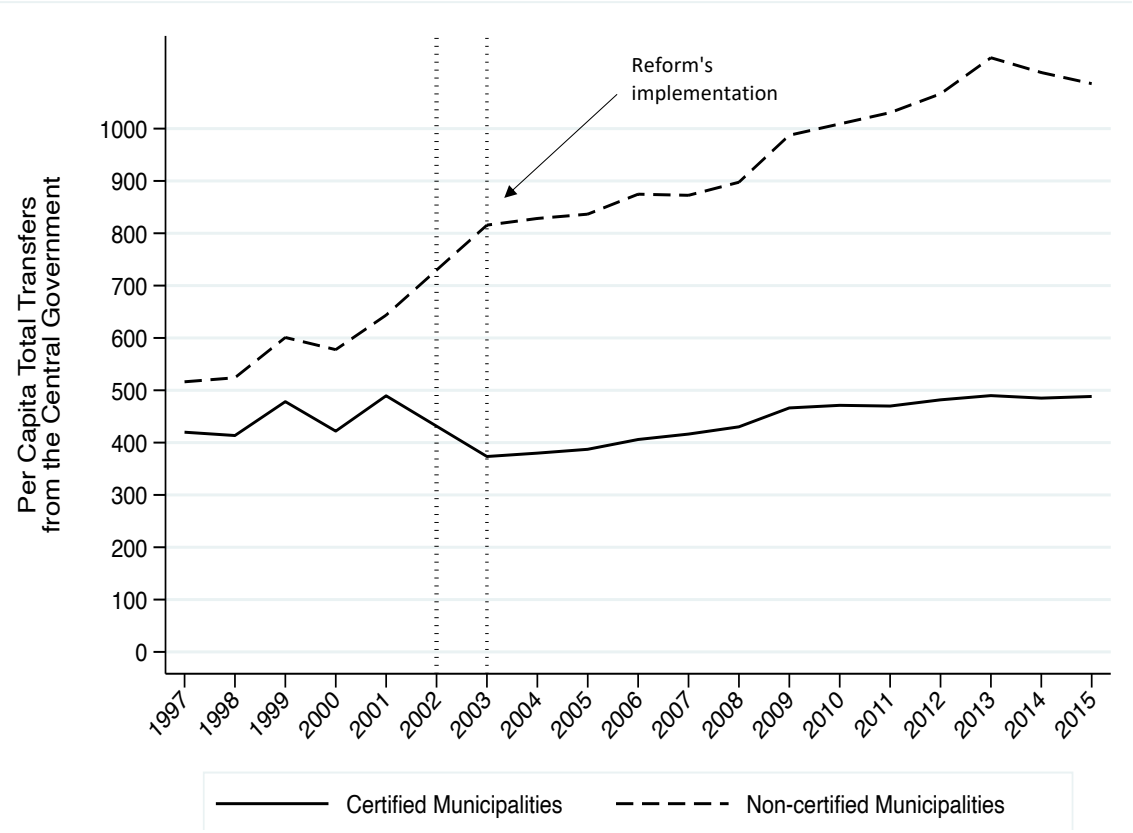
[13] According to Law 715, a typology is a set of variables that characterizes the provision of educational services. In practice, the typologies correspond to groups of subnational entities that receive the same allocation per student. Once the allocations per student have been defined, the total transfer results from multiplying the per-student transfer by the total enrollment. The allocation varies according to school zone (rural and urban) and level (pre-primary, primary, and secondary). One of the main criticisms of the financing model for education prior to 2001 was that transfers of resources from the central government were determined by costs, mainly teacher salaries, without considering educational outcomes in terms of access and quality. The 2001 reform intended to reverse this, introducing a formula based on the enrollments of each ETC and a per student or "typology" allocation. One of the key changes under the reform was the introduction of the per student formula to encourage the entities to increase total enrollment as a strategy to increase their educational budget (Alvarez et al., 2018).

improvement (e.g., school transportation, school meals, utilities, minor school construction, school computers, teacher training) (Alvarez et al., 2018).

Figure 3.1 and figure 3.2 presents the evolution of per capita central government transfers to departments and municipalities using the Law 715 classification of "certified" and "not-certified" entities for the period of 1994–2015. It can be seen how the 2001 reform profoundly altered the distribution of central government transfers. During 1996–2002, the municipalities to be certified in 2002 received the same per capita transfers for education as those that would become non-certified. In 2003, the transfers for non-certified municipalities abruptly declined while transfers for certified municipalities and departments sharply increased. Nonetheless, total transfers for education spending were much higher for non-certified municipalities, as they depended on their own transfers plus the departments' transfers.

The following sections will take advantage of the arbitrary rule used in Colombia to define the municipalities that can autonomously manage their provision of public education and evaluate the effect of greater administrative decentralization on educational outcomes, including student enrollment and student achievement, and on the contractual and educational characteristics of teachers. The analysis will use two methods: difference-in-differences panel regression and regression discontinuity. For the difference-in-differences approach, we will include the universe of municipalities during 1996–2015, using as the treatment being "certified" after 2002. For the regression discontinuity estimation, we will employ information on educational outcomes and teachers at the school level for municipalities around the cutoff of 100,000 population. The information corresponds to the period 2010–2015 – 10 years after the enactment of the reform –when it is expected that the effects of greater administrative decentralization are already consolidated. We will explore the potential differences in the quality of teachers and local fiscal effort as mechanisms to explain differences in student outcomes between certified and non-certified municipalities. As discussed above, we hypothesize that certified municipalities would show better educational outcomes, as the functions to offer a high-quality education are more efficiently performed at the local level (Guerra and Lastra-Anadón, 2019; Pritchett and Pande, 2006; Pritchett, 2014). The functions to accom-

Figure 3.1: Trends of central government total transfers before and after the administrative decentralization reform



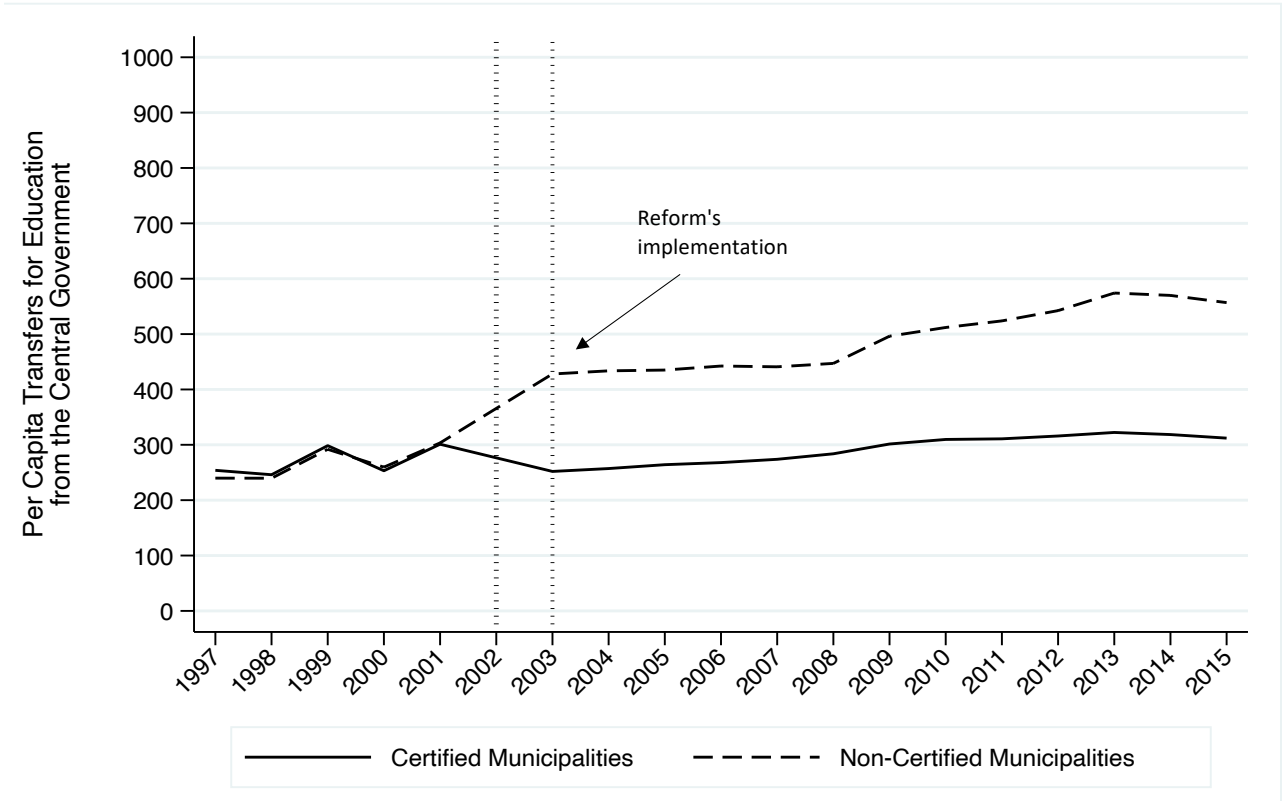
Note: Figure 3.1 depicts the per-capita total transfers in thousands of Colombian 2018 pesos. Until 2002, all municipalities received central government transfers both directly and indirectly through departmental spending. Since 2003, certified municipalities receive only direct transfers from the central government, while non-certified municipalities receive central government transfers both directly and indirectly through departmental spending.
Source: National Planning Department, Authors' Calculations

plish greater student enrollment and higher student achievement are discretionary, require local knowledge, involve a great deal of negotiations and transactions, and can be locally evaluated.

Thus, more local autonomy not only facilitates the selection, hiring, and assignment of teachers across schools but also reduces the teachers' uncertainty regarding the schools to which they may be assigned. In this regard, the market of teachers would operate more efficiently in the certified municipalities.[14] Moreover, certified municipalities have better local information about active stu-

[14]However, these positive effects could be offset if the smaller size of the labor market where decentralized governments can hire teachers makes it more difficult to find high-performing teachers, or if local governments are more

Figure 3.2: Trends of central government education transfers before and after the administrative decentralization reform



Note: Figure 3.2 depicts the per-capita transfers for education in thousands of Colombian 2018 pesos. Until 2002, all municipalities received central government transfers both directly and indirectly through departmental spending. Since 2003, certified municipalities receive only direct transfers from the central government, while non-certified municipalities receive central government transfers both directly and indirectly through departmental spending.
Source: National Planning Department, Authors' Calculations

dents, out-of-school children, and schools' needs than do departments, allowing for more precise and better targeted interventions.

3.3 Data

To assess the impact of greater administrative decentralization on educational outcomes (student enrollment and results on standardized tests) and on the quality of teachers in the municipality, we merged different databases containing school and municipal information on education-related

exposed to the risk of being captured by interest groups (Salinas, 2014).

variables. The different sources of data, including the unit of information and years covered, are outlined below.

3.3.1 Socioeconomic Characteristics

The panel database, constructed by the Center of Economic Studies of Los Andes University, contains data from different public sources and from diverse geographic, demographic, and socioeconomic characteristics of the 1,121 Colombian municipalities. Some of the municipal variables contained in the database used here to assess the differences between certified and non-certified municipalities were in place before the decentralization reforms were enacted. Thus, these characteristics allow for checking for balance between the treatment and control group in the regression discontinuity estimations (see Table B.3 in the Appendix). Additionally, we used the 1993 Colombian census, which reports the total municipal population of 1993 and the projected population from 1994 to 2005. These projections served to determine the municipalities that became certified in 2002.[15]

3.3.2 Quality of Education

To assess the effect of greater administrative decentralization on student achievement, we use the individual results of the Saber 11 tests at the end of the 11th grade, the last year of secondary school from 1996 to 2015.[16] This test is organized and administered by the Colombian Institute for the Evaluation of Education (Instituto Colombiano para la Evaluación de la Educación - ICFES). We compute the test results – total, in Spanish, and in math – at the school and municipal levels. This information will be used in the difference-in-differences and regression discontinuity models. The results of the Saber 3, 5, and 9 tests that students take in the respective grades are available for 2009 and for 2012–2017 at the school level and will be used in the regression discontinuity models.

[15] We verified this information with data from the Colombian National Planning Department, which allowed for verifying which municipalities started receiving resources for their decentralized public education administration.

[16] Saber is the name of a set of compulsory standardized tests administered in the 3rd, 5th, 9th, and 11th grades. The exams evaluate all schools in the system, including public and private both in urban and rural areas. They focus on the basic competences that students must develop in language and mathematics. More information on Saber is available at http://www2.icfes.gov.co/instituciones-educativas-y-secretarias/acerca-de-las-evaluaciones/informacion-general.

These data contain the school's average tests scores for each grade as well as four variables that indicate the number of children within each school who scored within four different categories: insufficient, below average, satisfactory, and exemplary. We used the percentage of 3rd, 5th, and 9th grade students with insufficient performance on the math and Spanish tests for each school from 2012 to 2017.

3.3.3 Student Enrollment

We use the C-600 database of the National Bureau of Statistics (Departamento Administrativo Nacional de Estadística - DANE), which contains information on the number of students by level of education (preschool, primary, and secondary) in all Colombian public schools since 1996. More recently, DANE has also gathered information on private school and teachers.

3.3.4 Quality and Type of Contract for Teachers

We used two different databases provided by the Ministry of Education for teacher quality measures. The first contains information from 2008–2016 on all teachers hired by the education system, including their sex, date of birth, year of hiring, level of education (high school, college, post-graduate, etc.), ranking within the teacher career, place of work (school and municipality), subject and level (primary or secondary) of teaching, and type of contract, among other information.[17] Since the teacher database has the year of hiring, we were able to compute the accumulated number of teachers hired in each municipality as a total and by characteristics. The second DANE database contains teacher scores on the mandatory entry exam. This exam assesses the verbal, numeric, and specific subject knowledge competencies of the candidate. This teachers' test is administered by the ICFES. These data are merged with the administrative teacher database of the Ministry of Education.

[17]Temporary teachers in Colombia are recognized as public servants but are only hired temporarily and are not eligible for the benefits that permanent teachers receive. They are usually hired when there is a lack of permanent teaching staff. They do not have to take the entry exam that permanent teachers are required to pass. Because they lack credentials and do not meet other hiring requirements of permanent teachers, research shows that temporary teachers are often less effective than permanent ones (Guerrero et al., 2017).

3.3.5 Central Government Transfers and Subnational Fiscal Data

The source of the information on transfers and local finances is the National Planning Department (Departamento Nacional de Planeación - DNP). This agency calculates the amount of transfers going to the subnational entities for each public good under its responsibility –education, health, water and sewage, and sports and culture, among others. DNP is also in charge of collecting and analyzing the financial information of the municipalities, including local taxes, transfers received from different sources, and local spending. The period of the information goes from 1996 to 2016.

3.4 Empirical Strategy and Results

As observed in Figures 3.1 and 3.2, the central government transfers were equal in Colombian per capita pesos for the municipalities that would be certified in 2001 and those that would not. After 2002, certified municipalities gained more autonomy and received larger per capita transfers, the non-certified municipalities lost autonomy and received smaller per capita transfers, and the departments acquired stronger administrative powers over the non-certified municipalities and consequently received larger per capita transfers. This section presents the empirical approach used to estimate the effects of greater administrative decentralization in education provision using both a difference-in-differences approach and a regression discontinuity design, exploiting the natural experiment of the 2001 reform.

3.4.1 Difference-in-Differences Approach

Non-flexible Model

The difference-in-differences approach will take advantage of the panel structure of the data and the fact that the rule established to declare a municipality as certified – 100,000 inhabitants at the end of 2002 – was arbitrary. It is valid to use a difference-in-differences approach if no municipality self-selected in 2002 to become certified and if the assumption of parallel trends in

the outcome variables before the intervention is fulfilled. The first condition has full compliance and we will empirically test the second condition with a flexible model.

The difference-in-differences model to estimate is the following:

$$Y_{it} = \beta_i + \beta_t + \beta_1 * Certified_{it} + \beta_2 * Controls_{it} + \mu_{it} \tag{3.1}$$

Where Y_{it} represent the different variables of interest – student enrollment and scores on standardized tests, the quality and type of contracts of teachers, and local per capita taxes. β_i is the municipal fixed effect, β_t is the year fixed effect, and β_2 is the set of coefficients for the control variables. The key coefficient is β_1, which indicates the effect of being certified after 2003 on Y. As observed in Table 3.1, being certified increases the Saber 11 test scores by, on average, 0.048 standard deviations, after controlling (in addition to the municipality and year fixed effects) for the interaction between the departmental dummies and year dummies. This interaction would pick up the diverse educational policies and interventions in non-certified municipalities that are carried out by the departmental authorities.

Table 3.1: The effect of municipal administrative decentralization on educational indicators

	Exit high school Exam (Standardized)		**Enrollment in public schools (Log)**		**Proportion Teachers higher-education**		**Proportion teachers permanent-contracts**		**Local Taxes (Log)**	
Certified X (Year>2002)	0.114***	0.060***	0.091***	0.087***	0.019***	0.021***	0.043***	0.041***	0.037***	0.044***
	(0.025)	(0.021)	(0.008)	(0.009)	(0.001)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
Constant	-0.158***	-0.157***	8.032***	8.027***	0.906***	0.906***	0.892***	0.892***	0.104***	0.104***
	(0.003)	(0.003)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Department X Year FE	NO	YES	NO	YES	NO	YES	NO	YES	NO	YES
N	19251	19181	19440	19382	19370	19312	19370	19312	19459	19401
Mean non-certified	-0.169	-0.169	7.913	7.913	0.905	0.905	0.896	0.896	0.101	0.101
N Years	19	19	19	19	19	19	19	19	19	19
N Municipalities	1071	1071	1073	1073	1073	1073	1073	1073	1073	1073
N Departments X Years		552		565		565		565		565

Note: Difference in difference estimation. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the quality of education (ICFES). Colombian National Bureau of Statistics (DANE). Colombian Ministry of Education, administrative database of public teachers. Authors' calculations

Table 3.1 also shows that in certified municipalities, the growth in the number of enrolled students in public schools exceeded by 10 percent the enrollment growth in non-certified municipalities. Table 3.1 also indicates that, compared to the non-certified municipalities, the quality of teachers in certified municipalities (measured as the proportion with a college degree) was 2 percentage points higher, while the stability of teachers' contracts (measured as the proportion of teachers with permanent contracts) was 4 percentage points higher. Table 3.1 also shows that, in certified municipalities, the growth of per capita local taxes exceeded by 4% that of the non-certified municipalities – revealing that greater local autonomy provides greater incentives for increasing local fiscal effort. We will explore whether the stronger fiscal effort also contributed to improve the educational outcomes. Thus, from the results it can be concluded that being certified led to better educational outcomes in terms of higher standardized test scores and student enrollment, as well as a superior quality of schooling inputs as measured by the proportion of teachers with higher education and permanent contracts. Being certified brought about both increasing student enrollments and improving the quality of education services, which suggests that greater administrative decentralization allows administrators in certified municipalities to use local knowledge and interactions to improve educational outcomes.[18]

Flexible Model

With a flexible model we can, one the one hand, test the assumption of parallel trends of the difference-in-differences models and, on the other, establish whether the effect of being certified increases or declines over time. A flexible model estimates a coefficient for the certification dummy every year and is specified as follows:

$$Y_{it} = \beta_i + \beta_t + \sum_{t=1997}^{2015} \beta_{1t} * Certified_{it} + \beta_2 * Controls_{it} + \mu_{it} \tag{3.2}$$

[18]We performed the same econometric estimations excluding the municipalities that became certified after 2003 and obtained similar results. See Table **??** in the Appendix.

The coefficients of interest (see Table B.1 in the Appendix) are β_{1t}, which denote the effect of being certified each year. Before 2003, the "being certified" dummies work as placebos (there was no treatment yet) and the associated coefficients should not be statistically significant, whereas from 2003 onward they should be statistically significant if being certified affects educational outcomes and inputs.

Panel A in Figure 3.3 depicts the β_{1t} for the Saber 11 standardized test scores. As illustrated, the coefficients are not statistically significant before 2002 (2002 is the excluded year dummy, since it was a transition year), proving the assumption of parallel trends of certified and non-certified municipalities. From 2003 to 2007, the coefficients remained non-significant yet growing in magnitude and turned significant with an upward trend after 2008. Panel A in Figure 3.3 suggests that the quality of education after the inception of greater administrative decentralization of education takes some time to consolidate, particularly in terms of the policies that would affect the cognitive assessment at the end of high school (Saber 11). Panel B in Figure 3.3 displays the β_{1t} for the log of student enrollment. The graph reveals the existence of parallel trends before 2003 and significant differences in the growth of enrolled students after 2003, also with an upward trend. The effects show that local interventions aimed at increasing student enrollment seem to work rapidly.

Panel C and Panel D in Figure 3.3 present β_{1t} for the proportion of teachers with college degrees and with permanent contracts. The graphs clearly show parallel trends before 2003 for both variables and ascending trends after 2003. Thus, the quality of teachers and work stability improved right after the enactment of the decentralization reform. These results may combine changes both in the supply and demand of the market for teachers. On the supply side, teachers may have decided to remain in the certified municipalities, since their assigned school and working conditions were more certain. In addition, in 2003 the government instituted a reform in the hiring process of teachers based on an entry exam as described above, which may also have increased the quality of the local pool of new teachers. On the demand side, in certified municipalities the procedure used by the educational authorities to identify the most effective teachers may have

become more efficient. Moreover, the higher proportion of permanent teachers may be explained because the 2003 reform established that only candidates who passed the entry exam could begin a teaching career with a permanent contract. Lastly, Panel E in Figure 3.3 illustrates parallel trends in the level of per capita local taxes before 2003. Nonetheless, it also suggests that certified municipalities began to increase local resource mobilization after 2003 through a more intense fiscal effort over time.

Figure 3.3: The Effect of Certification on Educational Indicators and local taxes

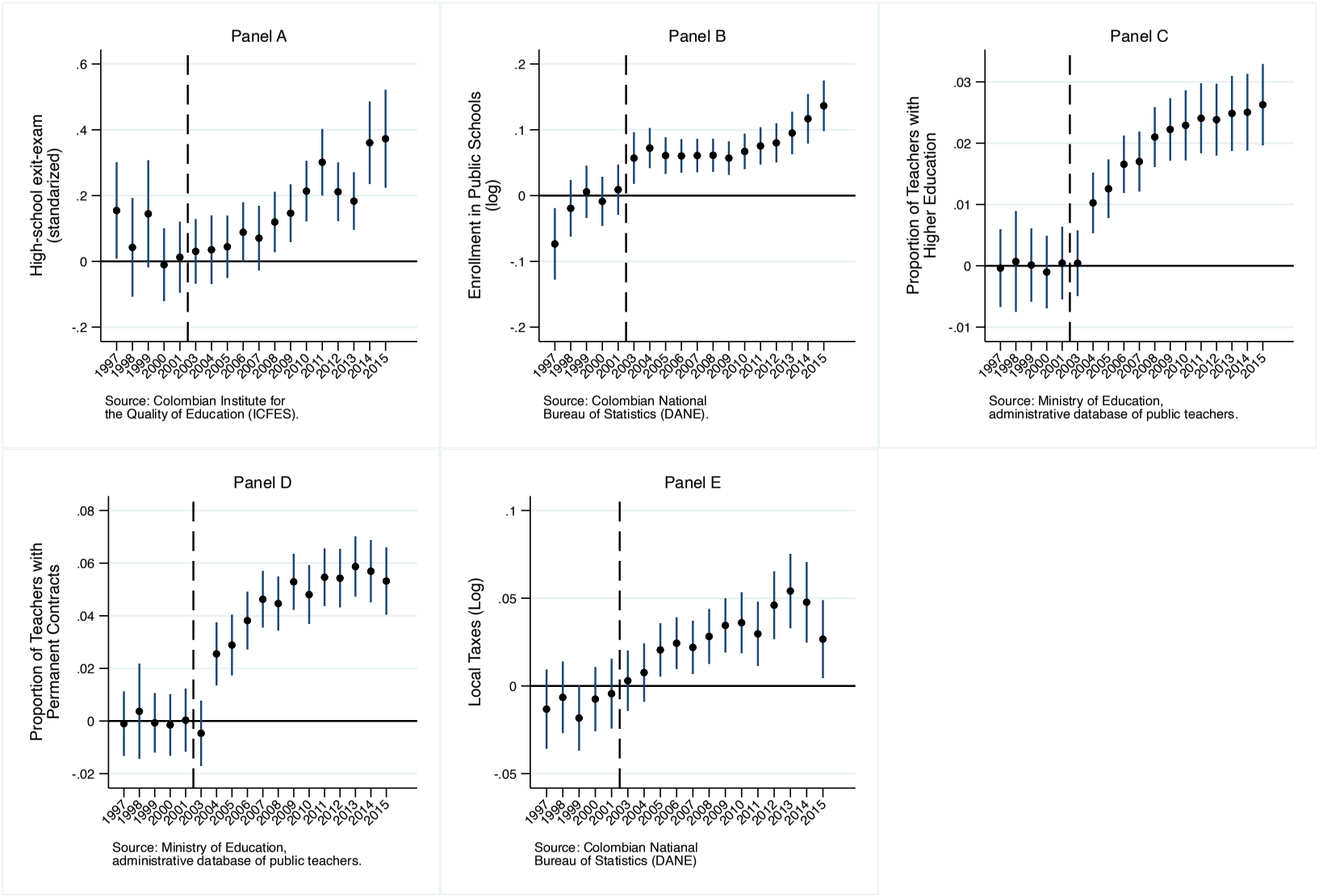


Figure 3.3 illustrates the estimated coefficients obtained using a difference-in-differences flexible model. All estimates include municipal and year fixed-effects. Please refer to Table B.1 for the corresponding results tabulated. Source: Authors' Calculations

Channels

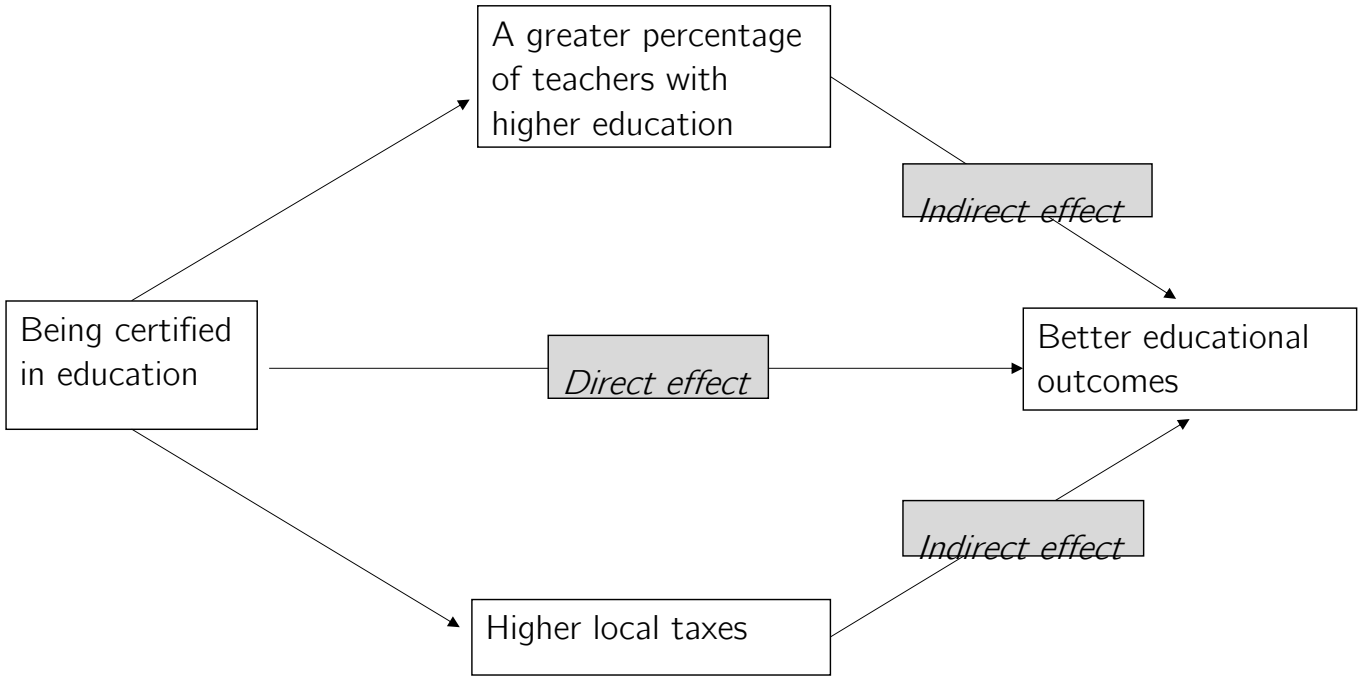
This section will analyze some of the channels that likely influence the outcomes of being a certified municipality in terms of quality of education and student enrollment. As explained above, among the corollaries of Law 715 was that certified municipalities would receive greater transfers, as shown in Figures 3.1 and 3.2. These transfers, complemented by the municipalities' own resources, would raise the total local resources for education. Panel E in Figure 3.3 shows that after 2002 the per capita local taxes in certified municipalities were 5.0 percent above that of non-certified municipalities and would likely contribute to the provision of public goods more in accordance with local needs.

Thus, according to our finding, certified municipalities were able to both hire higher-quality teachers and collect a larger amount of local taxes in their jurisdictions. Both results would lead to better educational outcomes. Higher-quality teachers would improve student learning and increase pupils' motivation, which eventually would lead to lower dropout rates (Chetty et al., 2014; Araujo et al., 2016). Moreover, if higher local taxes contribute to the improvement of the local provision of public goods in general and, more specifically, educational services, they should also translate into better educational outcomes. In order to determine whether the improvement in the educational outcomes stems from higher quality of teachers or from the greater own resource mobilization through stronger local fiscal effort, we estimate the mediation model displayed in Figure 3.4.

As was seen in Table 3.1, being a certified municipality affects both the quality of teachers and educational outcomes. Now we will explore how much of the impact of being certified on those outcomes is explained by variables that local authorities can to some degree control: the quality of teachers and per capita taxes. The exercise is carried out through a mediation analysis using the technique of seemingly unrelated regressions. According to Diagram 1, we will have two types of results: the indirect effect defined as the fraction of the total effect of being certified on the educational outcomes that is explained by the mediators, and the direct effect defined as the fraction of the total effect prompted by unknown variables and the remaining part unexplained.

In order to estimate the total effect of being certified divided into indirect and direct effects,

Figure 3.4: Explaining Likely Channels



we need to simultaneously estimate the effects of (1) being certified on the outcome variables; (2) being certified on the mediating variable, and (3) being certified on the outcome variables controlling for the mediating variable (see Table B.2 and section B.0.1 in the Appendix for details on the mediation methodology). After a series of straightforward replacements and a bootstrap procedure (see Table B.2 at the appendix) the results of the mediation analysis are presented in Table 3.2.

Table 3.2 indicates that 27.9 percent of the effect of being certified on Saber 11 scores is due to the increase in the quality of teachers and 7.1 percent is due to the higher local fiscal effort. The remaining 65.1 percent is due to other factors associated with being a certified entity. Regarding student enrollment, Table 3.2 indicates that the effect is negatively mediated by the proportion of teachers with higher education (-6.0 percent). This indicates that there seems to be a sort of trade-off between hiring high-quality teachers – which should involve greater costs – and enrolling more students. In contrast, higher fiscal effort positively mediates the effect of being certified on student

Table 3.2: Direct and Indirect effect of administrative decentralization on educational outcomes

	Exit-High-school Exam (Standardized)		**Enrollment in public-schools (Log)**	
	Magnitude	*Percentage*	*Magnitude*	*Percentage*
Total Effect - Certified X (Year>2002)	0.057***	100%	0.087***	100%
	(0.019)		(0.008)	
Magnitude explained by the following Channels :				
1. Proportion of teachers with higher education	0.016***	27.9%	-0.005***	-6.0%
	(0.002)		(0.001)	
2. Local Taxes	0.004*	7.1%	0.013***	14.7%
	(0.002)		(0.001)	
3. Unkown Channel	0.037**	65.1%	0.079***	91.3%
	(0.019)		(0.008)	
Year FE	YES		YES	
Municipality FE	YES		YES	
Department X Year FE	YES		YES	
N	20,158		19,351	

Note: Bootstrapped standard errors in parentheses (200 reps). For the details of the mediation model see appendix B. *** p<0.01, ** p<0.05, * p<0.1.
Source: Colombian Institute for the quality of education (ICFES). Colombian National Bureau of Statistics (DANE). Colombian Ministry of Education, administrative database of public teachers. National Planning Department. Authors' calculations.

enrollment, yet with a relatively sizable magnitude (14.7 percent).

The mediation analysis suggests that achieving better outcomes is only moderately related to the additional tax revenues that certified municipalities are collect. It seems that being certified prompts significant efficiency gains that boost educational outcomes. These efficiency gains may be the consequence of lower transaction costs due to accessing more and better information, more transparent negotiation processes, and rapid adjustment to correct errors (Pritchett, 2014, Pritchett and Pande, 2006). Certified municipalities had the mandate to plan, manage, and deliver the provision of education to increase enrollment and improve quality and equity. Departments had a

similar mandate and received higher per capita transfers from the central government to deliver education in the non-certified municipalities (see Figure 3.4) showing nonetheless lower educational outcomes.

3.4.2 Regression Discontinuity Models

The Model's Specification

Starting in 2003, Law 715 determined that the autonomy over the delivery of educational services assigned to municipalities was solely based on whether they had exceeded the 100,000-inhabitant threshold at the end of 2002. This exogenous rule for administrative decentralization based on population size allows for comparing certified (decentralized) and non-certified municipalities with similar population sizes using a regression discontinuity approach.

More specifically, we will estimate the effect of being a certified or non-certified municipality on student performance as measured by the percentage of a school's students who failed to meet the minimum standards on the 3rd, 5th, and 9th grade national standardized tests (Saber) and by the standardized high school exit tests (Saber 11). We will also estimate the effect of a school being certified on the quality of teachers, as measured by the scores on the teachers' entry exam. As described in Section 3.2, certified municipalities hire teachers based on the entry exam and also manage the teaching staff, while for non-certified municipalities those tasks are managed by the departments.

Given that starting in 2003 the rule for a municipality to become certified was based on its population size, with no exceptions, we were able to employ a regression discontinuity design. The effect of being a certified municipality in education on academic performance and teacher quality can be estimated by:

$$\delta = \lim_{D_i \uparrow \rho} E[Y_{imt} | P_{im} = \rho] - \lim_{D_i \downarrow \rho} E[Y_{imt} | P_{im} = \rho] \tag{3.3}$$

where Y_itm represents the dependent variable of interest for school i in the year t of the municipality m, P_im represents the population size of the municipality of school i, and ρ represents 100,000 inhabitants. This identification strategy assumes that the municipalities cannot manipulate their population for 2002, which would have been unlikely given that population sizes were forecast by DANE (National Bureau of Statistics) with the population census from 1993. Moreover, a key assumption for the regression discontinuity design is that there should not be any differences in the observable characteristics of the municipalities that were certified and those that were not around the population threshold. We test these assumptions in table A.4 of appendix A, as we will explain below.

Assuming our assumptions hold, the model, for the estimation of the treatment effect would be:

$$Y_{imt} = f(population_{mi}) + \delta * Certified_{mi} + \varepsilon_{imt} \tag{3.4}$$

In this equation, population equals the difference between the population size of the municipality m of school i and the cutoff to be a certified municipality (100,000 inhabitants). Eligibility is given by the dummy variable $Certified_{im}$, which takes the value of one if the municipality m of school i had more than 100,000 inhabitants in 2002. The regression discontinuity literature uses two types of estimators to estimate δ : the local polynomial and the flexible parametric model. In what follows, we use a flexible polynomial. Also, we employ a quadratic polynomial for the population size of the municipality and interact it with the "certified" municipality dummy, following the guidelines of Gelman and Imbens, 2019. Thus, the estimation equation becomes the following:

$$Y_{imt} = \beta_0 + \sum_{j=1}^{2} \pi_j population_{mi}^{j} + \sum_{j=1}^{2} \pi_j population_{mi}^{j} * Certified_{im} + \delta Certified_{im} + \nu Year_t + \epsilon_{imt} \tag{3.5}$$

where $\sum_{j=1}^{2} \pi_j population_{mi}^{j}$ represents the municipal population quadratic polynomial and ν $Year_t$ represents year fixed effects. δ measures the effect of greater administrative decentralization on the dependent variables. In all of the estimations, the error terms ε_{imt} are clustered at the municipality level.

Additional Considerations

Although the regression discontinuity to assess the impact of decentralization is defined by an exogenous decision, there are still a few limitations. First, only 46 municipalities out of the 1,122 became decentralized by meeting the 100,000-population threshold. However, the populations of the certified municipalities range from 105,080 to more than 6.7 million, which makes it difficult to determine an optimal bandwidth of comparable municipalities to estimate the regression discontinuity model (see Figure B.1 in the Appendix). Hence, we will use different bandwidth sizes and will present the findings for each one. Moreover, Law 715 established that a municipality could apply and become certified by its respective department after meeting certain criteria regarding its technical, administrative, and financial capacity to deliver the education service. Since 2003, 17 additional municipalities have been formally certified using these other criteria.

Thus, given that some municipalities self-selected to be certified and did not comply with the 100,000-inhabitant rule of 2002, our regression discontinuity estimation becomes an intent-to-treat (ITT) model. As a consequence, the estimated ITT effects of being certified on the educational variables at the school level can be considered a lower-bound estimator. Thus, treating the municipalities that became certified after 2003 as non-compliers, the estimates will likely underestimate any possible effect of greater autonomy on our outcome variables.

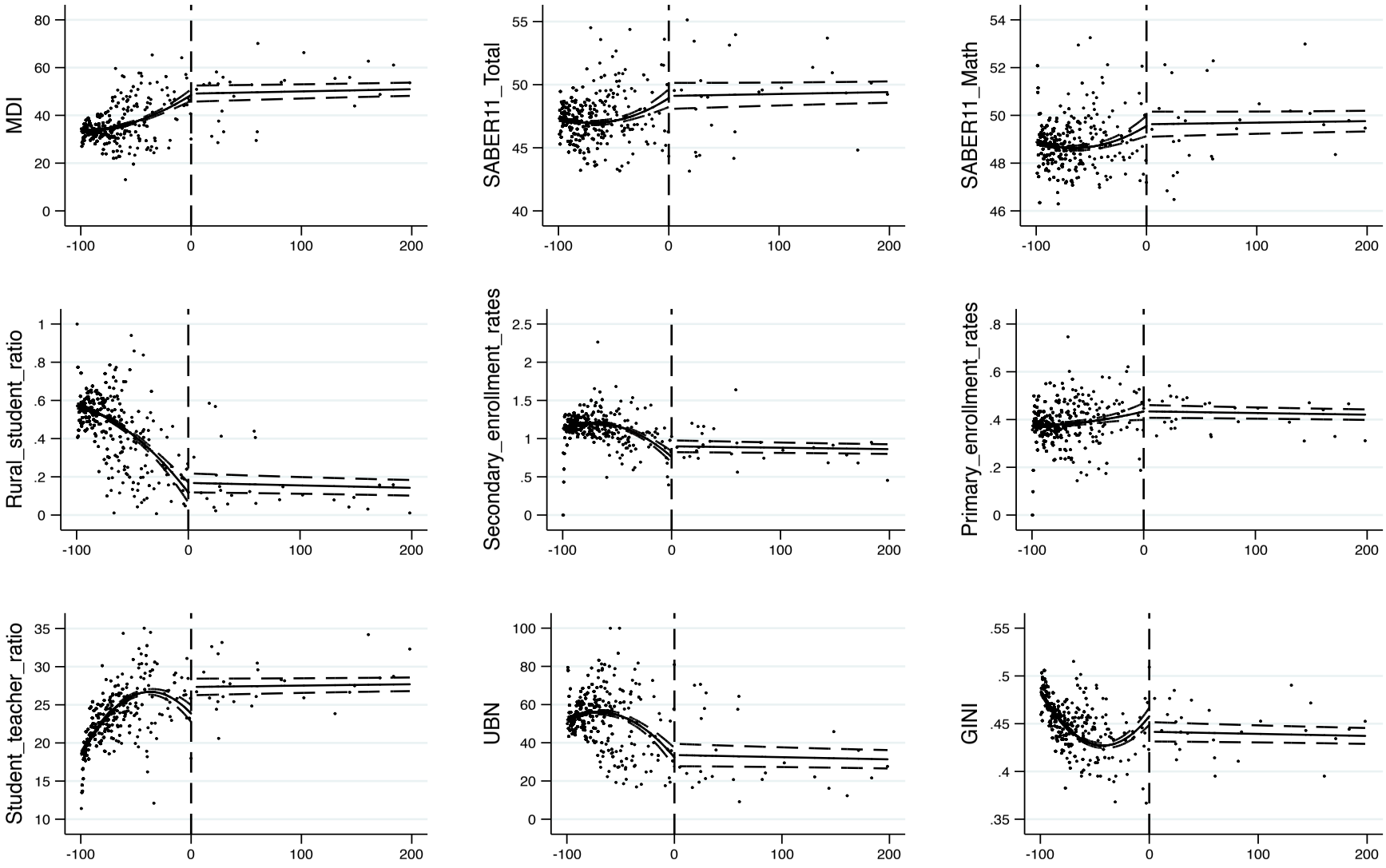
Tests on the Regression Discontinuity Assumptions

The two most important regression discontinuity assumptions are local continuity on observable covariates and no manipulation at the cutoff point. Local continuity states that at the threshold,

(100,000 inhabitants) there should be no discontinuity around the eligibility cutoff of the running variable (population size) and pre-treatment covariates related to education quality (i.e., variables correlated with Y (outcome variable) different from being a certified municipality. Accordingly, if local continuity holds, we can assume that schools on both sides of the cutoff point are very similar. Another way to assess whether the control and treatment groups are similar in aspects that could affect educational outcomes is by performing balance tests. In Table 3.2, it is evident that, on average, municipalities' covariates within different bandwidths are not significantly different. The results of the balance tests are presented in Table B.3 in the Appendix and in Figure 3.5. Regression discontinuity models require continuity of the distribution of the running variable around the cutoff. The continuity assumptions may not be plausible if municipalities had been able to manipulate their forecast population size (McCrary, 2008), but this seems improbable given that the 2002 population figures were based on government projections using the 1993 census. Figure 3.6 displays the McCrary test with different specifications. Figures 3.5 and 3.6 illustrate that with 95 percent of confidence, the population size was not manipulated at the cutoff point.

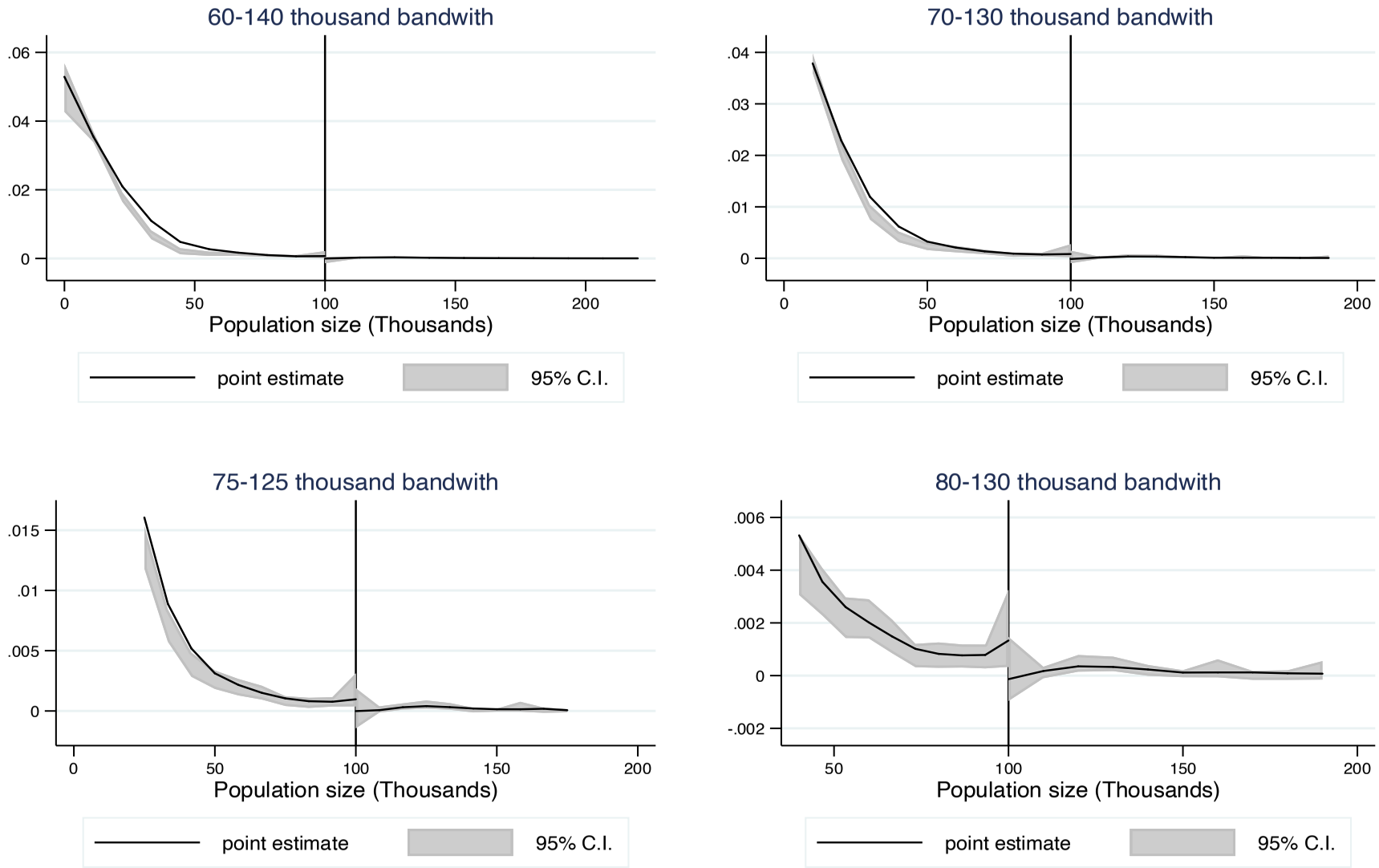
Regression discontinuity models require continuity of the distribution of the running variable around the cutoff. The continuity assumptions may not be plausible if municipalities had been able to manipulate their forecast population size (McCrary, 2008), but this seems improbable given that the 2002 population figures were based on government projections using the 1993 census. Figure 3.6 displays the McCrary test with different specifications. Figures 3.5 and 3.6 illustrate that with 95 percent of confidence, the population size was not manipulated at the cutoff point.

Figure 3.5: Continuity of observable at the cutoff



Source: Municipal Data Panel of the Economic Development Research Center at Universidad de los Andes, Colombia. Author's Calculations.

Figure 3.6: McCrary's Density Test of no manipulation



Source: Municipal Data Panel of the Economic Development Research Center at Universidad de los Andes, Colombia. Author's Calculations.

3.4.3 Regression Discontinuity Results

Academic Performance

We use different bandwidths to assess, at the school level, the ITT effects of higher administrative decentralization in education on the proportion of low-performing students in the 3rd, 5th, and 9th grades and on standardized tests scores for 11th grade. The results are presented in tables 3.3 to 3.6.

Table 3.3: Effects of administrative decentralization on academic performance: Proportion of low performing students in 3rd grade

	Spanish					**Math**				
Threshold (Thousands)	60-140	65-135	70-130	75-125	80-130	60-140	65-135	70-130	75-125	80-130
Certified	-0.233***	-0.217	-0.219	-0.250	-0.252*	-0.223***	-0.219*	-0.222*	-0.263	-0.252*
	(0.076)	(0.133)	(0.134)	(0.188)	(0.134)	(0.069)	(0.127)	(0.127)	(0.186)	(0.127)
Constant	0.204***	0.223***	0.227***	0.233***	0.261***	0.177***	0.199***	0.203***	0.207***	0.231***
	(0.046)	(0.045)	(0.046)	(0.046)	(0.044)	(0.042)	(0.040)	(0.041)	(0.041)	(0.040)
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Schools (N)	5602	4396	4128	3683	3548	5654	4435	4165	3704	3579
Municipalities	59	44	38	33	30	59	44	38	33	30
Mean	0.183	0.183	0.174	0.174	0.169	0.172	0.172	0.164	0.163	0.157
SD	0.191	0.195	0.186	0.186	0.188	0.183	0.187	0.177	0.178	0.177

Note: The results correspond to regression discontinuity estimations using a flexible second degree polynomial. Robust standard errors in parentheses and clustered at municipality level. *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the Quality of Education (ICFES)

Regarding the results, though for some bandwidths the effects are not statistically significant from zero, all of the ITT effects are consistently negative. In other words, schools in certified municipalities compared to those in non-certified municipalities have a lower proportion of low-performing students for all of the tests analyzed, especially those for the 5th and 9th grades. The effect appears to strengthen for older students, being higher and more significant for 9th grade than for 5th and 3rd grade. Specifically, schools belonging to certified municipalities reduce by between 10 and 15 points the percentage of students scoring insufficiently on both math and Spanish tests in the 5th and 9th grade. For 3rd grade there appears to be no significant difference between certified

Table 3.4: Effects of administrative decentralization on academic performance: Proportion of low performing students in 3rd grade

	Spanish					**Math**				
Threshold (Thousands)	60-140	65-135	70-130	75-125	80-130	60-140	65-135	70-130	75-125	80-130
Certified	-0.233***	-0.217	-0.219	-0.250	-0.252*	-0.223***	-0.219*	-0.222*	-0.263	-0.252*
	(0.076)	(0.133)	(0.134)	(0.188)	(0.134)	(0.069)	(0.127)	(0.127)	(0.186)	(0.127)
Constant	0.204***	0.223***	0.227***	0.233***	0.261***	0.177***	0.199***	0.203***	0.207***	0.231***
	(0.046)	(0.045)	(0.046)	(0.046)	(0.044)	(0.042)	(0.040)	(0.041)	(0.041)	(0.040)
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Schools (N)	5602	4396	4128	3683	3548	5654	4435	4165	3704	3579
Municipalities	59	44	38	33	30	59	44	38	33	30
Mean	0.183	0.183	0.174	0.174	0.169	0.172	0.172	0.164	0.163	0.157
SD	0.191	0.195	0.186	0.186	0.188	0.183	0.187	0.177	0.178	0.177

Note: The results correspond to regression discontinuity estimations using a flexible second degree polynomial. Robust standard errors in parentheses and clustered at municipality level. *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the Quality of Education (ICFES)

and non-certified municipalities.

Table 3.6 presents the ITT regression discontinuity estimation on the effect of being certified on the compulsory high school exit test. The results confirm that student performance, measured at the school level, is close to one standard deviation higher in a certified municipality. The results seem less noisy for language than for math, though the latter nonetheless have point estimates of a relatively large magnitude. The regression discontinuity findings indicate that being a certified municipality improves the quality of education at the school level and for different grades. The next section will explore whether certified municipalities have higher-quality teachers than non-certified municipalities.

Teacher Quality

As shown in the difference-in-differences models, the proportion of teachers with higher education in the certified municipalities surpassed that of non-certified municipalities, which partially explained the former's higher student performance. To examine other sources of variation that can potentially explain the higher schooling performance of students in certified municipalities,

Table 3.5: Effects of administrative decentralization on academic performance: Proportion of low performing students in 3rd grade

	Spanish					**Math**				
Threshold (Thousands)	60-140	65-135	70-130	75-125	80-130	60-140	65-135	70-130	75-125	80-130
Certified	-0.258***	-0.265**	-0.279**	-0.206	-0.313**	-0.321***	-0.323**	-0.335**	-0.241	-0.375**
	(0.082)	(0.121)	(0.123)	(0.160)	(0.126)	(0.101)	(0.153)	(0.155)	(0.209)	(0.158)
Constant	0.190***	0.214***	0.228***	0.240***	0.262***	0.255***	0.281***	0.292***	0.305***	0.333***
	(0.054)	(0.055)	(0.057)	(0.059)	(0.063)	(0.064)	(0.065)	(0.068)	(0.070)	(0.075)
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Schools (N)	5242	4070	3840	3398	3222	5162	4013	3783	3345	3173
Municipalities	59	44	38	33	30	59	44	38	33	30
Mean	0.179	0.186	0.180	0.179	0.172	0.237	0.246	0.239	0.238	0.231
SD	0.176	0.179	0.176	0.176	0.177	0.200	0.203	0.202	0.202	0.206

Note: The results correspond to regression discontinuity estimations using a flexible second degree polynomial. Robust standard errors in parentheses and clustered at municipality level. *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the Quality of Education (ICFES)

we examine the differences in teachers' performance on their entry exam. Thus, we estimate an ITT–regression discontinuity model and find that teachers who work at schools located in certified municipalities perform better on the verbal and numeric entry tests (Table 3.7) scoring between one-half and nearly one standard deviation higher than teachers in non-certified municipalities.

One possible explanation for this result is related to the higher efficiency of the certified municipalities' hiring process, as for example in assertive recruiting. The greater autonomy of certified municipalities facilitates the ability to invest time and resources in persuading teachers to apply to their municipalities. Moreover, teacher preferences could also play a role, as teachers choose the territorial entity and school where they would like to work. Their entry exam score and the number of other candidates applying to the same entity and school determine whether or not teachers are granted a position at their preferred choice. Teachers who apply to a certified municipality may not be assigned to their preferred school, though they know that they will at least be assigned to a different school within the same municipality. In contrast, teachers who apply to a department may be assigned to a school within any of the non-certified municipalities within that department unless they score high enough to able to choose from the total pool of vacancies their preferred schools.

Table 3.6: Effects of administrative decentralization on academic performance: Proportion of low performing students in 3rd grade

	Spanish					Math				
Threshold (Thousands)	60-140	65-135	70-130	75-125	80-130	60-140	65-135	70-130	75-125	80-130
Certified	1.188***	1.224**	1.237**	0.679	1.418**	1.227**	1.106	1.142	0.465	1.309*
	(0.421)	(0.593)	(0.601)	(0.751)	(0.605)	(0.548)	(0.715)	(0.723)	(0.960)	(0.734)
Constant	-0.371	-0.478	-0.490	-0.491	-0.597*	-0.861***	-0.957***	-0.991***	-0.979***	-1.095***
	(0.278)	(0.315)	(0.327)	(0.310)	(0.310)	(0.307)	(0.345)	(0.358)	(0.352)	(0.369)
Semester FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Schools (N)	4318	3360	3124	2773	2598	4318	3360	3124	2773	2598
Municipalities	59	44	38	33	30	59	44	38	33	30

Note: The results correspond to regression discontinuity estimations using a flexible second degree polynomial. Robust standard errors in parentheses and clustered at municipality level. *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the Quality of Education (ICFES)

The greater certainty of where teachers will be assigned when applying to a certified municipality as opposed to a non-certified municipality may help to attract more qualified teachers to certified municipalities. To attempt to determine if the differences in teacher quality can be attributed to the actions of the certified municipalities during the hiring process or to the self-selection of the best applicants, we compared the scores of the 297,377 applicants in the 2013 teachers' entry exam between certified municipalities and departments. We run a simple regression of the applicants' score against a dummy of being certified and controlling by the applicant's sex and departmental fixed effects. As can be seen in Table 3.8, teachers who applied to certified municipalities performed 0.10 and 0.14 of a standard deviation higher on the numeric and the verbal tests, respectively, than teachers who applied to departments and who would be assigned to a non-certified municipality. As was shown in Table 3.7, teachers hired by certified municipalities performed more than a 0.70 standard deviation higher on the entry exam than those assigned to non-certified municipalities. This finding suggests that only a fraction of the teacher quality gap can be explained by differences in the quality of the pool of applicants from which certified municipalities can select teachers. As Table 3.8 suggests, it is likely that certified municipalities would attract better applicants through better information about vacancies or non-monetary perks or because the applicants from certified

Table 3.7: Effects of administrative decentralization on the quality of teachers hired

Teacher Score	**Verbal**					**Numeric**				
	60-140	**65-135**	**70-130**	**75-125**	**80-130**	**60-140**	**65-135**	**70-130**	**75-125**	**80-130**
Certified	0.447*	0.763**	0.799**	0.749*	0.860***	0.512**	0.773**	0.847**	0.465*	0.919**
	-0.231	-0.305	-0.304	-0.416	-0.289	-0.213	-0.327	-0.327	-0.256	-0.358
Year FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Schools	6691	5167	4785	4265	4074	6691	5167	4785	4265	4074
Municipalities	58	43	37	33	30	58	43	37	33	30
Mean Teacher Score	63.64	63.7	63.65	63.51	63.39	64.37	64.57	64.5	64.38	64.33
SD Teacher score	5.006	4.88	4.84	4.913	4.938	5.571	5.519	5.38	5.449	5.46

Note: The results correspond to regression discontinuity estimations using a flexible second degree polynomial. Robust standard errors in parentheses and clustered at municipality level. *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the Quality of Education (ICFES)

municipalities have been exposed to higher quality education in the past. Nonetheless, the fact that the differences in the quality of selected teachers is greater than differences in the quality of applicants implies that administrative decentralization facilitates the search for higher-quality teachers which certainly would bring about better-quality educational services.

Table 3.8: Performance in teachers' entry test for certified municipalities versus departments

	Numeric performance	**Verbal performance**
Certified Municipality	1.733***	2.272***
	-0.076	-0.076
Constant	50.868***	49.713***
	-1.033	-0.031
Department FE	Yes	Yes
N	297,376	297,377
Mean non-certified	50.469	50.01
Score standard deviation	16.6	16.56
Coefficient/Standard deviation	0.1	0.14

Note: All estimates include sex covariate. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the Quality of Education (ICFES). Data correspond to the teacher´s entry exam of 2013. Highest score is 100.

Mediation Analysis at the School Level

Does the quality of teachers affect student achievement? This is a key question if one wants to determine whether the higher-quality teachers who certified municipalities are able to hire influence student achievement. To explore this, we carry out a mediation analysis similar to the one developed in the difference-in-differences section above within an ITT regression discontinuity framework. The results in Tables 3.3- 3.6 and 4 showed that being certified has a positive impact on student achievement and teacher quality at the school level. Thus, here we explore if better student achievement is partially explained by the higher quality of teachers of certified municipalities. The mediation model we estimate has the following features: (1) student standardized test scores in math and Spanish constitute the outcome variables; (2) teacher test scores in numeric and verbal abilities represent the mediators; and (3) the independent variable is being certified. The estimation of the model is presented in Tables B.4 and B.5 in the Appendix and the mediation effects are displayed in Table 3.9.

Table 3.9: Direct and Indirect effect of administrative decentralization on Exit-High-school Exam

	Exit-High-school Exam- Math (Standardized)									
Threshold (Thousands)	60-140		65-135		70-130		75-125		80-130	
	Magnitude	*Percentage*	*Magnitude*	*Percentage*	*Magnitude*	*Percentage*	*Magnitude*	*Percentage*	*Magnitude*	*Percentage*
Total Effect - Certified X (Year>2002)	1.23***	100%	1.177***	100%	1.204***	100%	0.418***	100%	1.403***	100%
	(0.111)		(0.145)		(0.142)		(0.164)		(0.147)	
Magnitude explained by the following Channels :										
1. Teacher's Score- Math	0.045***	3.6%	0.049**	4.2%	0.040*	3.3%	0.015	3.6%	0.061*	4.3%
	(0.022)		(0.022)		(0.024)		(0.016)		(0.033)	
2. Teacher's Score- Verbal	0.143***	11.6%	0.310***	26.4%	0.313***	26.0%	0.247***	59.1%	0.321***	22.9%
	(0.026)		(0.040)		(0.046)		(0.051)		(0.050)	
3. Unkown Channel	1.040***	84.7%	0.817***	69.4%	0.851***	70.7%	0.156	37.3%	1.021***	72.8%
	(0.108)		(0.135)		(0.135)		(0.157)		(0.150)	
Year FE	YES		YES		YES		YES		YES	
N schools	3860		2982		2779		2476		2314	

Note: All estimates include sex covariate. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the Quality of Education (ICFES). Data correspond to the teacher´s entry exam of 2013. Highest score is 100.

Table 3.10: Direct and Indirect effect of administrative decentralization on Exit-High-school Exam

Threshold (Thousands)	60-140		65-135		70-130		75-125		80-130	
	Magnitude	*Percentage*	*Magnitude*	*Percentage*	*Magnitude*	*Percentage*	*Magnitude*	*Percentage*	*Magnitude*	*Percentage*
Total Effect - Certified X (Year>2002)	1.214***	100%	1.311***	100%	1.317***	100%	0.693***	100%	1.520***	100%
	(0.103)		(0.122)		(0.123)		(0.141)		(0.123)	
Magnitude explained by the following Channels :										
1. Teacher's Score- Math	0.021	1.7%	0.019	1.5%	0.018	1.3%	-0.003	-0.4%	0.036	2.4%
	(0.013)		(0.018)		(0.023)		(0.017)		(0.049)	
2. Teacher's Score- Verbal	0.154***	12.7%	0.303***	23.1%	0.293***	22.3%	0.240***	34.6%	0.289***	19.0%
	(0.023)		(0.034)		(0.042)		(0.042)		(0.043)	
3. Unkown Channel	1.039***	85.6%	0.988***	75.4%	1.006***	76.4%	0.456***	65.8%	1.195***	78.6%
	(0.099)		(0.012)		(0.122)		(0.139)		(0.123)	
Year FE	YES		YES		YES		YES		YES	
N schools	3860		2982		2779		2476		2314	

Note: All estimates include sex covariate. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1
Source: Colombian Institute for the Quality of Education (ICFES). Data correspond to the teacher´s entry exam of 2013. Highest score is 100.

Table 3.9 presents the mediation results for numeric scores on the high school exit exam for different bandwidths. Column 1 – for population bandwidth between 60,000 and 140,000 – indicates that being certified, as shown above, positively increases student math scores by 1.2 standard deviations. Table 3.9 shows that teachers' numeric scores mediate 0.04 standard deviations, while teachers' verbal scores mediate 0.14 standard deviations. It is noteworthy that teachers' verbal abilities are quite relevant for student achievement. Thus, teachers' numeric and verbal abilities mediated 15 percent of the effect of being certified on student achievement. This result is consistent with the findings reported above in the difference-in-differences model. For the bandwidth of the population between 65,000 and 135,000, the mediators explain 30 percent of the total effect of being certified on student achievement. For the population bandwidths of 70,000 to 130,000, 75,000 to 125,000, and 80,000 to 130,000, the mediators explain 29, 63, and 27 percent, respectively, of the effect of being certified on student achievement. Thus, the findings indicate that the teacher hiring process of the certified municipalities translates into higher student test scores. Table 3.10 presents the mediation results of the effects of teachers' verbal and numerical abilities on student test scores in Spanish for different bandwidths. Using the 60,000 to 140,000 population bandwidths, the total effect of being certified is 1.21 standard deviations. While the indirect effect of teachers' numeric abilities on students' scores in Spanish is 0.02 standard deviations and is not statistically significant, the indirect effect on students' score of teachers' verbal abilities is 0.15 standard deviations and is statistically significant,. Thus, the indirect effect of teachers' abilities explains 14 percent of being certified on students' scores. For the 65,000 to 135,000 population bandwidth, the indirect effect accounts for 24 percent of the total effect. Similar findings are obtained for the remaining population bandwidths. The mediation results at the school level indicate that teacher quality contributes substantially to improving student scores on the certified municipalities. However, several other policies, programs, and interventions undertaken by these municipalities have also boosted student achievement.

3.5 Conclusions

This paper has contributed to the debate about the effect of administrative decentralization of education on educational outcomes by taking advantage of the arbitrary population rule used in Colombia that grants greater administrative decentralization to municipalities that had a population above 100,000 in 2002. After 2003, "certified" municipalities could autonomously provide public education services, including teacher hiring, school supervision and oversight, school construction, and student enrollment programs, among other educational functions. The paper has evaluated the effect of greater autonomy finding positive gains on student achievement, student enrollment, and teacher quality using two different methodologies: difference-in-differences models using municipal data, and regression discontinuity models relying on school data. In this regard, deepening administrative decentralization is a feasible and proven way to reach a higher and more efficient provision of education.

The difference-in-differences results indicate that municipalities that gained autonomy to deliver public education after 2003 improved scores on the high school exit exam (Saber 11), increase students' enrollment, and hired a greater proportion of teachers with higher education and with permanent contracts. The mediation analysis suggests that the higher educational outcomes stem only partially from better teachers or from the greater local fiscal effort. We hypothesize that being certified produced efficiency gains that originated in access to more information about local educational needs and the stronger capacity to allocate resources efficiently. The regression discontinuity exercises that use information between 2010 and 2015 – seven years after enactment of the reform – indicate that certified municipalities had schools with a smaller proportion of low-performing students in 3rd and 5th grades, and especially 9th grades. The regression discontinuity estimations for 11th grade confirm the finding of the difference-in-differences models. Moreover, when analyzing teacher characteristics as a likely channel to explain academic performance, we found that teachers in certified municipalities scored, on average, 0.5 to 1 standard deviation higher on the mandatory competency test to become a permanent public school teacher. The mediation analy-

sis conducted within the regression discontinuity framework also reveals that the higher quality of teachers in certified municipalities works as an important channel to explain the higher student achievement on the high school exit exam.

One of the limitations in this paper is that we do not have enough information to understand many of the mechanisms through which decentralization may affect educational outcomes. As discussed in the first two sections, the positive effect of more autonomy could be explained, among other reasons, by the greater amount of information that the certified municipalities have about local needs, by their smaller geographic extension (which reduces coordination costs), or by the existence of greater accountability mechanisms in these municipalities. The results do suggest that one potential mechanism could be higher average teacher quality in certified municipalities, as measured either by the proportion of teachers with higher education or their score on the mandatory exam to become a permanent teacher. We also presented suggestive evidence indicating that a fraction of this teacher quality gap may be due to self-selection of better candidates into those municipalities. However, determining which fraction of the effect is attributable to the preferences of the teachers, how much is explained by the actions of the certified entities, and what specific policies certified municipalities implemented to attract and retain better teachers are topics for future research.

Finally, something that should be considered when interpreting the results of this paper is that we analyze the effect of greater administrative decentralization using the universe of municipalities in a difference-in-differences model and using a group of municipalities close to meeting the population threshold in a regression discontinuity model. The results of both approaches point to the role of administrative decentralization in the provision of quality education services and increased enrollment, though the difference-in-differences are interpreted as an average effect while the regression discontinuities as a local one. Yet it is less clear whether these findings can be extended to the smallest non-certified municipalities, which probably have much less capacity to influence their departmental authorities to deliver the needed education services in a timely manner. In such cases, the growing gap in educational outcomes should be offset with the implementation of other

policies that deliver greater resources to these municipalities.

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Appendix A: Chapter 1

Figure A.1: 4th grade math test scores by school type

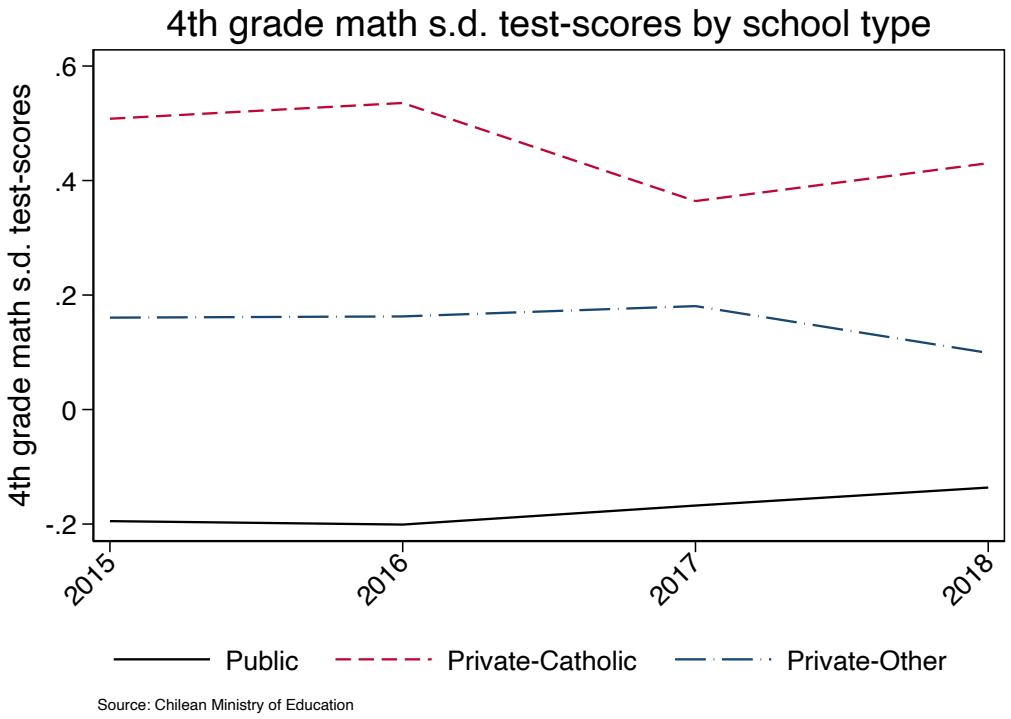
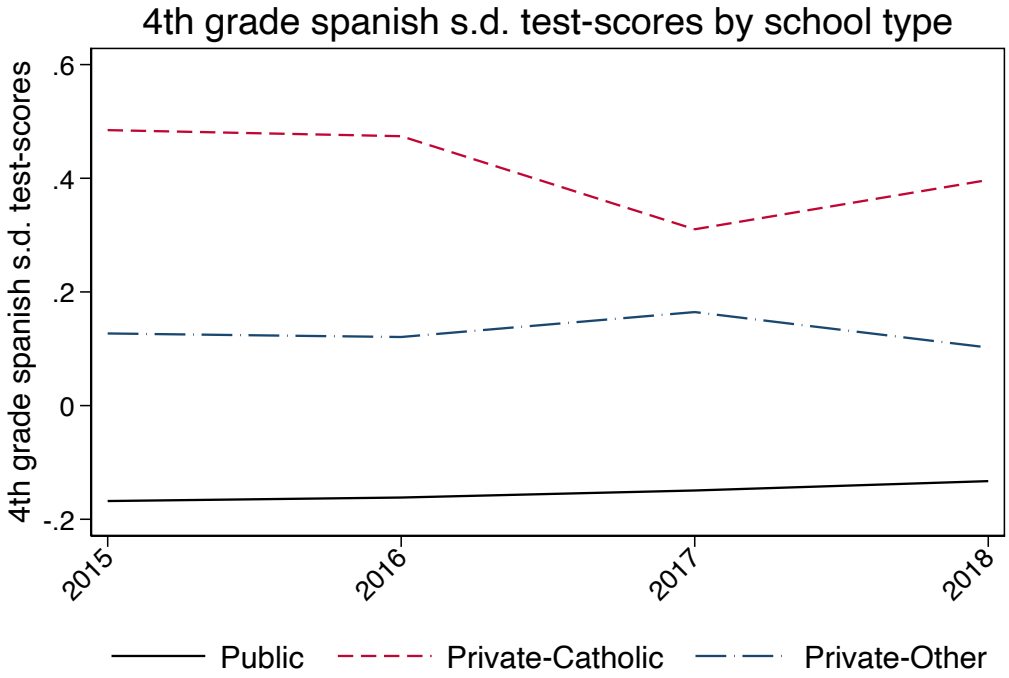
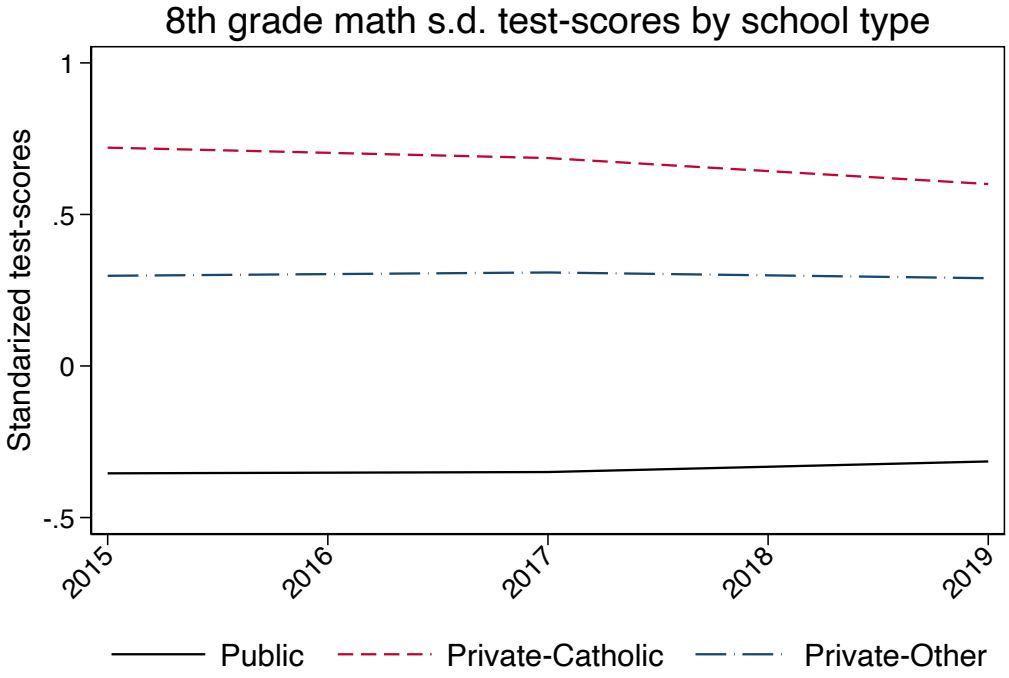


Figure A.2: 4th grade reading test scores by school type



Source: Chilean Ministry of Education

Figure A.3: 8th grade math test scores by school type



Source: Chilean Ministry of Education

Figure A.4: 8th grade reading test scores by school type

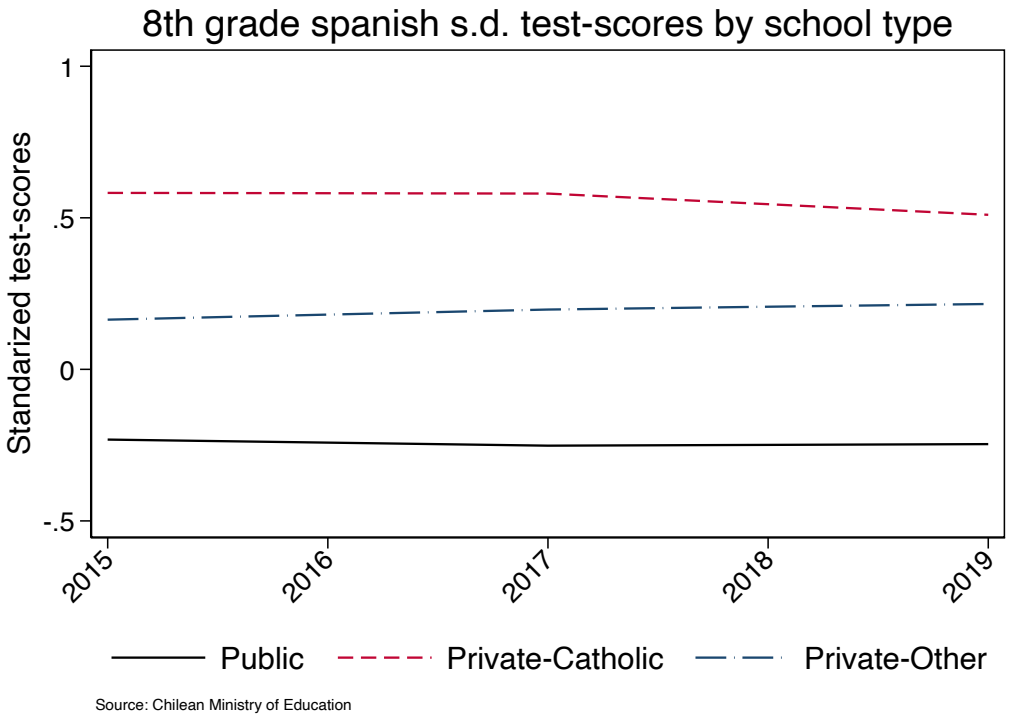


Table A.1: Female students results by baseline math: Dropout and academic performance

	High-School		CEE: Scored above national mean			
	Dropout	Took CEE	Math	Spanish	Science	History
A. Females below math-baseline class mean						
Private-Catholic	-0.021	0.112	0.053	0.114**	0.041	0.028
	(0.035)	(0.076)	(0.057)	(0.052)	(0.072)	(0.069)
Private-Secular	-0.033	0.109	-0.035	0.112*	0.021	0.114
	(0.043)	(0.093)	(0.070)	(0.064)	(0.089)	(0.085)
Observations	1,063	1,063	1,063	1,063	1,063	1,063
R-squared	0.002	0.019	0.001	0.022	0.006	0.018
Mean Pub	0.0590	0.497	0.121	0.0620	0.266	0.210
B. Females above math-baseline class mean						
Private-Catholic	-0.005	0.079	0.288***	0.225**	-0.005	0.133
	(0.022)	(0.072)	(0.088)	(0.087)	(0.089)	(0.086)
Private-Secular	-0.025	-0.033	0.153	0.202**	-0.063	0.153
	(0.023)	(0.078)	(0.095)	(0.095)	(0.096)	(0.094)
Observations	920	920	920	920	920	920
R-squared	0.000	0.022	0.000	0.009	0.018	0.007
Mean Pub	0.0180	0.761	0.407	0.367	0.468	0.361

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Table X presents IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by baseline math ability and gender. Panel A shows results for female students who enrolled in schools where their 8th-grade math test scores were below the class mean, while Panel B presents results for female students whose math test scores were above the class mean.Source: Author's calculations

Table A.2: Female students results by baseline math: College application

	Applied College				
	Any	STEM	Health	Arts&-Humanities	Accepted
A. Below math-baseline class mean					
Private-Catholic	0.075	-0.024	0.062	-0.010	0.064
	(0.065)	(0.026)	(0.045)	(0.019)	(0.046)
Private-Secular	0.041	-0.037	0.009	-0.002	0.050
	(0.080)	(0.032)	(0.056)	(0.023)	(0.057)
Observations	1,063	1,063	1,063	1,063	1,063
R-squared	0.006	0.000	0.005	0.001	0.013
Mean Pub	0.175	0.0180	0.0770	0.0120	0.0560
B. Above math-baseline class mean					
Private-Catholic	0.055	-0.079	0.091	-0.012	0.125
	(0.088)	(0.056)	(0.070)	(0.038)	(0.083)
Private-Secular	0.088	0.004	0.118	-0.023	0.089
	(0.095)	(0.060)	(0.076)	(0.041)	(0.089)
Observations	920	920	920	920	920
R-squared	0.010	-0.003	-0.000	0.006	0.007
Mean Pub	0.425	0.122	0.177	0.0460	0.312

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Table X presents IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by baseline math ability and gender. Panel A shows results for female students who enrolled in schools where their 8th-grade math test scores were below the class mean, while Panel B presents results for female students whose math test scores were above the class mean.Source: Author's calculations

Table A.3: Male students results by baseline math: Dropout and academic performance

	High-School		CEE: Scored above national mean			
	Dropout	Took CEE	Math	Spanish	Science	History
A. Below math-baseline class mean						
Private-Catholic	0.101**	0.087	0.038	0.036	0.058	0.048
	(0.044)	(0.077)	(0.054)	(0.050)	(0.061)	(0.063)
Private-Secular	0.103**	0.143	-0.010	0.008	0.025	0.177**
	(0.051)	(0.089)	(0.063)	(0.058)	(0.071)	(0.074)
Observations	838	838	838	838	838	838
R-squared	-0.003	0.027	0.028	0.036	0.014	0.017
Mean Pub	0.0700	0.377	0.104	0.0940	0.153	0.190
B. Above math-baseline class mean						
Private-Catholic	-0.071*	0.212**	0.105	0.124	0.136*	0.082
	(0.040)	(0.085)	(0.082)	(0.081)	(0.080)	(0.080)
Private-Secular	-0.029	0.189	0.101	0.117	0.218*	-0.137
	(0.065)	(0.138)	(0.134)	(0.131)	(0.130)	(0.131)
Observations	831	831	831	831	831	831
R-squared	0.008	-0.006	0.019	0.022	0.008	0.004
Mean Pub	0.0630	0.552	0.320	0.285	0.281	0.311

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Table X presents IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by baseline math ability and gender. Panel A shows results for male students who enrolled in schools where their 8th-grade math test scores were below the class mean, while Panel B presents results for male students whose math test scores were above the class mean.Source: Author's calculations

Table A.4: Male students results by baseline math: College application

	Applied College				
	Any	STEM	Health	Arts&-Humanities	Accepted
A. Below math-baseline class mean					
Private-Catholic	0.051	0.038	0.042	0.037*	0.049
	(0.052)	(0.037)	(0.032)	(0.021)	(0.044)
Private-Secular	0.043	0.009	-0.004	0.049**	-0.011
	(0.061)	(0.043)	(0.037)	(0.025)	(0.051)
Observations	838	838	838	838	838
R-squared	0.014	0.003	0.002	-0.002	0.006
Mean Pub	0.106	0.0440	0.0390	0.00800	0.0620
B. Above math-baseline class mean					
Private-Catholic	0.100	0.052	-0.032	-0.003	0.152**
	(0.076)	(0.062)	(0.045)	(0.031)	(0.071)
Private-Secular	0.075	0.112	0.026	0.032	0.150
	(0.124)	(0.101)	(0.073)	(0.050)	(0.116)
Observations	831	831	831	831	831
R-squared	0.011	-0.003	0.009	-0.006	0.006
Mean Pub	0.218	0.137	0.0490	0.0350	0.172

Note: Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Table 8 presents IV estimated coefficients for enrollment in Catholic or private-secular schools, stratified by baseline math ability and gender. Panel A shows results for male students who enrolled in schools where their 8th-grade math test scores were below the class mean, while Panel B presents results for male students whose math test scores were above the class mean.Source: Author's calculations

Table A.5: Principal components analyses questions used part 1

Component	Questions	Who answers? Student	Parent	Teachers
Selection at entrance before CAS	Which of the following requirements or background information were requested when the student applied to this institution?		x	
	1. Transcript from the previous school		x	
	2. Parent Interview		x	
	3. The student had to take a written exam or an entrance test.		x	
	4. Psychological or behavioral report.		x	
	5. Income resport		x	
Parental involvement	On a scale from 1 to 7, what grade would you give to the following aspects of the institution?		x	
	1. The frequency with which parents and guardians are informed about the academic and personal progress of the students.		x	
	2. How parents and guardians are informed about any issues that the student may have.		x	
	3. The frequency with which the headteacher schedules meetings with parents and guardians to discuss the student.		x	
	4. The willingness of the headteacher to address my concerns regarding the student (e.g., inquiries about their behavior, academic performance, interactions with peers, etc.).		x	
	5. The willingness of the school authorities to receive and listen to concerns and suggestions (e.g., they attend to me when I have a concern about my child's behavior or a suggestion regarding the functioning of the institution, etc.).		x	
	How much do you agree or disagree with the following statements related to the institution?		x	
	1. The institution values parental involvement in the development of students.		x	
	2. The opinions of parents and guardians are considered in the decisions made by the institution.		x	

Table A.6: Principal components analyses questions used part 2

Rigour in school policies	How much do you agree or disagree with each of the following statements?		
	1.Students respect the rules of the school's code of conduct.	x	
	2. The institution makes us comply with the sanctions established in the school coexistence manual	x	
	"What do you think of the following actions?"	x	
	1. Not attending classes	x	
	2. Escaping from school	x	
	3. Copying during exams	x	
	4. Copying assignments or tasks	x	
	5. Insulting a classmate	x	
	The teachers prohibit us from using our phones in class without their permission	x	
	On a scale from 1 to 7, what grade would you give to the following aspects of the institution?		
	1. The adherence to rules of the school's code of conduct		x
	2. The institution's work with students who have behavioral problems.		x
Well behaved students	How often do the following situations occur with students in your classes?		
	1. Students adhere to the rules inside the classroom		x
	2. Disruptions occur during classes that affect the learning atmosphere		x
	3. Students pay attention during classes		x
	4. I have to interrupt classes due to students' disorderly behavior.		x
Students like school	How much do you agree or disagree with each of the following statements related to your school?		
	1. I enjoy coming to school	x	
	2. I feel proud of my school	x	
	3. I speak highly of my school to others	x	
	4. I would recommend to a friend that they switch to this school.	x	
Students feel supported by their teachers	How much do you agree or disagree with each of the following statements?		
	1. My teachers tell me that I am capable of learning	x	
	2. My teachers tell me that I am a good student	x	
	3. My teachers motivate me to study and make an effort.	x	
	4. My teachers motivate me to become better every day.	x	
	5. My teachers make me feel that I am an important part of my institution	x	

Appendix B: Chapter 3

Figure B.1: Projected municipal population size for 2002

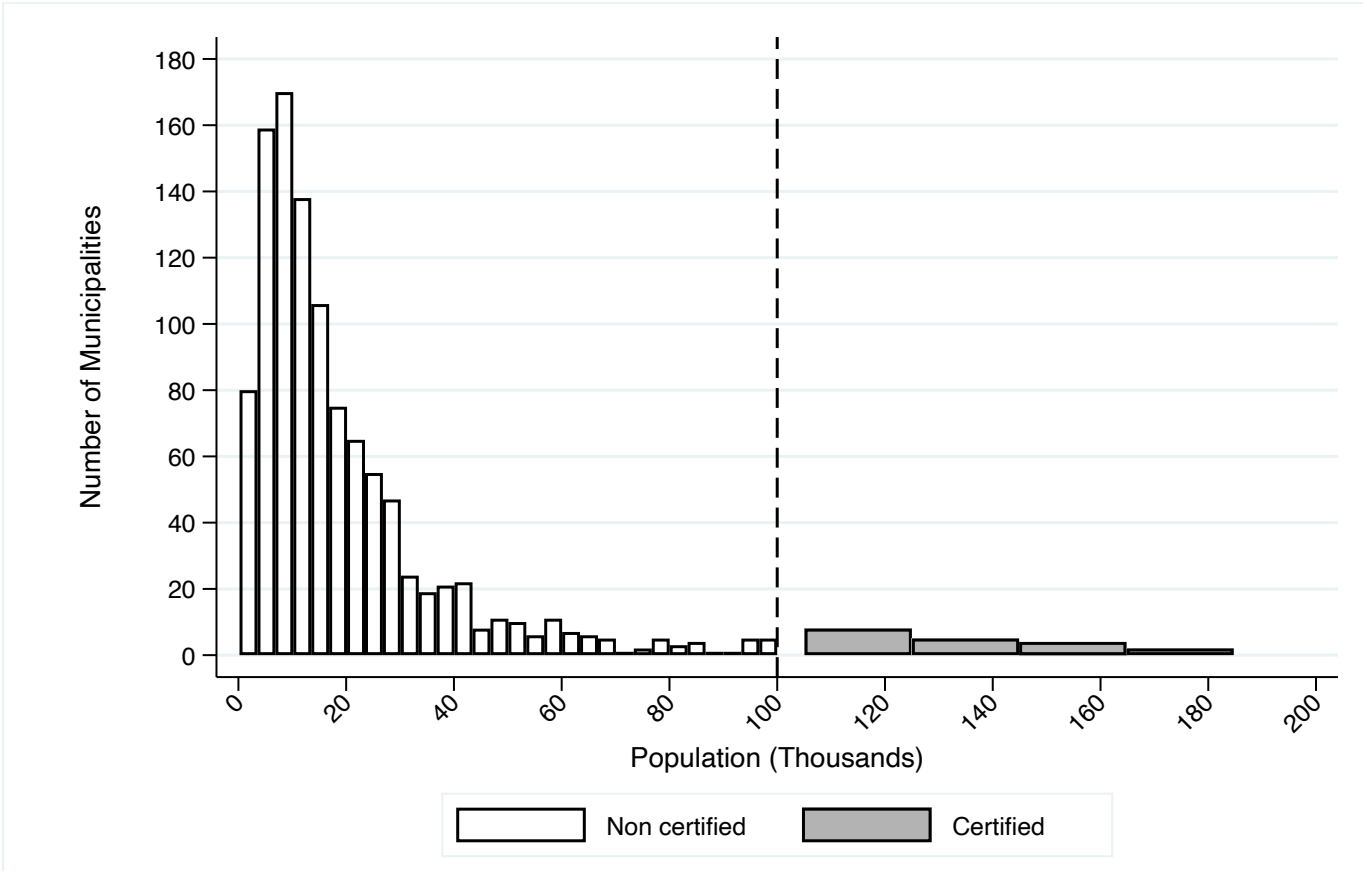


Table B.1: Coefficients of the flexible diff-in-diff model

	Exit-High-school Exam (Standardized)	**Enrollment in public schools (Log)**	**Proportion of Teachers with higher education**	**Proportion of teachers with permanent contracts**	**Local Taxes (Log)**
Certified X (Year=1997)	0.155**	-0.073***	-0.000	-0.001	-0.013
	(0.075)	(0.028)	(0.003)	(0.006)	(0.012)
Certified X (Year=1998)	0.042	-0.019	0.001	0.004	-0.007
	(0.077)	(0.022)	(0.004)	(0.009)	(0.010)
Certified X (Year=1999)	0.145*	0.006	0.000	-0.001	-0.018*
	(0.083)	(0.020)	(0.003)	(0.006)	(0.010)
Certified X (Year=2000)	-0.010	-0.009	-0.001	-0.002	-0.007
	(0.057)	(0.019)	(0.003)	(0.006)	(0.009)
Certified X (Year=2001)	0.013	0.009	0.000	0.000	-0.004
	(0.055)	(0.019)	(0.003)	(0.006)	(0.010)
Certified X (Year=2003)	0.030	0.057***	0.000	-0.005	0.003
	(0.050)	(0.020)	(0.003)	(0.006)	(0.009)
Certified X (Year=2004)	0.035	0.072***	0.010***	0.026***	0.008
	(0.053)	(0.016)	(0.003)	(0.006)	(0.009)
Certified X (Year=2005)	0.044	0.061***	0.013***	0.029***	0.021***
	(0.048)	(0.014)	(0.002)	(0.006)	(0.008)
Certified X (Year=2006)	0.088*	0.060***	0.017***	0.038***	0.024***
	(0.047)	(0.013)	(0.002)	(0.006)	(0.008)
Certified X (Year=2007)	0.071	0.061***	0.017***	0.046***	0.022***
	(0.050)	(0.013)	(0.002)	(0.005)	(0.008)
Certified X (Year=2008)	0.120**	0.061***	0.021***	0.045***	0.028***
	(0.047)	(0.013)	(0.002)	(0.005)	(0.008)
Certified X (Year=2009)	0.146***	0.057***	0.022***	0.053***	0.035***
	(0.045)	(0.013)	(0.003)	(0.005)	(0.008)
Certified X (Year=2010)	0.214***	0.067***	0.023***	0.048***	0.036***
	(0.047)	(0.014)	(0.003)	(0.006)	(0.009)
Certified X (Year=2011)	0.301***	0.076***	0.024***	0.055***	0.030***
	(0.052)	(0.014)	(0.003)	(0.006)	(0.009)
Certified X (Year=2012)	0.212***	0.080***	0.024***	0.054***	0.046***
	(0.046)	(0.015)	(0.003)	(0.006)	(0.010)
Certified X (Year=2013)	0.183***	0.095***	0.025***	0.059***	0.054***
	(0.045)	(0.016)	(0.003)	(0.006)	(0.011)
Certified X (Year=2014)	0.361***	0.117***	0.025***	0.057***	0.048***
	(0.064)	(0.019)	(0.003)	(0.006)	(0.012)
Certified X (Year=2015)	0.373***	0.137***	0.026***	0.053***	0.027**
	(0.076)	(0.020)	(0.003)	(0.007)	(0.011)
Constant	-0.160***	8.033***	0.906***	0.892***	0.104***
	(0.003)	(0.001)	(0.000)	(0.000)	(0.001)
Year FE	YES	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES	YES
N	19251	19440	19370	19370	19459
Mean non-certified	-0.169	7.913	0.905	0.896	0.101
N Years	1071	1073	1073	1073	1073
N Municipalities	19	19	19	19	19

Note: Difference in difference estimation. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: Colombian Institute for the quality of education (ICFES). Colombian National Bureau of Statistics (DANE). Colombian Ministry of Education, administrative database of public teachers. Authors' calculations

Table B.2: SUR model results for the mediation equations for the diff-in-diff model

	Outcome Variable: Exit-High-school Exam (Standardized)	**Outcome Variable: Enrollment in public school (log)**
A. Effects of being certified on Mediators		
Dependent Variable : Proportion of teachers with higher education		
Independent Variable:	0.020***	0.020***
Certified X (Year>2002)	(0.002)	(0.002)
Dependent Variable: Per capita Local Taxes (log)		
Independent Variable:	0.043***	0.043***
Certified X (Year>2002)	(0.004)	(0.004)
B. Effects on the Outcome variable		
Mediator 1:	0.776***	-0.254***
Proportion teachers higher education	(0.082)	(0.040)
Mediator 2:	0.093**	0.295***
Per capita Local Taxes (log)	(0.044)	(0.022)
Independent Variable:	0.037	0.079***
Certified X (Year>2002)	(0.026)	(0.013)
All estimations include:		
Year FE	YES	YES
Municipality FE	YES	YES
Department X Year FE	YES	YES
N	19,178	19,370
N Years	19	19
N Municipalities	1071	1073
N Departments X Years	552	565

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: Colombian Institute for the quality of education (ICFES). Colombian National Bureau of Statistics (DANE). Colombian Ministry of Education, administrative database of public teachers. National Planning Department. Authors' calculations

Table B.3: Balance test of municipal variables around the population cut-off

	60-140 thousand			*75-135 thousand*			*70-130 thousand*			*75-125 thousand*			*80-130 thousand*		
	Certified	**Non Certified**	**Difference**	**Certified**	**Non Certified**	**Difference**	**Certified**	**Non Certified**	**Difference**	**Certified**	**Non Certified**	**Difference**	**Certified**	**Non Certified**	**Difference**
1993 Population (Thousands)	103.6	65.5	38.104*** (5.039)	102	70.4	31.442*** (5.678)	101.9	72.5	29.388*** (5.989)	101.6	73.6	28.109*** (7.114)	101.9	75.3	26.674*** (6.797)
2002 Population (Thousands)	123.8	77.51	46.258*** (3.931)	121.4	83.35	38.007*** (3.597)	121.4	86.85	34.510*** (3.075)	118.6	87.99	30.585*** (3.258)	121.4	91.17	30.189*** (2.687)
2016 Population (Thousands)	138	95.8	42.206*** (13.556)	135.	103.7	31.350* (15.603)	135.02	108778	26240* (15.417)	140051	111705	28347 (17.983)	135019	120895	14123 (16.733)
2001 Municipal development Index	46.08	43.20	2,883 (3.796)	45.19	43.45	1,733 (4.356)	45.19	45.99	-0.801 (3.898)	45.77	45.80	-0.032 (4.504)	45.19	45.34	-0.152 (3.557)
2001 Unsatisfied-Basic-Needs (UBN)	39.20	43.80	-4.604 (6.409)	41	43.88	-2.884 (7.349)	41	40.25	0.745 (6.493)	38.20	41.12	-2926 (7.366)	41	40.58	0.417 (7.125)
2001 Land GINI	0.451	0.432	0.019** (0.009)	0.450	0.430	0.020* (0.011)	0.450	0.437	0.014 (0.011)	0.454	0.438	0.016 (0.013)	0.450	0.438	0.012 (0.013)
2001 SABER 11 Math Score	49.07	49.04	0.032 (0.432)	49.07	48.94	0.128 (0.484)	49.07	48.96	0.112 (0.502)	49.16	48.96	0.202 (0.598)	49.07	49.06	0.016 (0.592)
2001 SABER 11 Total Score	48.27	47.88	0.393 (0.857)	48.33	47.87	0.464 (0.984)	48.33	48.01	0.325 (1.051)	48.49	48.05	0.431 (1.241)	48.33	48.05	0.288 (1.204)
2001 Public Primary enrollment rates	0.960	0.990	-0.030 (0.072)	0.944	0.978	-0.034 (0.079)	0.944	0.973	-0.029 (0.079)	0.905	0.981	-0.076 (0.092)	0.944	0.942	0.002 (0.084)
2001 Public-Secondary Enrollment Rates	0.439	0.413	0.026 (0.032)	0.430	0.418	0.013 (0.039)	-0.003	(0.033)	-0.003 (0.033)	-0.001	(0.040)	-0.001 (0.040)	-0.001	(0.037)	-0.001 (0.037)
2001 Rural-Urban student Ratio	0.214	0.269	-0.055 (0.052)	0.238	0.260	-0.021 (0.060)	0.238	0.218	0.020 (0.052)	0.241	0.228	0.013 (0.059)	0.238	0.210	0.028 (0.057)
Student-Teacher Ratio	27.47	25.64	1.830 (1.351)	27.63	25.55	2082 (1.405)	27.63	25.79	1843 (1.167)	27.08	25.95	1131 (1.342)	27.63	25.93	1705 (1.356)
N municipalities	13	46		11	33		11	27		8	25		11	19	

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Data Source: Municipal Data Panel of the Economic Development Research Center, University of los Andes. Author´s calculation

Table B.4: SUR model results for the mediation equations for the RD model- Math

Exit-High-school Exam- Math (Standardized)					
Threshold (Thousands)	60-140	65-135	70-130	75-125	80-130
A. Effects of being certified on Mediators					
Dependent Variable : Numeric ability					
Independent Variable:	0.454***	0.590***	0.625***	0.387***	0.735***
Certified	(0.096)	(0.112)	(0.111)	(0.133)	(0.110)
Dependent Variable: Verbal ability					
Independent Variable:	0.549***	0.907***	0.890***	0.731***	1.057***
Certified	(0.095)	(0.102)	(0.109)	(0.131)	(0.009)
Year FE	YES	YES	YES	YES	YES
N schools	3,860	2,982	2,779	2,476	2,314
B. Effects on the Outcome variable					
Dependent Variable : High-school Exam- Math (Standardized)					
Mediator 1:	0.098***	0.083***	0.063*	0.039	0.083**
Numeric ability	(0.027)	(0.033)	(0.034)	(0.035)	(0.039)
Mediator 2:	0.260***	0.342***	0.351***	0.338***	0.304***
Verbal ability	(0.028)	(0.033)	(0.035)	(0.035)	(0.040)
Independent Variable:	1.040***	0.817***	0.851***	0.156	1.020***
Certified	(0.129)	(0.161)	(0.162)	(0.183)	(0.168)
	YES	YES	YES	YES	YES
	3,860	2,982	2,779	2,476	2,314

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: Colombian Institute for the quality of education (ICFES). Colombian Ministry of Education, administrative database of public teachers. Author's calculations.

B.0.1 Mediation analysis

Through the mediation analysis (see Imai, Tingley and Keeling, 2010; Imai, Keeling and Yamamto, 2010) it is possible to establish that there may exist an indirect effect of being certified through its impact on the mediating variables when:

- Being certified is related to the outcome variable i.e. the starting salary,

Table B.5: SUR model results for the mediation equations for the RD model- Spanish

Exit-High-school Exam- Spanish (Standardized)					
Threshold (Thousands)	60-140	65-135	70-130	75-125	80-130
A. Effects of being certified on Mediators					
Dependent Variable : Numeric ability					
Independent Variable:	0.454***	0.591***	0.625***	0.387***	0.736***
Certified	(0.096)	(0.112)	(0.111)	(0.133)	(0.110)
Dependent Variable: Verbal ability					
Independent Variable:	0.549***	0.907***	0.891***	0.731***	1.057***
Certified	-0.095	(0.110)	(0.110)	(0.131)	(0.110)
Year FE	YES	YES	YES	YES	YES
N schools	3,860	2,982	2,779	2,476	2,314
B. Effects on the Outcome variable					
Dependent Variable : High-school Exam- Spanish (Standardized)					
Mediator 1:	0.046**	0.033	0.028	-0.007	0.049
Numeric ability	(0.026)	(0.030)	(0.032)	(0.033)	(0.036)
Mediator 2:	0.281***	0.334***	0.329***	0.328***	0.273***
Verbal ability	(0.026)	(0.031)	(0.032)	(0.034)	(0.036)
Independent Variable:	1.039***	0.988***	1.006***	0.456***	1.195***
Certified	(0.123)	(0.150)	(0.151)	(0.174)	(0.154)
	YES	YES	YES	YES	YES
	3,860	2,982	2,779	2,476	2,314

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Source: Colombian Institute for the quality of education (ICFES). Colombian Ministry of Education, administrative database of public teachers. Author's calculations.

- Being certified is related to the channels of mediation i.e. proportion of teachers with higher education and locally managed investment,

- upon including both the being certified and the mediating variables, the latter significantly explains the outcome variable. If the significance of the eligibility variable disappears, it can be concluded that the total effect being certified has on the educational outcomes is indirect and occurs through the channels of mediation. If this is not the case, a percentage of the effect of being certified on the educational outcomes is explained directly by that variable while the remaining percentage is explained through the mediating channels.

The mediation model which explains the impact of being certified on the educational outcomes can be represented by the following equation:

$$Y_{it} = \beta_0 + \beta_1 TeacherHigherEd_{it} + \beta_2 LocalInv_{it} + \phi certified_{it} + \varrho Controls_{it} + \mu_i + \rho_t + \varepsilon_{it} \quad \text{(B.1)}$$

Where $certified_{it}$ is being a certified municipality, $TeacherHigherEd_{it}$ is the proportion of teachers with higher education, $LocalInv_{it}$ is the per capita amount of locally managed investment the time span of job search and Y_{it} are the educational outcomes – quality of education and student enrollment. Additionally, we include municipal and year fixed effects together with interactions with department and years.

In order to test mediation as explained in b) we should establish whether $certified_{it}$ affects the proposed channels of mediation: $TeacherHigherEd_{it}$ and $LocalInv_{it}$ as follows:

$$Y_{it} = \theta_0 certified_{it} + \varrho Controls_{it} + \mu_i + \rho_t + \varepsilon_{it} \quad \text{(B.2)}$$

$$TeacherHigherEd_{it} = \theta_1 certified_{it} + \varrho Controls_{it} + \mu_i + \rho_t + \varepsilon_{it} \quad \text{(B.3)}$$

$$LocalInv_{it} = \theta_2 certified_{it} + \varrho Controls_{it} + \mu_i + \rho_t + \varepsilon_{it} \quad \text{(B.4)}$$

Upon replacing (C.2), (C.3) and (C.4) in equation (c.1) we obtain the following expression:

$$Y_i = [(\beta_1 * \theta_1) + (\beta_2 * \theta_2) + \phi] * Elegible_i + \lambda Controls_{it} + \mu_i + \rho_t + \varepsilon_{it} \quad \text{(B.5)}$$

Where $\beta_1 * \theta_1$ measures the indirect effect of being certified on educational outcomes stemming from the proportion of teachers with higher education, while $\beta_2 * \theta_2$ measures the indirect effect of local investment. Conversely, ϕ captures the direct effect of being certified on educational outcomes.

To obtain the magnitude of these direct and indirect effects, we estimate models for the equations (C.2), (C.3), (C.4) and (C.5). To correct for potential correlation of the error terms among these equations we make use of the Seemingly Unrelated Regression (SUR) methodology (Zellner, 1962). Subsequently, we carry out a bootstrapping process to determine the statistical significance of the estimated coefficients capturing both the direct effect ϕ and the indirect effect $(\beta_1 * \theta_1)$ + $(\beta_2 * \theta_2)$ as stated in equation (C.5). (See Preacher and Haynes, 2008)