ABSTRACT

Title of dissertation:	ESSAYS ON EDUCATIONAL VOUCHERS
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This dissertation examines three different but related aspects of educational voucher programs.

An introductory chapter describes the relevant questions in the literature, and draws a connecting line between the three essays that follow.

Next, Tomás Rau, Sergio Urzúa and I examine a fundamental question in the voucher literature, that relates to the effects that vouchers have on the students who use them. We advance the literature by focusing not only on short-term outcomes, but also on long-term educational outcomes, namely college admission exams, college enrollment, and college degree attainment. We apply our analysis to administrative panel data from Chile, and find that vouchers have positive effects on test scores (0.07 and 0.01 standard deviations on verbal and math, respectively), which translate into important effects on college-related outcomes, especially on the likelihood that a student attends college. We also find substantial heterogeneity in the estimated effects, where in general low-ability students benefit more from vouchers than high-ability students.

In the chapter that follows, I study an aspect often overlooked in the literature: schools' responses to voucher policies. Using an equilibrium model of demand and supply of elementary schools in Chile, I empirically examine private schools' voucher program participation and tuition decisions under voucher regimes. I focus on universal (available to all students) and targeted (available only to low-income students) vouchers. I find that higher targeted voucher subsidies attract more schools to participate in the voucher program, but that high-quality schools join the program only if the subsidy is sufficiently high. I also find that targeted voucher policies have an almost negligible effect on schools' tuition setting. In contrast, schools' substantially respond in prices to universal voucher policies. Specifically, a $1 dollar increase in the universal voucher translate into a $0.58 decrease in average tuition. Consequences for students' school choices are also documented.

In the last chapter, I study another form of schools' responses to voucher policies, that relates to schools' strategic behavior to comply with some of the voucher programs' requirements. A targeted voucher program in Chile requires that participating schools meet specific academic goals in the form of schools' own average scores in standardized tests. Using rich administrative panel data from Chile, I show that schools engaged in a strategic behavior to meet the academic requirements: they kept their lowest-performing students from taking the standardized tests. Specifically, I find that low-performing students are 20% less likely to take the tests due to the program. Moreover, the program does not have an effect on the likelihood that high-performing students take the tests. Implications of this result for public policy and research are discussed.

ESSAYS ON EDUCATIONAL VOUCHERS

by

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Dedication

To my parents, Gloria and Juan, for teaching me about the value of education very early in my life.

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None of this would have been possible without the unconditional support and love from my parents, Gloria and Juan, and my siblings, Juan Carlos, Gloria, and Consuelo. I am fortunate to be part of their life.

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Chapter 1: Introduction to the Dissertation

Educational or school vouchers are usually defined as government-supplied coupons that are used by students to offset tuition at eligible private schools (Epple et al., 2017). The grounds of market-based educational vouchers were initially laid out by Friedman (1955, 1962), who invited for a revision of the role of government in education. He argued that, although externalities and financial constraints justify the financing of education by the State, it is harder to make the case for the government to be involved in the actual provision of education. He proposed the use of vouchers that families can redeem for educational services at approved institutions of their choice. Further, these educational institutions may well be of private for-profit and nonprofit nature. Friedman thus called for limiting the role of government in assuring that the institutions that render the educational services meet certain minimum standards. As a result, he argued, competitive forces would lead to a more efficient delivery of education, and to the proliferation of a wide variety of schools that satisfy the preferences of families.

With a long list of proponents and detractors, the reality is that educational vouchers have become an increasingly important aspect of modern educational systems. Countries as diverse as Chile, the Netherlands, Sweden, Denmark, New

Zealand, India, Colombia, and the United States have all implemented forms of educational voucher programs. In fact, there are currently about sixty five different voucher programs in operation only in the United States (Epple et al., 2017). This explosion of voucher experiences has attracted the attention of both researchers and policy advocates, who in turn have significantly contributed to our understanding of the consequences of this type of policies. However, the inherent complexity of educational systems, combined with the diversity of the actual voucher programs themselves, has left many questions still to be answered.

Motivated by the existing gaps in the literature, this dissertation examines three different but related aspects of educational vouchers. Chapter 2, written in collaboration with Tomás Rau and Sergio Urzúa, studies a fundamental question in the literature, that relates to the effects that vouchers have on the students who use them. We focus on long-term educational outcomes, thus expanding the current literature, that focuses mostly on the short-term test score effects of vouchers. We find an important effect of vouchers on college-related outcomes, especially on the likelihood that a student enrolls in a higher education institution. More importantly, we show that the effects of vouchers are heterogeneous among students, where in general low-ability students benefit more from attending a voucher school than high-ability students.

Once the existence of positive and heterogenous effects of vouchers has been documented, the study of policies promoting vouchers follows naturally. Chapter 3 examines, in a market equilibrium setting, how different voucher policies affect the decisions of both students and schools. It pays special attention to schools' responses to policies, an aspect often overlooked in the literature, but that is key to understand the mechanisms through which voucher programs operate. I show that targeted voucher policies, that offer vouchers only to disadvantaged students, do a decent job in expanding these students' school choice sets. However, I also show that high-quality private schools do not join the voucher program unless the subsidy they receive is sufficiently high. This finding is novel in the literature, and can help reconcile the positive effects of vouchers I find in chapter 2 with the null or even negative effects found in other studies (see e.g. Abdulkadiroglu et al., 2018).

Chapter 4 complements the study of schools' responses to voucher policies, by examining whether schools' strategic behavior can masquerade the true effects of certain policies. In particular, I show that the recent introduction of a targeted voucher program in Chile, which required participating schools to meet specific average test score goals, led schools to keep many of their low-performing students from taking the corresponding tests. Specifically, I find that low-performing students reduced their participation in the tests by about 20% due to the program. In contrast, high-performing students were as likely to take the tests after the introduction of the program as they were before. This unexpected response of schools has important policy implications, especially in a context where schools' test scores are used by the government to guide many of its policies, and by families to choose schools. It also highlights the importance of understanding schools' incentives and motivations when designing successful voucher programs.

I use the context of Chile to address all research questions in this dissertation. Chile is a particularly interesting case to study vouchers. Since 1981, its primary and secondary education systems operate under a nationwide voucher program, where students exercise unrestricted choice among public and private schools. Each student is entitled to a voucher that is redeemed at the school of her choice, and that covers all or part of the school's tuition. Schools, on the other hand, use the vouchers they receive to fund their operations.

Until 2007, Chile's voucher program followed a *universal* design. Under such a design, all students are eligible to receive vouchers, and all schools participate in the program (Epple et al., 2017).[1] In the first phase of its implementation, Chile's program did not allow schools to charge any tuition other than the voucher. A legislation passed in 1994 reversed that mandate, allowing private schools to charge a copayment to parents. Today, about half of private schools charge a top-up fee or copayment (Gazmuri, 2015; Sánchez, 2018b).

In 2008, the Chilean government introduced a second source of subsidy in the form of a *targeted* voucher. This new voucher came to complement the original universal voucher, and was aimed to expand low-income students' school choice sets. Under the targeted program, each disadvantaged student is eligible to receive a targeted voucher, that can be redeemed at any participating school. Schools are invited to participate in the targeted program, and those deciding to join receive the targeted voucher on top of the universal voucher for every disadvantaged student that they enroll, with the requirement that they do not charge tuition to those students (but can still charge any amount to non-disadvantaged). Today, all public

[1]In practice, a small group of private schools were allowed not to join the program. These schools are consequently very expensive, and represent about 8% of total enrollment (Gauri, 1998; Bravo et al., 2010; Sánchez, 2018b).

schools and about two thirds of subsidized private schools participate in the targeted voucher program, and enroll about 90% of disadvantaged students (Sánchez, 2018b).

The essays presented in this dissertation benefit from Chile's long experience with vouchers in many ways. Chapter 2 leverages Chile's experience with the universal voucher to study whether the use of vouchers allows students to attain better long-term educational outcomes. Chapter 3 takes advantage of Chile's simultaneous implementation of the universal and targeted vouchers to examine whether and how schools respond to policies affecting each of the vouchers, and to quantify the equilibrium effects of such policies. Chapter 4 examines schools' behavior before and after the introduction of Chile's targeted voucher program to learn about how this particular policy affected schools' strategic behavior.

In the chapters that follow, I elaborate on the theoretical and empirical considerations of educational vouchers. Each chapter draws upon broader themes in the literature, and expands our current knowledge on the corresponding matter. The following chapters also help distinguish the features of voucher programs that are beneficial for students and the efficiency of educational systems from those that are detrimental. The lessons from this dissertation have important consequences for the design of successful voucher programs.

Chapter 2: The Short- and Longer-Term Effects of Vouchers: Evidence from Chile

Note: This chapter is coauthored with Tomás Rau and Sergio Urzúa.

2.1 Introduction

A fundamental question in the literature of educational vouchers relates to the effects that vouchers have on the students who use them (Epple et al., 2017). Consequently, a number of studies have emerged to answer this question, mostly focusing on the short-run test scores effects of attending a voucher school.[1] The evidence is inconclusive, although the majority of the studies show that vouchers do little to students' performance (Epple et al., 2017). An arguably more important array in this question, but that has attracted much less attention from researchers, is whether vouchers affect longer-term outcomes, such as high-school graduation, college enrollment, college degree attainment, and even labor market outcomes. This paper directly addresses this question by investigating the effects that attending a voucher high school in Chile has on students' performance in college admission

[1]See Rouse (1998), Angrist et al. (2002), Mayer et al. (2002), Peterson et al. (2003), Wolf et al. (2010a), Lara et al. (2011), Muralidharan and Sundararaman (2015), Mills and Wolf (2017), Abdulkadiroglu et al. (2018), among others.

exams, college enrollment, and college degree attainment.[2]

Chile is an interesting scenario to study vouchers. With its more than thirty years of experience with a nationwide voucher program, it constitutes one of world's most important large-scale experiments of educational choice (Epple et al., 2017).[3] Since its inception in 1981, the basic aspects of the system have remained fairly unchanged, with students exercising unrestricted choice among public and subsidized private schools.[4] Each student is entitled to a voucher that is directly paid to the school of her choice, and that covers all or part of the school's tuition.[5] Schools, on the other hand, use the vouchers they receive to fund their operations.

In this paper, we posit a sequential model of schooling decisions and outcomes, that incorporates all essential decision stages that students face as they go through the educational system, starting with the decision of attending a voucher school. Our model is a generalization of the well-studied Roy model (Roy, 1951; Heckman and Honoré, 1990), where individuals are assumed to make their decisions by comparing the net benefits associated to each of the alternatives at hand.[6] Further, we allow for both observed and unobserved characteristics to influence decisions and outcomes,

[2]There is a small, but growing, literature that has analyzed the effects of vouchers on longer-term educational outcomes, mainly high school graduation and college enrollment. These studies include Angrist et al. (2006), Wolf et al. (2010b), and Chingos and Peterson (2015).

[3]Gauri (1998) describes Chile's voucher system as "...perhaps the world's most ambitious attempt to design and implement a program of educational choice...".

[4]In 2008, the Chilean government introduced an important reform to its voucher system, that, among other things, created a differentiated voucher for low-income students. However, since my data covers a period that precedes this reform, I do not go into the details of the implied changes in the system's structure. See Correa et al. (2014), Gazmuri (2015), Feigenberg et al. (2017), Navarro-Palau (2017), Murnane et al. (2017), Neilson (2017), and Sánchez (2018a) for studies that analyze this reform.

[5]Public schools are mandated to be tuition-free. Subsidized private schools are allowed to charge tuition; however, only few of them charge any amount to its students (Gazmuri, 2015; Sánchez, 2018b).

[6]See, also, Willis and Rosen (1979).

and our identification strategy facilitates the interpretation of students' unobserved heterogeneity as a combination of inherent scholastic abilities (Carneiro et al., 2003; Hansen et al., 2004; Heckman et al., 2006a). In addition, the model allows us to recover the distribution of the treatment effects associated to attending a voucher school.[7]

We fit our model to a panel of administrative data from Chile, that tracks individuals from middle school to the completion of their education. We use the model, its estimates, and simulations to compute a variety of treatment parameters for the effects of attending a voucher high school. We also compute the distribution of the corresponding treatment parameters. We find that attending a voucher high school has positive effects on college admission test scores, with average treatment effects of 0.07σ and 0.01σ for verbal and math, respectively.[8] We also find positive effects of vouchers on the probability of enrolling in college, with an average treatment effect of 1.9 percentage points (p.p.), out of a base of 57%. Finally, we find that attending a voucher high school increases the probability of graduating from college (conditional on having enrolled in college) for students actually attending voucher high schools in about 1.2 p.p., but decreases such probability for students actually attending public high schools in about 3.3 p.p. We explain this last result by conjecturing that attending a voucher high school increases the chances not only of enrolling in college, but also of enrolling in higher-quality and more academically

[7] This is in contrast to other approaches, such as instrumental variables, difference-in-difference, and regression discontinuity, from which one can only identify specific treatment parameters, but not their entire distribution. See the discussions in Heckman et al. (2006b), Heckman and Vytlacil (2007), and Heckman and Urzua (2010).

[8] Standard deviation units are represented by σ.

challenging colleges. In such institutions, graduation strongly depends on students' endowments and family background, which students in public high schools usually lack. We also find substantial heterogeneity in the treatment effects, with low-ability students in general benefitting more of attending a voucher school than high-ability students.

This paper contributes to the large literature of educational vouchers.[9] More specifically, it adds to the small but growing set of papers that study the effects of vouchers on long-term outcomes. The evidence from the United States include Wolf et al. (2010b,a), Chingos and Peterson (2015), and Chingos (2018). Using data from the Washington DC Opportunity Scholarship Program, Wolf et al. (2010b,a) report that, while the program is shown to have no significant impact on short-run test scores, it substantially improved students' chances of graduating from high school, with an estimated effect of about 21 p.p. (from a base of 70%).[10] In contrast, subsequent evidence from the program shows no significant effects on college enrollment (Chingos, 2018). A similar result is found for the New York School Choice Scholarships Foundation (SCSF) Program. Chingos and Peterson (2015) show that the SCSF program had no significant impact on college enrollment or degree attainment for the population of students that received a voucher offer. However, when looking at heterogeneous effects, they find significant effects for some subgroups. In particular, they show that the program increased the likelihood that African Americans

[9] See Epple et al. (2017) for a comprehensive review of the theoretical and empirical literature on educational vouchers.

[10] The reported effect of 21 p.p. corresponds to the local average treatment effect (LATE), where random assignment of the voucher offer is used as an instrument for voucher school attendance. The intent-to-treat (ITT) effect is 12 p.p.

enroll in college (6 p.p., from a base of 42%) and obtain a college degree (3 p.p., from a base of 6%). The question of why the large effects on high school graduation do not translate into differences in college enrollment and degree attainment for the D.C. program remains a puzzle, and further research should be directed towards finding the mechanisms that help explain this result. Although, some may argue that the real puzzle is on the large high school graduation effects, given the nonexistent impact on short-run test scores.[11] This paper's evidence from Chile, on the other hand, shows a consistent trend for the voucher effects, where positive effects on test scores translate into positive effects on college enrollment and graduation (for treated individuals).

Angrist et al. (2006) look at the long-term effects of the PACES program in Colombia, a government initiative that offered students vouchers to attend private secondary schools in the nineties. This is perhaps the program with the most positive effects in the voucher literature. After a first study showing ninth-grade test score effects of 0.2σ (Angrist et al., 2002), Angrist et al. (2006) find that test scores in high-stakes college entrance exams also increased by 0.2σ due to the program, and that voucher recipients were 15-20 percent more likely to graduate from high school. Some of the requirements of the PACES program, however, make it difficult to attribute all of the effects of the program to the vouchers alone. In particular, the vouchers were renewable contingent on grade completion, and thus the program

[11] Epple et al. (2017) interpret the evidence from the United States as being consistent with vouchers improving some types of skills more than others. In particular, they argue that it is possible that vouchers improve noncognitive skills, which may explain the positive effects on high school graduation (Heckman et al., 2006a, 2016b), while the lack of an effect on test scores may be the result of weaker impacts on cognitive skills. Though plausible, this interpretation falls short in explaining the zero effects on college enrollment and degree attainment.

included a strong incentive component. The program also required that students had already been accepted in a private school before applying to the program. As a result, not only were the voucher recipients very likely to attend private schools (94%), but so were the students in the control group (88%). This is in contrast with our context, where the treatment and counterfactual are clearly defined as using vouchers to attend a private school, and attending a school in the public sector, respectively, as is the case in most of the studies in the literature.

In a study using the Chilean case, Bravo et al. (2010) investigate the long-term effects on schooling and work choices, and earnings, of the introduction of the universal voucher reform in 1981. They fit a structural dynamic model of education and labor market choices and outcomes on a sample of individuals that were differentially exposed to the voucher system while at school, i.e. some students attended school after the new regime was introduced, some experience their schooling both before and after the reform, and others attended school only before the voucher system was in place. Using their simulated model, they show that the reform increased high school graduation and the likelihood of completing at least two years of college. They also show that earnings inequality decreased and lifetime utility increased due to the reform. These results are encouraging, but as is the case with the PACES program, it is hard to disentangle the true effect of the vouchers from the other components of the reform.[12] For instance, the reform also included the decentralization of the public schools, and transferred their management from the

[12] It is worth noting that the authors are well aware of this aspect of their study, and are careful in attributing the effects they find to the school reform as a whole, and not only to its school choice component.

central government to the municipalities (Gauri, 1998). Lastly, the education and labor sectors were impacted by many other shocks unrelated but contemporaneous to the voucher reform, putting additional noise to the interpretation of the results.[13]

Finally, this paper fits into a literature that uses structural and semi-structural models to estimate economically interpretable and policy-relevant treatment effects. This literature uses a variety of sources of identification, including exclusion restrictions, conditional independence assumptions about unobservables, and functional form assumptions. It also identifies causal effects at well-defined margins of choice, and can evaluate the impacts of policies that have not yet been implemented (Heckman, 2010; Heckman and Urzua, 2010; Heckman et al., 2016b). This paper's methodology is closest to Aakvik et al. (2005), Sarzosa and Urzúa (2015), Heckman et al. (2016b), Rodríguez et al. (2016), and Prada and Urzúa (2017) in that literature.

This paper is organized as follows. After this introduction, Section 3.2 briefly describes Chile's universal voucher system. Section 2.3 presents the various data sets we use, and discusses the construction of our sample. Section 3.4 presents our empirical model of schooling decisions and outcomes, and discusses its identification and estimation strategy. Section 2.5 presents the empirical implementation of the model. Section 3.5 presents our results. Finally, Section 3.7 concludes.

[13] Most notably, the country suffered a major economic crisis in 1982.

2.2 Chile's Universal Voucher System: A Brief Overview

Since 1981, Chile's educational system operates under a nationwide voucher agenda. It combines families' preferences with (public and private) schools competition for attracting students. Funding comes from the government, that pays voucher subsidies directly to the schools. Residential restrictions are nonexistent, and therefore students can attend any school that they are willing to travel to (and pay for).

For the period that our data spans, the educational system operated under a universal voucher design. That is, all public and almost all private schools participate in the program, which implies that they fund their operations through a per-student voucher subsidy that they receive directly from the government. Participating private schools are also allowed to charge a complementary fee to parents, although only about half of them opt to do so (Gazmuri, 2015). Every student, poor and rich, is entitled to a voucher that can be used to pay part or all of the tuition charged by voucher schools.

A third group of schools exists, and includes private schools that do not participate in the voucher program, and therefore do not receive subsidies from the government. Students cannot use their vouchers to offset tuition at these schools, and as a result the fees charged by the non-voucher schools are about ten times higher than the fees charged by the private-voucher schools (Sánchez, 2018b). The share of students attending the non-voucher schools is only about 8% (Bravo et al., 2010; Sánchez, 2018a). For our empirical analysis, we follow the standard practice in the related literature, and disregard this group of schools (Contreras et al., 2010; Lara et al., 2011; Correa et al., 2014). We therefore focus our analysis only on the public and private-voucher schools, that include all of the schools that are part of the voucher system, and that enroll more than 90% of the student population.[14]

2.3 Data

Our sample consists in the universe of 8th grade students enrolled in public primary schools that do not offer secondary grades, in the year 2000. The majority of these students are 14 years old by then. We follow these students through high school. Once graduated from high school, we observe whether they take the national college admission exams, and if so their performance on the exams. Then, regardless of whether they take the admission exams, we observe whether they enroll in college. Lastly, for students enrolled in college, we observe whether they complete their degree on or before their 30th birthday (year 2016).

To understand our selection criteria, it is worth noting some institutional aspects of Chile's education system. Primary education consists in grades 1st–8th, and secondary education consists in grades 9th–12th. Schools, public and private, offer either only primary education grades, only secondary education grades, or both primary and secondary education grades. As a consequence, students enrolled in schools offering only primary grades are forced to choose a new school to pursue their secondary education. The new school may be one that offers only secondary edu-

[14] For a more detailed description of the universal voucher system in Chile, see Gauri (1998), and McEwan and Carnoy (2000).

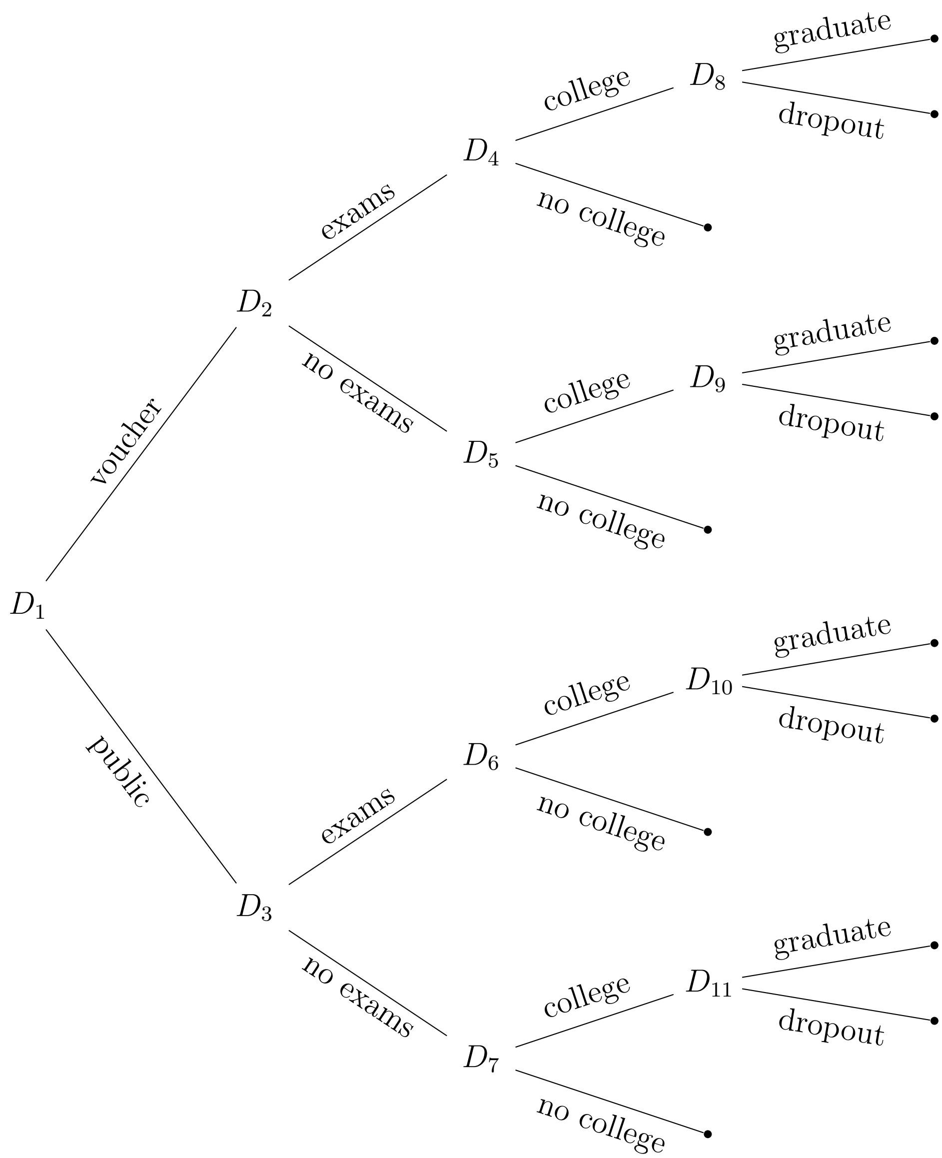
cation grades or both primary and secondary education grades. For these students (and their families), the period right after completing 8th grade is of intensive school shopping. This is in contrast with students enrolled in schools offering both primary and secondary grades, where the end of 8th grade is not too different than the end of 7th or 9th grades, and consequently the majority of these students continue their secondary education in the same school they attend in 8th grade. For this reason, and since we are interested in students' high school decisions, we restrict our analysis to students enrolled in schools offering only primary education grades. Furthermore, we follow Lara et al. (2011), and drop students enrolled in private primary schools. Thus we focus our analysis on arguably the most vulnerable students, for whom the public policy lessons we draw from this paper are most relevant. Additionally, and as discussed in section 3.2, we follow the related literature and disregard students enrolling in private-non-voucher high schools (Contreras et al., 2010; Lara et al., 2011; Correa et al., 2014). These schools do not take up vouchers and have strict admission requirements, and therefore are not part of the school choice framework of public and private-voucher schools. Only about 2% of students in primary public schools that do not offer secondary grades pursue their secondary education in a private-non-voucher high school. Next, and because we do not have information on the high school attended for students that do not earn a high school diploma, we decide to disregard these students. They represent about 13% of students. In a final step, we only keep observations with no missing covariates. This last step brings our final sample size from 95,802 to 66,009.

Our data come from the national standardized exams for primary and secondary education levels (SIMCE), the censuses of students and schools, the national standardized college admission exams (PSU), the census of students attending higher education institutions, and the census of students earning a higher education degree. We use several years for each of these data sets, spanning the period 1998-2016. In addition, we use data from the 2003, 2006, and 2009 versions of the national household survey (CASEN) to construct the instruments we use as part of our identification strategy. These variables relate to the local availability of private-voucher schools, local labor market tightness and opportunities, and local availability of higher education institutions. See appendix A for a more detailed description of each of the data sets we use.

2.4 A Sequential Model of Schooling Decisions and Outcomes

We postulate a model of sequential schooling decisions, that starts with the choice of whether to enroll in a private-voucher or public high school, and is followed by all major schooling decisions the student makes thereon, including taking the college admission exams, enrolling in college, and obtaining a college degree. Figure 2.1 displays the complete diagram of the decisions incorporated in our model. We adjoin students' performance in the college admission exams to our sequential schooling decisions model.

Figure 2.1: Diagram of Sequential Schooling Decisions



Notes: This figure displays the multistage decision process we incorporate in our model. Node D_1 relates to the decision of attending a private-voucher or a public high school. Nodes D_2 and D_3 relate to the decision of whether to take the college admission exams. Nodes D_4–D_7 relate to the decision of whether to enroll in college. Nodes D_8–D_{11} relate to the decision of whether to graduate from college. A terminal node is denoted by a dot at the end of a branch.

Our model is a generalization of the Roy framework (Roy, 1951; Heckman and Honoré, 1990). We characterize each schooling decision using a flexible discrete choice model, and recognize that individuals make decisions by taking into account the consequences of their choices. In that sense, our model approximates a dynamic discrete choice model without being explicit about the precise rules used by individuals or about their information sets.[15] On the other hand, and similar to reduced-form strategies, we use exclusion restrictions as a source of identification. However, unlike that literature, we are able to define a variety of treatment effects at well-defined margins of choice. We also allow for unobserved heterogeneity to play a key role in determining choices and outcomes. Moreover, we are able to interpret the unobserved heterogeneity as a combination of students' inherent scholastic abilities, following the identification argument in Carneiro et al. (2003), and Hansen et al. (2004).[16]

2.4.1 Schooling Decisions and Counterfactual Outcomes

Let $D_{j'|j}$ denote the decision of attaining schooling level j' given that the student attained schooling level j. For instance, $D_{j'|j}$ may denote the decision of graduating from college given that the student enrolled in college (nodes D_8–D_{11} in Figure 2.1). The optimal decision process is assumed to be characterized by an index threshold-crossing model,

$$D_{j'|j} = \begin{cases} 1 & \text{if } I_{j'|j} \geq 0 \\ 0 & \text{otherwise,} \end{cases}$$

[15] See the discussion in Taber (2000), Cameron and Taber (2004), and Heckman et al. (2016b).

[16] See, also, Heckman et al. (2006a), Urzua (2008), Rau et al. (2013), and Rodríguez et al. (2016).

where $I_{j'|j}$ is the perceived value of attaining schooling level j' for a student with schooling level j.

In addition, we model performance in college admission exams for individuals deciding to take the exams. In the context of our application and diagram of decisions (Figure 2.1), let $Y^k_{j'}$ be the score in exam of subject k for a student attaining schooling level $j' \in \{4, 6\}$ (i.e. deciding to take the exams). Then,

$$Y^k = D_{j'|j} Y^k_{j'}, \qquad \text{for } j' = 4, 6 \text{ and } j'|j \in \{4|2\} \cup \{6|3\}$$

is the observed exam k score. In other words, the scores are observed only if the student reaches node $j' \in \{4, 6\}$.

2.4.2 Parameterization and Assumptions About Unobservables

We use a linear-in-the-parameters model to approximate student's perceived value of transitioning from schooling level j to schooling level j',

$$I_{j'|j} = Z_{j'|j}\gamma_{j'|j} + \theta\lambda_{j'|j} + \nu_{j'|j},$$

where $Z_{j'|j}$ is a vector of contemporaneous observed variables that affect the schooling decision, θ is student's unobserved (to the econometrician) heterogeneity, and $\nu_{j'|j}$ is an idiosyncratic error term. Notice that we do not impose forward-looking behavior or any type of rationality, which adds flexibility to our model, at the cost of not being able to identify fully structural preference parameters.

We also use a linear-in-the-parameters formulation to model the performance in college admission exams,

$$Y_{j'}^k = X^Y \beta_k + \theta \alpha_k + \eta_{j'}^k,$$

where X^Y is a vector of observed variables determining test scores, and $\eta_{j'}^k$ is an idiosyncratic error term.

The individual's unobserved heterogeneity plays an important role in our methodology.[17] In particular, we assume that, after controlling for observables, the unobserved heterogeneity drives all statistical dependence between the equations in our model. That is, if the researcher were able to observe θ, she could use matching on (Z, X, θ) to fully identify the model (Carneiro et al., 2003).[18]

Let $\perp\!\!\!\perp$ denote statistical independence. We assume that, conditional on (Z, X),

$$\begin{aligned}
\nu_{j'|j} \perp\!\!\!\perp \nu_{j'''|j''}, &\qquad \text{for any } j'|j \neq j'''|j'' \\
\eta_{j'}^k \perp\!\!\!\perp \eta_{j'}^{k'} \perp\!\!\!\perp \eta_{j''}^{k'}, &\qquad \text{for any } j' \neq j'', k \neq k' \\
\nu \perp\!\!\!\perp \eta, & \\
(\nu, \eta) \perp\!\!\!\perp \theta, &
\end{aligned}$$

where ν is the stacked vector of all $\nu_{j'|j}$ terms, and η is the stacked vector of all $\eta_{j'}^k$ terms. In addition, we assume that all unobservables are statistically independent

[17]This is a common feature of the literature on dynamic discrete choice models. See, for example, Keane and Wolpin (1997), and Aguirregabiria and Mira (2010).

[18](Z, X) denotes the stacked vector of all observables.

from the observable variables, i.e $(\nu, \eta, \theta) \perp\!\!\!\perp (Z, X)$.

2.4.3 Measurement System for the Unobserved Heterogeneity

We adjoin to our model a measurement system of equations to help identify the distribution of the unobserved heterogeneity, θ, as well as to facilitate its interpretation. Notice that the use of a measurement system is not strictly necessary for the model of schooling decisions and outcomes to be identified, and we could instead treat the unobserved heterogeneity as a nuisance or random effect, as is usual in the structural literature (see, e.g., Keane and Wolpin, 1997, and Aguirregabiria and Mira, 2010). However, the use of a measurement system allows us to give a clear interpretation to the unobserved factor as a proxy of the measurements (Carneiro et al., 2003; Hansen et al., 2004).

The measurement system is given by,

$$M_l = X^M \delta_l + \theta \psi_l + \epsilon_l,$$

where M_l is the l-th measurement, X^M is a vector of observed variables determining the measurement, and ϵ_l is an idiosyncratic error term. Notice that the measurements do not depend on the schooling levels, and therefore are observed for all students independent of their schooling choices. In practice, we use measurements taken before the student makes the decisions relevant to our model.

In addition to the independence assumptions mentioned above, we assume that $\epsilon_l \perp\!\!\!\perp \epsilon_{l'} | (Z, X)$ for any $l \neq l'$, and that $\epsilon_l \perp\!\!\!\perp (Z, X, \theta, \nu, \eta)$.

2.4.4 Identification

The main argument for identification of our model uses a version of matching, and follows Heckman et al. (2016a). If θ were observed, then we could condition on (Z, X, θ), and identify all parts of the model. Since θ is not observed, we use the measurement system to proxy θ, and allow for measurement error captured by $\epsilon = (\epsilon_1, \ldots, \epsilon_L)$. Using the conditions presented in Heckman et al. (2016a), we can nonparametrically identify our model, including the distributions of θ and ϵ. This last part in the identification requires that we have at least three measurement equations for a one-dimensional factor structure.[19] In practice, we use four measurements.

The factor loadings are identified up to a normalization. We set one of the loadings in the measurement system to be equal to one, which anchors the scale of the factor.

We also benefit from the use of instruments, that is, variables that shift the schooling decisions but that do not enter the outcome equations. This identification argument works even without imposing a factor structure in the error terms or invoking the independence conditional on (Z, X, θ) assumption. See Heckman et al. (2016a) and the papers cited therein for a formal proof of identification of a general version of a model that shares the characteristics of ours.

[19] See, also, Carneiro et al. (2003), Hansen et al. (2004), and Theorem 1 in Kotlarski (1967).

2.4.5 Estimation

We estimate the model by maximum likelihood. The conditional on (Z, X, θ) independence of the error terms assumption is key when constructing the likelihood function, which is given by,

$$\begin{aligned}\mathcal{L} &= \prod_{i=1}^{N} \int f(Y_i, D_i, M_i \mid Z_i, X_i, \theta) f(\theta) d(\theta) \\ &= \prod_{i=1}^{N} \int f(Y_i, D_i \mid Z_i, X_i, \theta) f(M_i \mid X_i, \theta) f(\theta) d(\theta),\end{aligned}$$

where $f(\cdot)$ denotes a probability density function, and we integrate over the distribution of the unobserved factor. We assume mean zero normal distributions for the error terms, and approximate the distribution of the factor using a mixture of two normals. That is,

$$\theta \sim pN(\mu_1, \sigma_1^2) + (1-p)N(\mu_2, \sigma_2^2),$$

where we constrain the factor mean to be zero, and $p \in [0, 1]$.

We perform the estimation in two stages. First, we estimate the measurement system and factor distribution parameters, using the following first-stage likelihood function,

$$\mathcal{L}^1 = \prod_{i=1}^{N} \int f(M_i \mid X_i, \theta) f(\theta) d(\theta).$$

We obtain estimates $\hat{f}(M_i | X_i, \theta)$ and $\hat{f}(\theta)$, which we use to form the second-stage likelihood function,

$$\mathcal{L}^2 = \prod_{i=1}^{N} \int f(Y_i, D_i \mid Z_i, X_i, \theta) \hat{f}(M_i \mid X_i, \theta) \hat{f}(\theta) d(\theta).$$

By proceeding the estimation in two stages, we reduce the computational time, but also ensure that the estimation of the factor distribution is done using only the measurement system, which reinforces the interpretation of the unobserved factor as a proxy of the measurements. Moreover, since the schooling decisions, D, and outcomes, Y, are independent of the measurement system, M, conditional on (Z, X, θ), we obtain consistent estimates.

We use the Gauss-Hermite quadrature for integration, and correct the second-stage standard errors following the procedure suggested by Murphy and Topel (1985).[20]

2.4.6 Definition of Treatment Effects

The model just described identifies distributions for counterfactual outcomes. We use these counterfactuals to construct treatment effect parameters. In our context, treatment is attending a private-voucher high school in lieu of a public high school. The relative gain an individual gets from attending a private-voucher school is $Y_1 - Y_0$. Our model allows us to obtain the distribution of those gains over the entire population of students. We further define three different treatment effects by averaging those gains over different subsets of the population (Heckman et al., 2001;

[20] See, also, Greene (2008).

Aakvik et al., 2005).

The average treatment effect (ATE) is defined by averaging the treatment gains over the entire student population,

$$ATE = \int\int E(Y_1 - Y_0 \mid X = x, \theta = \bar{\theta}) dF_{X,\theta}(x, \bar{\theta}).$$

The average treatment effect on the treated (TT) is defined by averaging the treatment gains over the subset of students that actually choose to be treated,

$$TT = \int\int E(Y_1 - Y_0 \mid X = x, \theta = \bar{\theta}, D = 1) dF_{X,\theta|D=1}(x, \bar{\theta}),$$

where $D = 1$ denotes receipt of the treatment. This treatment effect informs the average gain for students that endogenously choose to be treated, and it has particular policy relevance whenever a policymaker is interested in knowing the effect of a policy that has a strong self-selection component. That is the case of the voucher policy we study. Notice that this treatment effect is generally different from what IV identifies in a context of heterogeneous treatment effects (i.e. LATE), but offers an arguably clearer interpretation (Heckman et al., 2001, 2006b; Heckman and Vytlacil, 2007).

The average treatment effect on the untreated (TUT) is defined by averaging the treatment gains over the subset of students that actually choose not to be treated,

$$TUT = \int\int E(Y_1 - Y_0 \mid X = x, \theta = \bar{\theta}, D = 0) dF_{X,\theta|D=0}(x, \bar{\theta}),$$

where $D = 0$ denotes non-receipt of the treatment. This treatment effect informs the average gain for students that endogenously choose not to be treated. It has particular policy relevance whenever a policymaker is, for example, considering an expansion of an existing policy, which is expected to cover a larger share of the population than it actually does.

2.5 Empirical Implementation

2.5.1 Schooling Decisions

As displayed in Figure 2.1, we model four levels of schooling choices the students make through the course of their education: enrolling in a private-voucher high school in lieu of a public high school, taking the college admission exams, enrolling in college, and graduating from college (for students enrolled in college). Table 2.1 displays summary statistics for the schooling choices observed in our sample (students that attended primary public schools offering only primary grades). About a third of students enroll in private-voucher high schools. 47% of students take the college admission exams. 57% of students enroll in a higher education institution. Notice that the higher share of individuals enrolling in college than taking the admission exams reflects the fact that most, but not all, higher education institutions require applicants to take the admission exams, and therefore there is a number of students that enroll in college even without taking the exams.[21] About a third of students in our sample earn a higher education degree. Lastly, there is a considerable number of students that drop out from college. More precisely, of the students ever enrolled in college, only 55% are able to graduate (i.e finish their degree).

Table 2.1: Summary Statistics - Endogenous Variables

	mean	std. dev.	min	max
schooling decisions:				
voucher high school	0.36	0.48	0.00	1.00
take college admission exams	0.47	0.50	0.00	1.00
college enrollment	0.57	0.49	0.00	1.00
college degree[a]	0.32	0.46	0.00	1.00
college graduation[b]	0.55	0.50	0.00	1.00
college admission exams:				
verbal	-0.42	0.88	-3.13	2.90
math	-0.43	0.86	-3.18	3.17
measurement system:				
verbal	-0.11	0.91	-2.81	2.90
math	-0.11	0.91	-2.68	2.63
social sciences	-0.11	0.92	-2.79	3.06
natural sciences	-0.11	0.92	-2.76	2.81

Notes: This table displays summary statistics for the set of endogenous variables used in the empirical implementation of our model. Test scores, both from college admission exams and the measurement system, are normalized to have mean zero and standard deviation one in the entire population of test takers. [a] College degree is a dummy for earning a college degree, unconditional on college enrollment. [b] College graduation is a dummy for graduating from college, conditional on having enrolled in college.

[21] For a detailed description of the college admission exams, and the college admission process in Chile, see Rau et al. (2013), Espinoza et al. (2016), Hastings et al. (2016), Rodríguez et al. (2016), Espinoza (2017), and Bucarey (2018).

2.5.2 Outcomes

We consider the following outcomes: college admission test scores, college enrollment, and college graduation (conditional on having enrolled in college). The college admission tests are not mandatory, but are key in determining students' chances of attending college, and therefore the majority of students willing to pursue higher education take them. The battery of admission exams consist of two obligatory tests, verbal and mathematics, and two optative tests, social sciences, and sciences (biology, chemistry, physics). We consider only verbal and mathematics exams in our analysis, and normalize the scores in each subject to have mean zero and standard deviation one among all test takers (including students that are not part of our sample). Table 2.1 displays summary statistics for the college admission test scores in our sample. Both verbal and math distributions have negative means, -0.42σ and -0.43σ, respectively, indicating that the students in our sample perform on average worse than the average student in the entire population of test takers.

The outcomes of enrolling in college, and graduating from college are part of the schooling choices in our model, and were analyzed above.

2.5.3 Measurement System

For the measurement system, we use the 8th grade national standardized exams taken in 2000, which was the first year these tests were administered.[22] The

[22]In 1999, a similar battery of tests were administered to 4th graders. In subsequent years, different national standardized tests have been administered to students in 2nd, 4th, 6th, 8th,

exams are mandatory for all students in 8th grade, and evaluate knowledge in four subjects: verbal, mathematics, social sciences, and natural sciences. We include all four tests as part of our measurement system. These tests help us identify the distribution of the unobserved heterogeneity in our model, and allow us to interpret the unobserved factor as a combination of student's inherent scholastic abilities. In the remainder of the paper, we also refer to the unobserved heterogeneity as ability.

We normalize each test score distribution to have mean zero and standard deviation one in the entire population of test takers. Table 2.1 displays summary statistics for the tests that are part of the measurement system. All four tests have a sample mean of -0.11σ, which tell us that on average the students in our sample perform worse than the students in the entire population.

2.5.4 Covariates

The exogenous variables we use in our model's equations mostly reflect socio-economic characteristics, and are common in the related education/labor literature (see, e.g., Altonji (1993), Heckman et al. (2006a), Heckman et al. (2016b), Walters (2017)). Table 2.2 lists the covariates we use, and displays summary statistics for each of them. The variables for gender, parents' education, and broken home are measured when the students is 14 years old. The variable for broken home is a dummy that takes the value of one if no parent or only one of them resides in the student's home, and zero otherwise. Income per capita variables are measured at the household level, represent monthly figures, and are in US$ as of the year

10th, and 11th grades.

2000. Half of our sample consists in male students. Both mothers and fathers have on average 9 years of schooling, which represents having graduated from primary but not from secondary education. Average monthly income per capita is around US$42–62. Lastly, about a fifth of the students in our sample reside in the country's Northern region, and about half of the students reside in the Central region. The rest reside in the South. Notice that we observe income per capita and region of residence at ages 14 and 18.

Table 2.2: Summary Statistics - Exogenous Variables

	mean	std. dev.	min	max
covariates:				
male	0.50	0.50	0.00	1.00
mother's education	9.0	3.3	0.0	22.0
father's education	9.4	3.4	0.0	22.0
broken home	0.26	0.44	0.00	1.00
log income per capita (age 14)	3.73	0.84	1.06	7.41
log income per capita (age 18)	4.13	0.58	1.92	7.47
region: north (age 14)	0.18	0.38	0.00	1.00
region: center (age 14)	0.48	0.50	0.00	1.00
region: north (age 18)	0.18	0.38	0.00	1.00
region: center (age 18)	0.48	0.50	0.00	1.00
exclusion restrictions:				
% voucher schools in municipality	0.54	0.24	0.00	1.00
Δ local unemployment (high–low skill, age 17)	-0.05	0.06	-0.27	0.26
Δ local log wage (high–low skill, age 17)	0.74	0.31	-0.39	2.55
Δ local unemployment (high–low skill, age 20)	-0.03	0.06	-0.30	0.46
Δ local log wage (high–low skill, age 20)	0.74	0.28	-0.21	2.13
Δ local unemployment (high–low skill, age 23)	-0.04	0.06	-0.30	0.33
Δ local log wage (high–low skill, age 23)	0.69	0.27	-0.13	2.15
college in municipality (age 21)	0.61	0.49	0.00	1.00

Notes: This table displays summary statistics for the covariates used in our model. The variables for gender, parents' education, broken home, and % of voucher schools in the municipality are measured when the students is 14 years old. The variable for broken home is a dummy that takes the value of one if no parent or only one of them resides in the student's home, and zero otherwise. Income per capita variables are measured at the household level, represent monthly figures, and are in log US$ as of the year 2000. The variable for % of voucher schools in the municipality refers to the local availability of private-voucher high schools, and the reported figure is calculated taking into account private-non-voucher high schools. The variables for local unemployment and wages are differences in averages between high-skilled workers and low-skilled workers. The variable for presence of a college in the municipality is a dummy that is equal to one if there is one or more colleges in the student's municipality of residence, and zero otherwise.

2.5.5 Exclusion Restrictions

As stated in Section 2.4.4, our model is nonparametrically identified without the need of exclusion restrictions, and invoking a form of conditional independence assumption on mismeasured variables. However, we could also identify all parameters in our model with the use of node-specific instruments, or variables that shift the schooling choices but that do not enter the outcome equations. With instruments, identification is secured even without relying on the matching-like assumption just mentioned.

We use a variety of instruments that shift the schooling decisions. Table 2.2 lists these instruments, and provide summary statistics for each of them. The variable for the percentage of voucher high schools in the municipality is measured when the student is 14 years old. The variables for local unemployment and wages are differences between high-skilled and low-skilled municipality averages. The variable for presence of a college in the municipality is a dummy that is equal to one if there is one or more colleges in the student's municipality of residence, and zero otherwise. On average, students live in a municipality where 54% of high schools are private-voucher. Local unemployment rates for high-skilled individuals are on average 3–4 percentage points lower than local unemployment rates for low-skilled workers. On average, local wages for high-skilled workers are about twice as high as the wages earned by low-skilled workers. Lastly, 61% of students at age 21 reside in a municipality where one or more colleges are present. Notice that we observe many of the instruments at different moments in the course of the student's education.

Finally, Table 2.3 displays the exact inclusion of the covariates and instruments in the various equations of our model.

Table 2.3: Variables Used in the Empirical Analysis

	measurement system	choices: D_1	D_2–D_3	D_4–D_7	D_8–D_{11}	outcomes: test scores
covariates:						
male	Y	Y	Y	Y	Y	Y
mother's education	Y	Y	Y	Y	Y	Y
father's education	Y	Y	Y	Y	Y	Y
broken home	Y	Y	Y	Y	Y	Y
log household income per capita (age 14)	Y	Y				
log household income per capita (age 18)			Y	Y	Y	Y
region: north (age 14)	Y	Y				
region: center (age 14)	Y	Y				
region: north (age 18)			Y	Y	Y	Y
region: center (age 18)			Y	Y	Y	Y
exclusion restrictions:						
% voucher schools in municipality		Y				
Δ local unemployment (high–low skill, age 17)			Y			
Δ local log wage (high–low skill, age 17)			Y			
Δ local unemployment (high–low skill, age 20)				Y		
Δ local log wage (high–low skill, age 20)				Y		
Δ local unemployment (high–low skill, age 23)					Y	
Δ local log wage (high–low skill, age 23)					Y	
college in municipality (age 21)			Y	Y		
unobserved heterogeneity:						
factor	Y	Y	Y	Y	Y	Y

Notes: This table shows the allocation of the covariates and exclusion restrictions used in the various equations of our model. The symbol Y means that the variable is included in the corresponding equations. The variables for gender, parents' education, broken home, and % of voucher schools in the municipality are measured when the students is 14 years old. The variable for broken home is a dummy that takes the value of one if no parent or only one of them resides in the student's home, and zero otherwise. Income per capita variables are measured at the household level, and represent monthly figures. The variable for % of voucher schools in the municipality refers to the local availability of private-voucher high schools, and the reported figure is calculated taking into account private-non-voucher high schools. The variables for local unemployment and wages are differences in averages between high-skilled workers and low-skilled workers. The variable for presence of a college in the municipality is a dummy that is equal to one if there is one or more colleges in the student's municipality of residence, and zero otherwise.

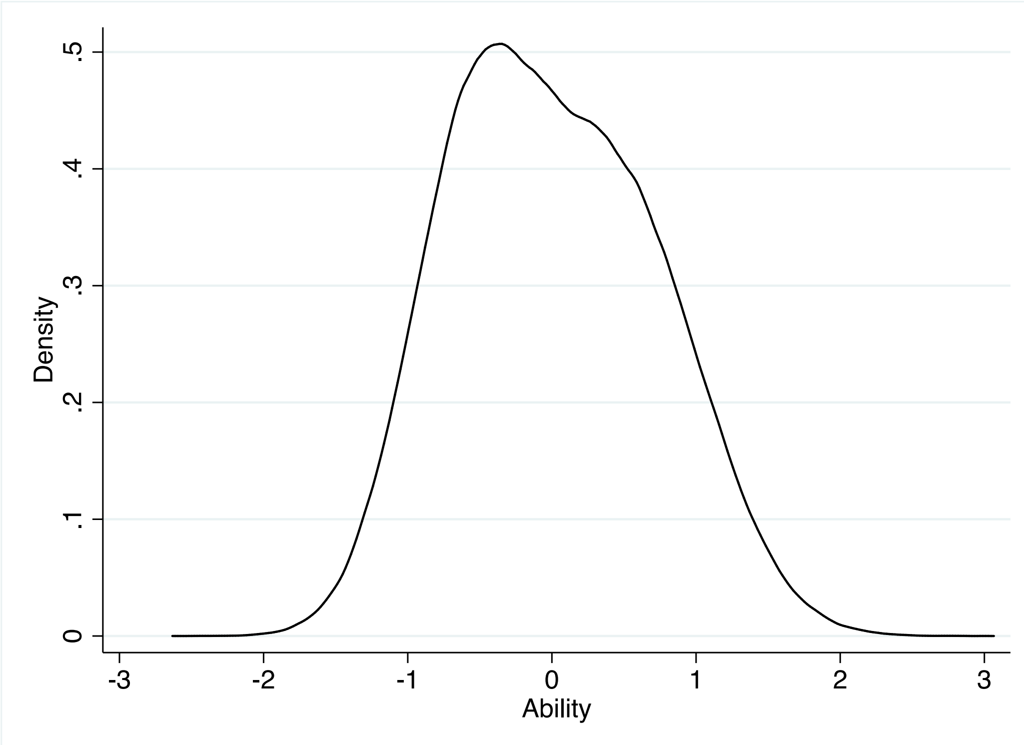
2.6 Results

2.6.1 Estimates

2.6.1.1 Distribution of the Unobserved Heterogeneity

Figure 2.2 displays the estimates for the distribution of the unobserved heterogeneity. It also plots the estimated distribution. A first look at the plotted distribution suggests its departure from the normal distribution. In particular, the estimated distribution presents two modes, one positive and one negative. This result confirms our approach of allowing for a degree of flexibility in the distribution of the factor.

Figure 2.2: Distribution of Ability



$$f \sim pN(\mu_1, \sigma_1^2) + (1-p)N(\mu_2, \sigma_2^2)$$

where

$$(\mu_1, \mu_2) = (0.44, -0.08)$$
$$(\sigma_1, \sigma_2) = (0.58, 0.44)$$
$$p = 0.19$$

Notes: This figure displays the estimated distribution of the unobserved factor. Estimated parameters were obtained from a maximum likelihood procedure on the measurement system.

2.6.1.2 Measurement System

The estimates for the measurement system are reported in Table 2.4. Consistent with other studies for the case of Chile, we find that female students outperform males in verbal, but the opposite occurs in math.[23] A gender effect also exists in social sciences, favoring males. Both mother's and father's education are strong determinant of students' performance, although the effect of mother's education is estimated to be stronger in all subjects. Residing in a household without both parents being present does not affect test scores. That is not the case for household's income per capita, which increases students' performance. Residing in the Southern region also increases test scores. Finally, the unobserved ability factor is estimated to be a strong determinant of test scores, playing a comparable role in all subjects.

[23] See Rau et al. (2013), and Rodríguez et al. (2016).

Table 2.4: Estimates - Measurement System

subject:	verbal		math		social sciences		natural sciences	
	coef.	std. err.	coef.	std. err.	coef.	std. err.	coef.	std. err.
male	-0.226	0.007	0.055	0.007	0.154	0.007	-0.003	0.007
mother's education	0.034	0.001	0.031	0.001	0.032	0.001	0.027	0.001
father's education	0.022	0.001	0.022	0.001	0.024	0.001	0.020	0.001
broken home	0.004	0.008	-0.004	0.008	0.007	0.008	0.004	0.008
log income per capita	0.042	0.004	0.036	0.004	0.054	0.004	0.034	0.004
region: north	-0.070	0.010	-0.076	0.010	-0.077	0.010	-0.093	0.010
region: center	-0.108	0.007	-0.108	0.007	-0.092	0.008	-0.120	0.008
constant	-0.592	0.017	-0.687	0.017	-0.845	0.017	-0.594	0.018
factor	1.000	-	0.932	0.005	0.950	0.005	0.985	0.005
$\log(\sigma)$	-0.674	0.003	-0.550	0.003	-0.565	0.003	-0.583	0.003
observations	66,009		66,009		66,009		66,009	

Notes: This table reports the estimated coefficients of the maximum likelihood procedure on the measurement system. All variables are measured when the students is 14 years old. The variable for broken home is a dummy that takes the value of one if no parent or only one of them resides in the student's home, and zero otherwise. The variable for income per capita is measured at the household level, represents monthly figures, and is in log US$ as of the year 2000. The factor loading for verbal is normalized to be equal to one. All tests are taken in 8th grade, and are normalized to have mean zero and standard deviation one in the entire population of test takers. The variable $\log(\sigma)$ is the natural logarithm of the standard deviation of the corresponding test's distribution.

2.6.1.3 Schooling Decisions

Estimates for the decision of attending a private-voucher high school in lieu of a public high school are presented in Table 2.5. This decision corresponds to node D_1 in Figure 2.1. Males are more likely to enroll in a voucher high school. Higher levels of mother's education increases the likelihood that a student attends a voucher high school. The effect of father's education is not statistically different from zero. Higher levels of household income also increase the likelihood of attending a voucher school. Residing in the Northern region decreases the chances of going to a private school, and the opposite occurs with residency in the Central region; all, relative to residing in the South. Notice that the exclusion restriction, which captures local availability of voucher high schools, is a strong determinant of the decision. Lastly, higher levels of the unobserved ability increase the likelihood of enrolling in a voucher school.

Table 2.5 also reports the estimates for the decision of taking the college admission exams, which corresponds to the nodes D_2 and D_3 in Figure 2.1. Female students are more likely to take the admission exams. Both mother's and father's education increase the likelihood of taking the exams. Not having both parents at home reduces such chances. Higher levels of household's income increase the likelihood of taking the exams. The regional dummies estimates are statistically significant, with a positive sign for students in voucher high schools and a negative sign for students in public high schools. We use three exclusion restrictions in these schooling choices. The first one is the difference between the local unemployment rate of high-skilled workers and the local unemployment rate of low-skilled workers. The corresponding estimated coefficients are not too precise, but are of negative sign, meaning that higher rates of high-skilled unemployment (relative to low-skilled unemployment) lead to fewer individuals to take the college admission exams. The second instrument we use in these equations is the difference between the local log wage of high-skilled workers and the local log wage of low-skilled workers. The estimated coefficients are statistically significant, and negative for students in voucher high schools and positive for students in public high schools. A positive coefficient indicates that a higher wage differential increases student's likelihood of taking the college admission exams. Our third instrument is the local availability of a higher education institution. The corresponding estimated coefficients are statistically significant, and positive for students in voucher high schools and negative for students in public high schools. A positive coefficient indicates that local availability of college increases the likelihood of taking the college admission exams. Lastly, the loading for the unobserved ability factor is strongly positive, meaning that higher levels of ability increase the chances of taking the admission exams.

Table 2.5: Estimates - Schooling Decisions D_1, D_2, D_3

conditional on:			$D_1 = 1$		$D_1 = 0$	
decision node:	D_1: voucher school		D_2: take exams		D_3: take exams	
	coef.	std. err.	coef.	std. err.	coef.	std. err.
male	0.084	0.010	-0.233	0.018	-0.278	0.014
mother's education	0.008	0.002	0.090	0.003	0.093	0.003
father's education	0.001	0.002	0.071	0.003	0.066	0.002
broken home	-0.012	0.012	-0.093	0.021	-0.055	0.015
log household income per capita (age 14)	0.107	0.007	-	-	-	-
log household income per capita (age 18)	-	-	0.147	0.017	0.050	0.013
region: north (age 14)	-0.475	0.016	-	-	-	-
region: center (age 14)	0.191	0.012	-	-	-	-
region: north (age 18)	-	-	0.190	0.036	-0.042	0.019
region: center (age 18)	-	-	0.057	0.021	-0.122	0.016
% voucher schools in municipality	0.947	0.022	-	-	-	-
Δ local unemployment (high–low skill, age 17)	-	-	-0.021	0.165	-0.148	0.110
Δ local log wage (high–low skill, age 17)	-	-	-0.116	0.029	0.039	0.022
college in municipality (age 21)	-	-	0.065	0.019	-0.121	0.014
constant	-1.429	0.027	-2.064	0.076	-1.469	0.057
factor	0.040	0.008	0.643	0.014	0.691	0.011
observations	59,711		23,582		42,427	

Notes: This table reports the estimated coefficients for the schooling decision nodes D_2 and D_3 in Figure 2.1. The estimates were obtained by maximum likelihood. The variables for gender, parents' education, broken home, and % of voucher schools in the municipality are measured when the students is 14 years old. The variable for broken home is a dummy that takes the value of one if no parent or only one of them resides in the student's home, and zero otherwise. The variable for income per capita is measured at the household level, represents monthly figures, and is in log US$ as of the year 2000. The variables for local unemployment and wages are differences in averages between high-skilled workers and low-skilled workers. The variable for presence of a college in the municipality is a dummy that is equal to one if there is one or more colleges in the student's municipality of residence, and zero otherwise.

Estimates for the decision of enrolling in college are presented in Table 2.6. This decision corresponds to the nodes D_4–D_7 in Figure 2.1. Similar to the results for the decision of taking the college admission exams, female students are more likely to enroll in college. Family observable endowments, i.e. parents' education and household's income, strongly increase the likelihood that a student enrolls in college. Residing in a household without both parents being present decreases the chances of attending college. Regional dummies are mostly significant, and all negative, meaning that residing in the South increases the chances of enrolling in college. We use the same instruments as for the decision of taking the college exams, with the difference that local labor market conditions are measured when the student is 20 years old. The instrument for the relative unemployment rate of high-skilled workers is not precisely estimated, and of negative sign for students taking the college admission exams and of positive sign for student not taking the exams. The instrument for the relative wage of high-skilled workers is negative in all equations, but only significant for students in public high schools. The instrument for local college availability is mostly positive and significant, indicating that having a college in the municipality of residence increases the likelihood of attending college. Lastly, the loading for the unobserved ability factor is strongly positive and significant, meaning that higher levels of ability increase the likelihood of pursuing higher education. This is in line with the related existing evidence from Chile (Rau et al., 2013; Rodríguez et al., 2016) and the U.S. (Heckman et al., 2006a, 2016b).

Table 2.6: Estimates - Schooling Decisions D_4, D_5, D_6, D_7

conditional on:	$D_2 = 1$		$D_2 = 0$		$D_3 = 1$		$D_3 = 0$	
decision node:	D_4: enroll college		D_5: enroll college		D_6: enroll college		D_7: enroll college	
	coef.	std. err.	coef.	std. err.	coef.	std. err.	coef.	std. err.
male	-0.057	0.031	-0.082	0.024	-0.085	0.023	-0.197	0.018
mother's education	0.055	0.006	0.044	0.004	0.060	0.004	0.047	0.003
father's education	0.044	0.006	0.042	0.004	0.050	0.004	0.039	0.003
broken home	-0.136	0.035	-0.096	0.027	-0.126	0.025	-0.082	0.020
log household income per capita (age 18)	0.219	0.025	0.229	0.027	0.168	0.020	0.228	0.020
region: north (age 18)	-0.066	0.061	-0.233	0.051	-0.252	0.031	-0.154	0.026
region: center (age 18)	-0.214	0.037	-0.028	0.027	-0.296	0.026	-0.174	0.021
Δ local unemployment (high–low skill, age 20)	-0.127	0.288	0.353	0.204	-0.072	0.186	0.076	0.144
Δ local log wage (high–low skill, age 20)	-0.036	0.060	-0.069	0.044	-0.090	0.040	-0.075	0.032
college in municipality (age 21)	0.059	0.032	-0.002	0.024	0.125	0.024	0.061	0.019
constant	-0.740	0.120	-1.742	0.113	-0.633	0.088	-1.751	0.083
factor	0.480	0.025	0.400	0.020	0.510	0.018	0.389	0.015
observations	11,158		12,424		19,872		22,555	

Notes: This table reports the estimated coefficients for the schooling decision nodes D_4–D_7 in Figure 2.1. The estimates were obtained by maximum likelihood. The variables for gender, parents' education, and broken home are measured when the students is 14 years old. The variable for broken home is a dummy that takes the value of one if no parent or only one of them resides in the student's home, and zero otherwise. The variable for income per capita is measured at the household level, represents monthly figures, and is in log US$ as of the year 2000. The variables for local unemployment and wages are differences in averages between high-skilled workers and low-skilled workers. The variable for presence of a college in the municipality is a dummy that is equal to one if there is one or more colleges in the student's municipality of residence, and zero otherwise.

The decision of graduating from college is estimated only for students that enroll in college, and its estimates are presented in Table 2.7. This decision corresponds to the nodes D_8-D_{11} in Figure 2.1. Female students are more likely than males to graduate from college. Mother's education is a significant determinant of college graduation, where higher levels of education increase the likelihood of earning a college degree. That is not the case of father's education, that has a small and mostly insignificant effect on college graduation. Growing up in a household without both parents being present decreases the chances of obtaining a college degree. The coefficients for household's income are only significant for students that take the college admission exams, and indicate that higher levels of income translate into higher chances of graduating from college. Regional dummies' effects indicate that residing in the South increases college graduation. We use only local labor market instruments, measured when the individual is 23 years old. The coefficients for the relative rate of unemployment for high-skilled workers are mostly insignificant. Same is the case of the coefficients for the relative wage of high-skilled workers. Lastly, the loadings for the unobserved ability factor are strongly positive, meaning that higher levels of ability increase the chances of earning a college degree. This is, again, in line with the related evidence (Heckman et al., 2006a, 2016b; Rau et al., 2013; Rodríguez et al., 2016).

Table 2.7: Estimates - Schooling Decisions D_8, D_9, D_{10}, D_{11}

conditional on:	$D_4 = 1$		$D_5 = 1$		$D_6 = 1$		$D_7 = 1$	
decision node:	D_8: college degree		D_9: college degree		D_{10}: college degree		D_{11}: college degree	
	coef.	std. err.	coef.	std. err.	coef.	std. err.	coef.	std. err.
male	-0.329	0.027	-0.372	0.038	-0.379	0.021	-0.356	0.030
mother's education	0.016	0.005	0.021	0.007	0.015	0.004	0.011	0.006
father's education	0.009	0.005	-0.004	0.007	0.007	0.004	-0.006	0.006
broken home	-0.162	0.031	-0.157	0.044	-0.089	0.023	-0.098	0.035
log household income per capita (age 18)	0.057	0.020	-0.003	0.042	0.079	0.016	0.023	0.033
region: north (age 18)	-0.271	0.048	-0.313	0.087	-0.227	0.028	-0.184	0.041
region: center (age 18)	-0.284	0.032	-0.188	0.042	-0.204	0.024	-0.164	0.034
Δ local unemployment (high–low skill, age 23)	0.036	0.263	-0.356	0.366	-0.713	0.173	0.032	0.255
Δ local log wage (high–low skill, age 23)	0.010	0.051	0.035	0.067	-0.074	0.041	-0.051	0.060
constant	0.084	0.098	-0.095	0.174	0.051	0.075	-0.071	0.137
factor	0.349	0.021	0.222	0.031	0.286	0.016	0.221	0.026
observations	9,504		4,722		16,380		7,346	

Notes: This table reports the estimated coefficients for the schooling decision nodes D_8–D_{11} in Figure 2.1. The estimates were obtained by maximum likelihood. The variables for gender, parents' education, and broken home are measured when the students is 14 years old. The variable for broken home is a dummy that takes the value of one if no parent or only one of them resides in the student's home, and zero otherwise. The variable for income per capita is measured at the household level, represents monthly figures, and is in log US$ as of the year 2000. The variables for local unemployment and wages are differences in averages between high-skilled workers and low-skilled workers.

2.6.1.4 Outcomes: College Admission Exams

We include performance in the college admission exams as outcomes in our model. The corresponding scores are observed only for individuals taking the exams, that is, students that reach the nodes D_4 and D_6 in Figure 2.1 (or, that choose $D_2 = 1$ and $D_3 = 1$ in the same figure). The estimated coefficients for verbal and math scores are presented in Table 2.8. Analogous to the results we obtained for the measurement system, we observe that females outperform males in verbal, and that the opposite occurs in math. Observable family endowments, i.e. parents' education and household's income, are strong determinants of students' performance, with higher levels of family endowments increasing test scores. Growing up in a household without both parents being present has a negative effect on performance. The coefficients for the regional dummies indicate that residing in the South increases test scores. Lastly, the unobserved ability factor is a strong and positive determinant of students' performance in college admission exams.

Table 2.8: Estimates - College Admission Exams Scores

conditional on:	$D_2 = 1$		$D_2 = 1$		$D_3 = 1$		$D_3 = 1$	
subject:	verbal		math		verbal		math	
	coef.	std. err.	coef.	std. err.	coef.	std. err.	coef.	std. err.
male	-0.039	0.012	0.223	0.013	-0.058	0.010	0.193	0.010
mother's education	0.037	0.002	0.033	0.002	0.040	0.002	0.035	0.002
father's education	0.031	0.002	0.025	0.002	0.034	0.002	0.030	0.002
broken home	-0.031	0.014	-0.053	0.015	-0.020	0.011	-0.052	0.011
log income per capita (age 18)	0.078	0.009	0.067	0.009	0.049	0.007	0.052	0.008
region: north (age 18)	-0.136	0.021	-0.047	0.022	-0.206	0.013	-0.131	0.013
region: center (age 18)	-0.164	0.014	-0.174	0.015	-0.098	0.011	-0.116	0.011
constant	-1.492	0.040	-1.497	0.042	-1.515	0.031	-1.498	0.033
factor	0.929	0.009	0.806	0.009	0.943	0.007	0.798	0.007
$\log(\sigma)$	-0.613	0.007	-0.497	0.007	-0.620	0.005	-0.494	0.005
observations	11,158		11,158		19,872		19,872	

Notes: This table reports the estimated coefficients for the college admission exams, and were obtained by maximum likelihood. The variables for gender, parents' education, and broken home are measured when the students is 14 years old. The variable for broken home is a dummy that takes the value of one if no parent or only one of them resides in the student's home, and zero otherwise. The variable for income per capita is measured at the household level, represents monthly figures, and is in log US$ as of the year 2000. The tests are normalized to have mean zero and standard deviation one in the entire population of test takers. The variable $\log(\sigma)$ is the natural logarithm of the standard deviation of the corresponding test's distribution.

2.6.2 Goodness of Fit

Using the model and its estimates, we simulate 500,000 observations. We test the ability of our model to reproduce the actual data. Tables 2.9–2.11 compare our model's predictions with the data. Table 2.9 reports comparisons for the measurement system. Table 2.10 reports comparisons for schooling decisions. Table 2.11 does analogously for college admission exams. In general, our model fits the data satisfactorily well, which allows us to use the model to compute counterfactuals, treatment effects, and learn more about the consequences of schooling decisions (in particular, attending a voucher high school).

Table 2.9: Goodness of Fit - Measurement System

	mean		std. dev.	
	actual	model	actual	model
verbal	-0.105	-0.106	0.912	0.908
math	-0.108	-0.108	0.907	0.902
social sciences	-0.112	-0.111	0.918	0.912
natural sciences	-0.112	-0.112	0.920	0.916

Notes: This table compares our simulated model with the actual data. Simulations consist in 500,000 draws taken from the model and its estimates.

Table 2.10: Goodness of Fit - Schooling Decisions

	actual	model
D_1	0.357	0.358
D_2	0.473	0.475
D_3	0.468	0.473
D_4	0.852	0.851
D_5	0.380	0.382
D_6	0.824	0.825
D_7	0.326	0.330
D_8	0.616	0.617
D_9	0.382	0.383
D_{10}	0.632	0.632
D_{11}	0.387	0.389

Notes: This table compares our simulated model with the actual data. Simulations consist in 500,000 draws taken from the model and its estimates.

Table 2.11: Goodness of Fit - College Admission Exams

	mean		std. dev.	
	actual	model	actual	model
voucher high school:				
verbal	-0.347	-0.362	0.874	0.861
math	-0.400	-0.413	0.866	0.851
public high school:				
verbal	-0.459	-0.466	0.882	0.863
math	-0.444	-0.451	0.860	0.844

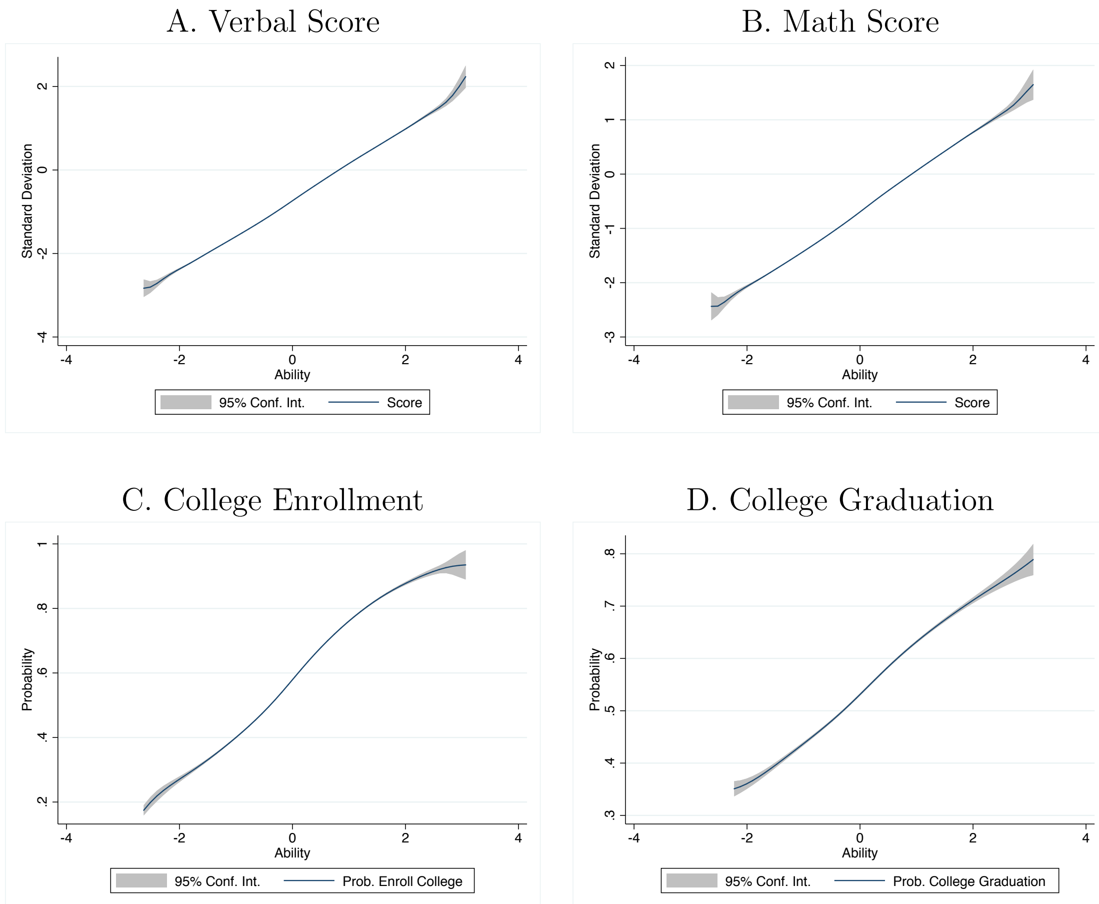
Notes: This table compares our simulated model with the actual data. Simulations consist in 500,000 draws taken from the model and its estimates.

2.6.3 Effects of and Sorting on Ability

Using our simulated model, we investigate the effects of ability on outcomes. We are interested in the outcomes of college admission exams, college enrollment, and college graduation (conditional on having enrolled in college). Figure 2.3 plots the effects of ability on each of the outcomes. Higher levels of ability strongly determine higher test scores and higher chances of college enrollment and graduation.

These results, previewed by the analysis of estimates in Section 2.6.1, and confirmed with the analysis from the simulations, underscore the key role that inherent abilities have on socio-economic outcomes. They also connect this paper with a growing literature on the effects of skills (Heckman et al., 2006a, 2016b; Sarzosa and Urzúa, 2015; Prada and Urzúa, 2017; Sarzosa, 2017), and call for the importance of policies aimed at developing those skills, especially in early stages of children's development (Cunha and Heckman, 2007, 2008; Cunha et al., 2010; Noboa-Hidalgo and Urzúa, 2012; Campbell et al., 2014; Heckman and Mosso, 2014).

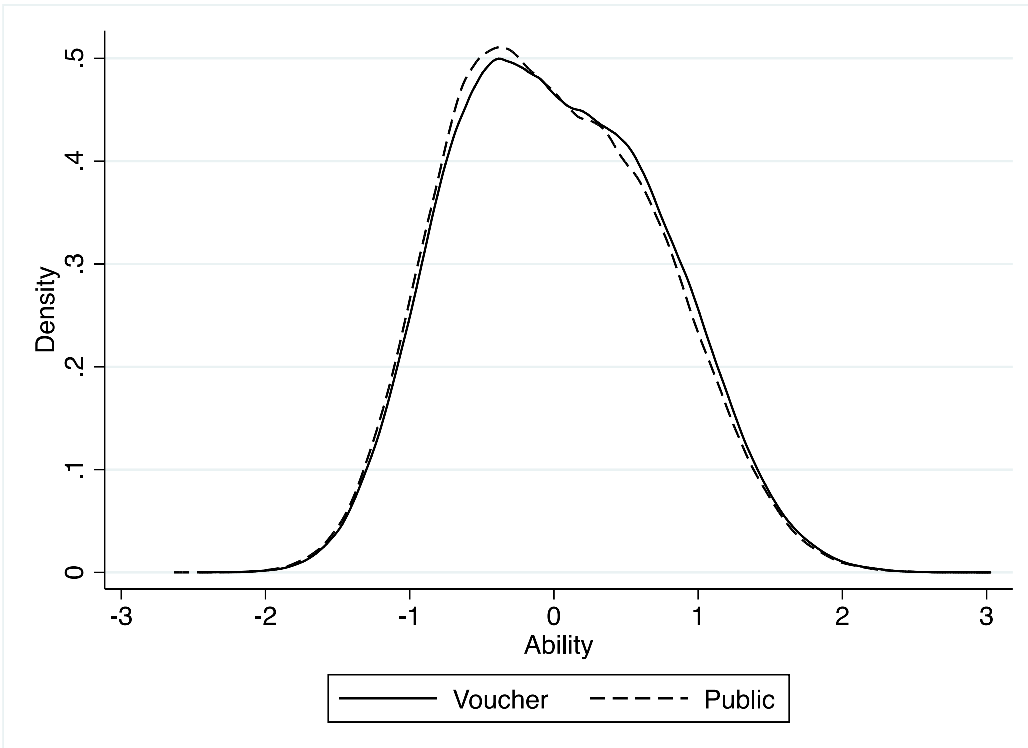
Figure 2.3: The Effects of Ability on Outcomes



Notes: This figure plots nonparametric relationships between abilities and outcomes. The non-parametric estimations are performed using the simulations from the model. College graduation is conditional on having enrolled in college.

We also investigate how ability determines the sorting of students into intermediate and final schooling levels. In particular, we are interested in the sorting effect of ability on students' decision to attend a private-voucher high school, and on final schooling levels (i.e. high school degree, college dropout, college degree). Figure 2.4 plots distributions of ability for students deciding to attend a private-voucher school and for students deciding to attend a public school. The two distributions are very similar one from another. If anything, students in voucher schools have somewhat higher levels of ability, but the differences are almost negligible. We conclude that students of similar ability enroll in private-voucher schools and in public schools.

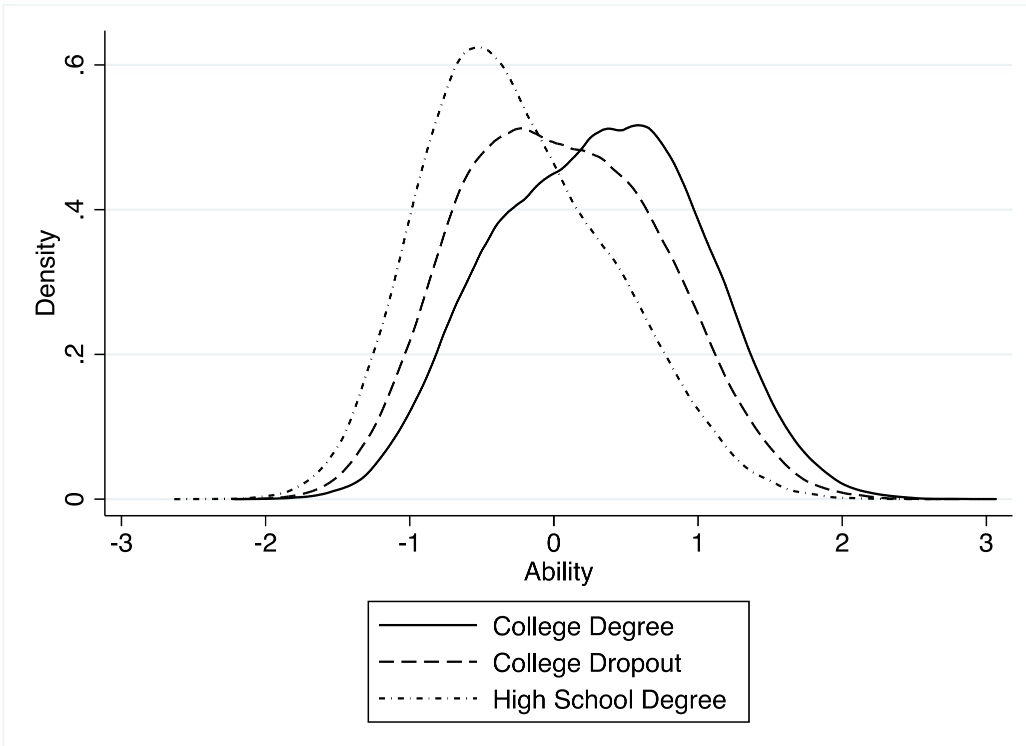
Figure 2.4: Distribution of Ability by Voucher/Public High School



Notes: This figure plots distributions of ability for students attending private-voucher schools and for students attending public schools. The distributions are nonparametrically estimated using the simulations from the model.

Figure 2.5 plots distributions of ability for students attaining the following final schooling levels: high school degree, college dropout (i.e. enrolling in college but not earning the degree), and college degree. The sorting on ability is clear. Individuals earning a college degree have higher levels of ability than individuals dropping out from college, who in turn have higher levels of ability than individuals earning a high school diploma. These results are in line with the existing evidence on the role of skills in educational attainment (Heckman et al., 2006a, 2016b; Rodríguez et al., 2016; Prada and Urzúa, 2017), and, again, highlight the key role of ability in educational success.

Figure 2.5: Distribution of Ability by Final Schooling Level



Notes: This figure plots distributions of ability for individuals attaining three different levels of schooling: high school degree, college dropout, and college degree. The distributions are nonparametrically estimated using the simulations from the model.

2.6.4 The Effects of Vouchers

We investigate the effects of attending a private-voucher high school in lieu of a public high school on the performance in college admission exams, the likelihood of enrolling in college, and the likelihood of graduating from college (conditional on having enrolled in college). To that aim, we use simulated counterfactuals from our model to construct the treatment effect parameters defined in Section 2.4.6. More precisely, we compute the gains of attending a private-voucher school, $Y_1 - Y_0$, for each of our simulated individuals, and then compute averages that correspond to the definition of the treatment effects.

Table 2.12 reports the estimated treatment effects. It displays estimates for the average treatment effect (ATE), the average treatment effect on the treated (TT), and the average treatment effect on the untreated (TUT). The statistical significance of the treatment effects is tested by using a t-test in means. The estimated effects on test scores are all significant, and are all but one positive. On average, attending a voucher school increases verbal scores by 0.07σ. This effect is somewhat smaller for the subsample of students actually attending voucher high schools, or treated individuals (0.06σ), and larger for students attending public schools, or untreated individuals (0.08σ). The effect sizes are in the mid-range of the existing evidence, and are higher than many of the voucher effects reported in the literature (Epple et al., 2017). The effects found for math are somewhat smaller. The average treatment effect is 0.01σ. Moreover, students actually deciding to attend voucher high schools see their math scores slightly decrease by 0.004σ. On the contrary, the voucher effect is positive and significant for students that attend public high schools. The estimated TUT effect is 0.02σ. These estimated effects lie in the mid- to low-range in the existing literature.

Table 2.12 also reports the estimated effects on the outcomes related to higher education, namely college enrollment and graduation. Attending a voucher high school increases the likelihood of enrolling in college by 1.9 percentage points (p.p.)

on average. In contrast to what we observe for the effects on test scores, it is the subsample of treated students (i.e. that attend a voucher high school) that present the highest effects. The corresponding TT effect is 2.3 p.p., and the TUT effect is 1.6 p.p. Recall from Table 2.1 that the average college enrollment rate in the actual sample is 57%. When compared to the existing small literature that looks at the effects of vouchers on college enrollment, our estimates are in line with what is found elsewhere (Chingos and Peterson, 2015; Chingos, 2018). An interesting result is found for the outcome of college graduation (conditional on having enrolled in college). On average, attending a voucher high school reduces the chances of graduating from college by 1.6 p.p. However, the estimated effect is highly heterogeneous among students. For students actually attending a voucher high school (treated group), the effect is positive and of about 1.2 p.p. For students actually attending a public high school (untreated group), the effect is negative and of about -3.3 p.p. An immediate question that arises is, what is driving these disparities? Our model as it is does not provide an exact explanation of the actual mechanisms, but it does allow us to shed some light on the underlying factors. We conjecture that the large and positive effects of vouchers on test scores forcefully allow students not only to attend college with a higher probability, but also to attend "better" higher education institutions (e.g. higher-quality, more prestigious, more professional than vocational).[24] But "better" institutions are also presumably more difficult to graduate from (e.g. stricter grading and passing rules, more competition from higher-ability peers). Thus, students attending public high schools may find it

[24] See Rodríguez et al. (2016).

harder to complete their college degree in "better" colleges whenever they lack the endowments and family background that are necessary to avoid dropping out (see Table 2.7). That may not be the case of students actually attending voucher high schools, who on average have better endowments and family background (see Table 2.5). Thus, the positive TT and negative TUT effects.

Table 2.12: Estimated Treatment Effects of Attending a Voucher High School

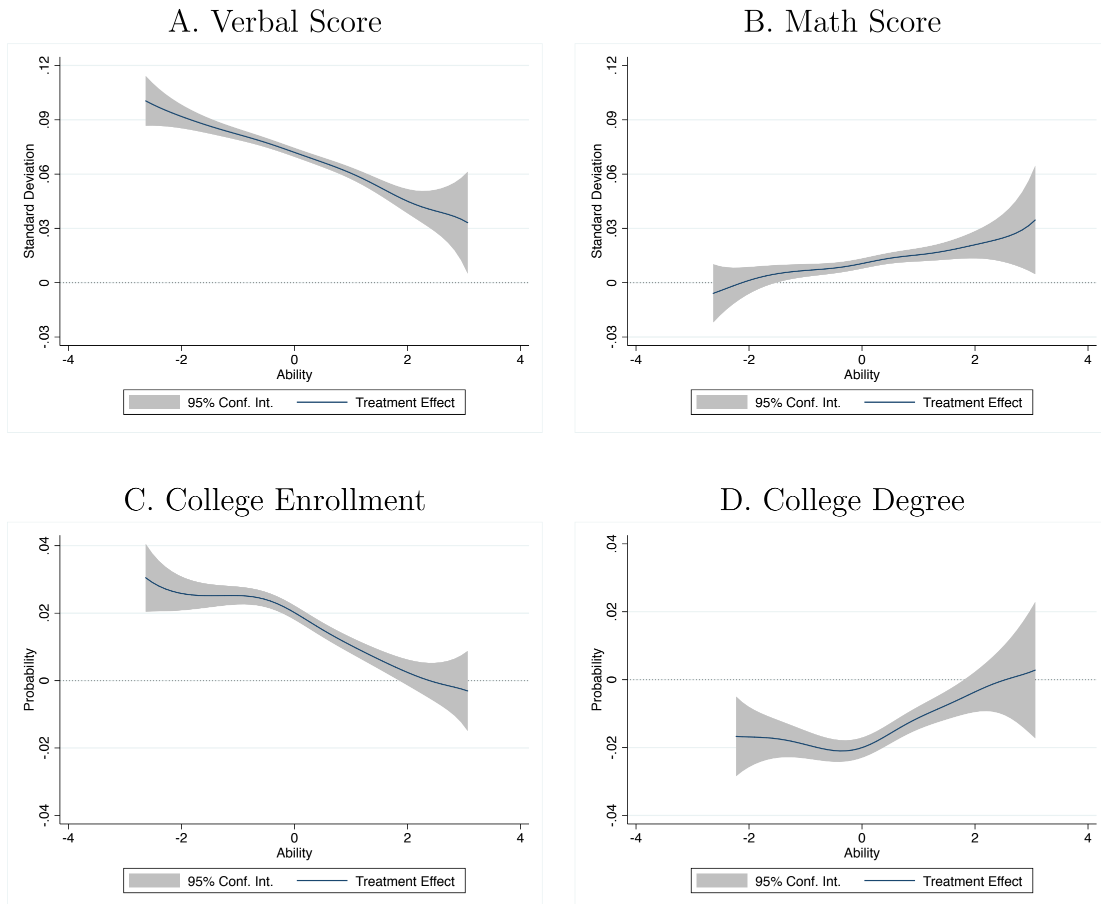
	ATE	TT	TUT
college admission exams (std. dev.):			
verbal	0.071***	0.058***	0.079***
math	0.011***	-0.004**	0.019***
higher education (probability):			
college enrollment	0.019***	0.023***	0.016***
college graduation	-0.016***	0.012***	-0.033***

Notes: This table presents the estimated treatment effects of attending a private-voucher high school in lieu of a public high school. We compute the treatment effects by using counterfactuals from our simulated model. The statistical significance of the treatment effects is tested by using a t-test in means. ATE refers to the average treatment effect, or $E\left[Y_1 - Y_0\right]$. TT refers to the average treatment effect on the treated, or $E\left[Y_1 - Y_0 | D = 1\right]$. TUT refers to the average treatment effect on the untreated, or $E\left[Y_1 - Y_0 | D = 0\right]$. ** and *** denote statistical significance at the 0.05 and 0.01 levels, respectively.

Our last exercise examines the heterogeneity of the voucher effects with respect to students' ability. Specifically, we use our simulated sample to estimate the statistical relation between the individual treatment gains, $Y_1 - Y_0$, and ability. We call this relation the effect of ability on the treatment effect. Figure 2.6 plots this effect for all four outcomes we study. We observe a negative relation between the treatment effect and ability for verbal scores and college enrollment (panels A and C). That is, low-ability individuals benefit more of attending a voucher high school than high-ability individuals. In particular, students with very low levels of ability experience a treatment effect of about 0.09σ on verbal scores, which is almost three times as large as the effect experienced by high-ability students. Similarly, the treatment effect for college enrollment varies from about 3 p.p. for low-ability students to about 0 p.p. for high-ability students. A different pattern is found for math scores (panel B). Students with low levels of ability benefit less of attending a voucher high school than students with high levels of ability. The treatment effect varies from about 0 p.p. to about 3 p.p. Lastly, the treatment effect on the probability of graduating from college (conditional on having enrolled in college) is estimated to be fairly constant at -0.02 p.p. for individuals with low levels of ability, and then to be increasing in ability for individuals with high levels of ability. This is consistent with our above-mentioned conjecture that the ability endowment is an important factor driving positive treatment effects.

The analysis presented in Figure 2.6 is key to better understand how vouchers affect students. They show that the treatment effects are highly heterogeneous, and can certainly help policymakers better target the implementation of policies.

Figure 2.6: The Effect of Ability on Treatment Effects



Notes: This figure plots the statistical relation between the treatment effect, $Y_1 - Y_0$, and ability, for the outcomes of verbal scores, math scores, college enrollment, and college degree attainment. The relations are estimated nonparametrically using simulations from the model.

2.7 Conclusions

We investigate the short and longer-term effects of attending a private-voucher high school in Chile. To that aim, we postulate a sequential model of schooling decisions and educational outcomes, which we estimate using rich administrative panel data from Chile. We find that attending a private-voucher high school increases performance in high-stakes college admission exams, increases the probability of enrolling in college, and increases the probability of graduating from college (conditional on having enrolled in college) for students that actually attend voucher high schools, but decreases such probability for students that actually attend public high schools. We explain this last result by conjecturing that attending a voucher high school increases the likelihood of attending a higher-quality but also more academically challenging college. In such institutions, graduation strongly depends on endowments and family background, which students in public high schools usually lack. We also show important heterogeneity in the treatment effects, where in general low-ability students benefit more from attending a voucher high school than high-ability students.

Our results are novel, and show an advantage of private schools over public schools in many educational outcomes. They also suggest that some efficiency gains can be obtained by targeting voucher policies to low-performing and low-ability students.

Future research should build on our results and investigate the effects that vouchers ultimately have on labor market outcomes. Such evidence is nonexistent to the best of our knowledge, and can certainly increase our knowledge about the consequences of vouchers.

Chapter 3: Targeted or Universal? Mobilizing Students Through School Vouchers

3.1 Introduction

In the past two decades, the education literature has made significant progress in understanding how vouchers affect the demand side of education markets (i.e. students). We have learned, from both experience and research, that vouchers: 1) have at most small effects on students' test scores; 2) have positive effects on high school graduation and college enrollment, especially for minority students; and 3) tend to induce a nonrandom migration from the public to the private sector, where high-income and high-ability students are the most likely to transition from public to private schools (Epple et al., 2017). Now, what do we know about the effects on the supply side (i.e. schools)? Unfortunately, our knowledge on this matter is very limited.[1] Moreover, understanding how schools respond to vouchers is critical,

[1] There is a small literature that has studied the competition effects that voucher policies have on public schools' performance (Hoxby, 2003; Sandström and Bergström, 2005; Hsieh and Urquiola, 2006; Figlio and Rouse, 2006; Chakrabarti, 2008; Chan and McMillan, 2009; Card et al., 2010; Chakrabarti, 2013a,b; Figlio and Hart, 2014). The consensus is that vouchers induce some pressure on public schools to improve (although, Hsieh and Urquiola, 2006 show that, for the case of Chile, public schools' performance worsened in municipalities that experienced greater private competition). However, Epple et al. (2017) argue that in many of these studies it proves hard to truly identify the effects of increased competition on productivity, and that competition is easily confounded with composition and accountability effects. In another vein, Neilson (2017) studies quality responses of schools to the introduction of a targeted voucher program in Chile, while in

as voucher programs are greatly determined by schools' program participation decisions, as well as by their choices regarding tuition, educational inputs, etc. This paper contributes to filling this gap in the literature by explicitly studying schools' responses to voucher policies. It does so by combining economic theory and empirical analysis of administrative data from Chile.

Chile is a particularly interesting scenario to study educational vouchers. It has more than thirty years of experience with a nationwide voucher agenda, in which students choose among public and private schools facing no residential restrictions, and schools (either fully or partially) fund their operations through voucher subsidies that they receive from the government. In addition, the system combines two different voucher designs to subsidize enrollment: a universal voucher, which is a per-student subsidy paid to all schools; and a targeted voucher, which is a per-disadvantaged student subsidy paid to schools that choose to participate in the targeted voucher program. Thus, the Chilean case represents a one-of-a-kind implementation of a large scale voucher program, that allows the study of policies that differentially affect the universal and targeted voucher subsidies.

This paper develops an equilibrium model of school choice and competition under a voucher regime, which I solve using a new concept of equilibrium, and estimate using detailed and novel administrative data for elementary students and schools in Chile. In the demand side of the model, families choose schools by taking into account a number of schools' characteristics, such as proximity, after-voucher

Sánchez (2018a) I focus on educational inputs and other strategic responses by schools to the same targeted voucher policy.

tuition, whether the school is public or private, religious affiliation, and other observable and unobservable characteristics. In the supply side, schools are vertically and horizontally differentiated, and compete as in an oligopoly. Private schools simultaneously decide whether they participate in a targeted voucher program, and choose the tuition they charge to students. The inherent characteristics of urban education markets, where a large number of schools compete for attracting students, coupled with the fact that I explicitly model demand, makes solving the supply side game particularly challenging.[2] The difficulty arises in that, depending on the size of the market, schools' program participation decisions may lead to a very large number of different possible market configurations, each of which has (at least) an equilibrium set of tuitions associated to it.[3] For instance, a market with ten schools has 1,024 different possible market configurations. A market with twenty schools has 1,048,576 different possible market configurations. Considering that Chilean educational markets are typically comprised by tens, and sometimes hundreds, of schools, the task of solving for an equilibrium quickly becomes computationally intractable. To overcome such difficulties, I adapt the concept of oblivious equilibrium, that was initially introduced by Weintraub et al. (2008) to facilitate the computation of dynamic games of imperfect competition in industries with many firms. In my setting, oblivious equilibrium assumes that each school makes decisions based only

[2]Since demand is modeled explicitly, schools' payoffs are nonlinear functions of schools' program participation decisions. This adds an extra layer of difficulty and tractability, relative to models where discrete choices in supply enter linearly in firms's payoffs (see, for example, Bresnahan and Reiss, 1991, Berry, 1992, Seim, 2006, Ciliberto and Tamer, 2009, Sweeting, 2009).

[3]A market configuration in this context is a realization of schools' program participation decisions. For instance, for a market with two schools, let $\tau_1 \in \{0, 1\}$ and $\tau_2 \in \{0, 1\}$ be school 1's and school 2's participation decisions, respectively. Then, the market configuration $T = \{\tau_1, \tau_2\} = \{1, 0\}$ is different from the market configuration $T' = \{0, 1\}$.

on its own type (i.e. realization of its cost structure) and a belief of the expected equilibrium in the market. I further define a sufficient statistic that summarizes the market's expected equilibrium, and that schools use to base their decisions on. This assumption considerably reduces the computational burden, while still allowing the model to accurately predict the choices and outcomes observed in the data.

I estimate the model using detailed and novel administrative data for elementary students and schools in Chile. I use the model and its estimated parameters to study the economic consequences of a variety of counterfactual policy scenarios. I perform two series of counterfactual exercises. First, I study schools' program participation response to different targeted voucher amounts, that range from 30% to 200% the actual subsidy amount. Second, I study the consequences on schools' and students' choices of a 20% increase in government spending in vouchers, that is entirely allocated to either increasing the universal voucher or increasing the targeted voucher. Both counterfactual exercises are motivated by actual policy changes that are currently under implementation, and that increase government spending in vouchers by approximately 20%.

From the first counterfactual exercise, I find that a higher targeted voucher attracts more schools to join the targeted voucher program. More important, such response is heterogeneous with respect to schools' quality. The first schools that decide to join the program are low-quality schools, while high quality schools join only if the subsidy is sufficiently high. These results speaks directly to the evidence shown in Abdulkadiroglu et al. (2018), and highlight the importance of understanding schools' responses to voucher policies. Abdulkadiroglu et al. (2018) present striking evidence that a recently introduced targeted voucher program, the Louisiana Scholarship Program, lowers students' math scores by 0.4 standard deviations, and also lowers achievement in three other subjects. When trying to explain why these negative achievement impacts emerge, the authors show evidence suggesting that selection of low-quality schools into the program may greatly explain the results.

From the second counterfactual exercise, I find that allocating all the extra funds into increasing the universal voucher induces some schools to leave the targeted program. Moreover, these leaving schools tend to be of higher quality than the typical school that stays in the program. The increase in the universal voucher also makes schools respond by lowering tuition. I find that a $1 rise in the universal voucher translates into a $0.58 fall in average tuition. On the contrary, allocating all the extra funds into the targeted voucher induces more schools to join the targeted program. Once again, the marginal schools (i.e. those that change their participation decision following a policy change) are of higher quality than the typical school that participates in the program before and after the policy change. The price response of schools is not as steep as in the increase-in-the-universal-voucher scenario. In the demand side of the markets, some students respond to the policies by changing their school choices. Specifically, 7% of disadvantaged and 11% of non-disadvantaged students switch schools when the universal voucher is increased.[4] Likewise, 4% of disadvantaged and 2% of non-disadvantaged students switch schools when the targeted voucher is increased. In both cases, most of the switching stu-

[4] Disadvantaged (non-disadvantaged) students are students that are (not) eligible to receive the targeted voucher. A student is classified by the Ministry of Education as being disadvantaged according to an income-based index, that was initially set to capture approximately the poorest 40% of the population. In practice, 52% of the student population is classified as disadvantaged.

dents switch to a school of higher quality. Lastly, the rise in a measure of students' welfare is higher in the aggregate when the universal voucher is increased than when the targeted voucher is increased. However, the welfare gap between disadvantaged and non-disadvantaged students increases under the universal voucher policy, and it shrinks under the targeted voucher policy.

This paper contributes to the literature along several fronts. First, I move beyond analyzing the question of whether an education system with school vouchers is superior to a system without vouchers, but rather focus on studying the economic implications of specific voucher designs and policies. Though the former question is of great importance, and has attracted the attention of many studies (Rouse, 1998; McEwan and Carnoy, 2000; Angrist et al., 2002, 2006; Hsieh and Urquiola, 2006; Rouse and Barrow, 2009; Bravo et al., 2010), I choose to investigate a narrower, but arguably more policy relevant question. Voucher programs come in all shapes and sizes, and their effects on outcomes directly depend on their design and the institutional setting in which they are introduced. Hence the importance of understanding the economic consequences associated to specific voucher plans. Recent studies that analyze similar questions include Gazmuri (2015), Ferreyra and Kosenok (2017), Neilson (2017), and Singleton (2017). To my knowledge, this is the first paper that empirically studies the implications of both universal and targeted voucher policies.

Second, this paper also contributes to the existing literature on the industrial organization of education markets. Studies such as Manski (1992), Epple and Romano (1998, 2008), and Nechyba (1999, 2000, 2003a,b) develop theoretical and computational general equilibrium models of education markets in which competition between public and private schools is introduced through tuition vouchers. These papers are motivated by early implementations of school choice programs in the U.S., as well as by the ideas for market-based educational vouchers originally laid out by Friedman (1962). A second and more empirical set of studies in this literature use actual data from existing school systems to learn about the economic implications of increased school choice.[5] Along this front, this paper most closely relates to Gazmuri (2015) and Neilson (2017), that estimate demand models of school choice for Chile's elementary education. Both studies use the results from their demand models to draw conclusions on the sorting and competition effects related to the introduction of a targeted voucher program. This paper improves on those studies by adding the explicit modeling of schools' decisions, which allows me to quantify schools' responses to voucher policies. Thus, I am able to answer a broader set of questions than if I estimated schools' demand in an isolated fashion. Furthermore, I show that supply responses play an important role in determining markets' equilibria. This paper also relates to Ferreyra and Kosenok (2017), and Singleton (2017), that estimate demand and supply models for charters schools in Washington, D.C. and Florida, respectively. I advance those studies by allowing schools to respond to policies along two dimensions: participation in the targeted voucher program, and tuition setting. The above-mentioned studies assume that schools respond via one channel only (i.e. entry).

Finally, this study adds to the entry and location choice literature in indus-

[5]See e.g. Rouse (1998), Angrist et al. (2002, 2006), Hsieh and Urquiola (2006), Ferreyra (2007), Rouse and Barrow (2009), Bravo et al. (2010), Lara et al. (2011), Correa et al. (2014), Dinerstein and Smith (2014), Gazmuri (2015), Barrera-Osorio et al. (2017), Bau (2017), Ferreyra and Kosenok (2017), Neilson (2017), Singleton (2017), Walters (2017), Abdulkadiroglu et al. (2018).

trial organization (reviewed by Berry and Reiss, 2007, and Draganska et al., 2008). This literature typically uses reduced-form specifications for firms' profit functions, whereas I estimate structural models of school choice and price competition that determine schools' program participation decisions. In that respect, this paper closely relates to Draganska et al. (2009), Sullivan (2017), and Wollmann (2017), that specify sequential two-stage games, with oligopolistic firms making discrete choices on product assortment followed by continuous choices on prices. This paper differs from these studies by allowing an unusual large number of players (i.e schools) making sequential decisions in an also static discrete-continuous oligopolistic setting.

The remainder of the paper is organized as follows. Next section presents the institutional details of the Chilean school system. Section 3.3 describes the data used in the empirical analysis, defines the educational markets, and presents descriptive statistics and stylized facts. Section 3.4 presents an empirical model of school choice and school competition that approximates Chile's elementary education market. It also describes the identification and estimation strategy. Section 3.5 presents the estimation results. Section 3.6 presents the policy and counterfactual analysis, where I study the economic consequences of a series of counterfactual voucher policy scenarios. Finally, section 3.7 concludes.

3.2 School Vouchers in Chile

Chile's educational system operates under a nationwide school choice voucher agenda. It combines families' preferences with (public and private) schools competition for attracting students. Funding comes from the government, that pays voucher subsidies directly to the schools. Residential restrictions are nonexistent, therefore students can attend any school that they are willing to travel to (and are able to afford).

There exist three broad types of schools in Chile. *Public* schools, that are publicly managed, receive vouchers, and are tuition-free. *Private-voucher* schools, that are privately managed, receive vouchers, and are allowed to charge tuition (i.e. copayment) on top of the voucher subsidies. *Private-non-voucher* schools, that are privately managed, don't receive vouchers, and charge relatively high levels of tuition. In addition, private (voucher and non-voucher) schools operate under more lenient regulations regarding teachers hiring. They follow the Labor Code, as any other firm in the country, whereas public schools are subject to a Teacher Statute, that makes teachers hiring and firing harder.

The government combines two different voucher designs to subsidize enrollment:

- *Universal voucher:* per-student subsidy paid to all public and private-voucher schools.

- *Targeted voucher:* per-disadvantaged student subsidy paid to public and private-voucher schools that choose to participate in the targeted voucher program.[6]

Participation in the universal voucher program is mandatory for all public and

[6]From 1981 to 2007, the Chilean system operated under a universal voucher program only. In 2008, the government added the targeted voucher program to the universal program, in an effort to increase the access to private schools for low-income students. Since my data covers a period post-2007, I perform my analysis under the universal-and-targeted voucher setting.

private-voucher schools. In contrast, participation in the targeted voucher program is voluntary.[7] Private-non-voucher schools are not eligible to participate in any voucher program.[8] Schools that decide to participate in the targeted voucher program receive an additional subsidy per every disadvantaged student that they enroll, that supplements the subsidy received from the universal voucher. They are also required to charge no tuition to disadvantaged students, but they can charge any amount to non-disadvantaged. Table 3.1 summarizes the above-mentioned voucher regulations, distinguishing between schools' administrative type, and by whether they participate in the targeted voucher program. It also displays the corresponding enrollment shares for 1st graders for the year 2013. Notice that the vast majority (92%) of students attend a subsidized school, either public or private-voucher, which highlights the wide reach of any voucher policy within the student population.

Table 3.1: Voucher Policies, by School-type (year 2013)

school-type:	public	private-voucher		private-non-voucher
in targeted voucher program:	yes	yes	no	no
receive universal voucher	✓	✓	✓	✗
receive targeted voucher	✓	✓	✗	✗
can charge tuition	✗	to non-disadv.	✓	✓
enrollment (%)	40	35	17	8

Notes: This table summarizes the regulations that apply to schools, depending on whether the school is public, private-voucher, or private-non-voucher, and on whether it participates in the targeted voucher program. Enrollment shares correspond to 1st grade for the year 2013.

[7]While, in principle, public schools have the choice to participate in the targeted voucher program, in practice, virtually all of them opt in. On the other hand, there is a considerable number of private-voucher schools that decide not to participate in the program.

[8]It is important to note that, despite the fact that private schools are allowed to switch their voucher status (e.g. from private-voucher to private-non-voucher, and viceversa) from one year to another, such transitions are very rare.

3.3 Data, Educational Markets, and Descriptive Statistics

3.3.1 Data

I combine various administrative data sets for Chilean students and schools for the year 2013. First, I use the registry of all operating schools, in which I observe schools' management type, tuition, decision to participate in the targeted voucher program, address, and other characteristics such as religious orientation and urban status. Second, I use the registry of all students attending elementary education in the country. In these data I observe students' grade and school of attendance, whether the student is disadvantaged or non-disadvantaged, residential address, and other characteristics such as gender and date of birth.[9] Third, I use records on students' performance in mandatory national standardized tests taken by all 4th graders in the country. Finally, I use responses to a questionnaire sent to parents and tutors during the days 4th grade students take the national standardized tests. These responses provide additional demographic characteristics for students, such as parents' level of education, household income, and house amenities (e.g. computer and internet availability). Appendix A provides a more detailed description of the administrative data sets I use in this paper.

I use the address information contained in the administrative data to calculate students' geographical proximity to schools. The Ministry of Education already provides geocoded addresses in the form of latitude and longitude coordinates for

[9] Students' addresses represent confidential data that I obtained from the Ministry of Education after signing a non-disclosure agreement. I store and analyze these records in a secure machine.

all schools in the country. It does not, however, provide coordinates for students' residential addresses. I then use a combination of GIS tools to obtain geographic coordinates from these data. This process is key in order to specify a sensitive demand and supply model, because, as I show below, geographical proximity is a strong determinant of school choice and competition.

Finally, I collect data on private-non-voucher schools' tuition. Such information is not included in the administrative data that the Ministry of Education provides. I perform this process by manually collecting tuition amounts from either schools' websites or telephone conversations. I successfully retrieve tuition values for all private-non-voucher schools in the country.

3.3.2 Educational Markets

In this setting, there is no clear definition of geographic educational markets, because students face no geographical constraints when choosing schools, and there is no administrative boundaries that define and separate the markets. Gazmuri (2015) and Neilson (2017) face the same empirical challenge, and they both provide reasonable guides to define and form geographic educational markets for Chile. I follow their approaches, and use data on students' travelled distance to define the markets. Specifically, I join all contiguous municipalities where 5% or more of the students attending schools in those municipalities reside in.[10] This creates a network of municipalities that constitutes a market. Finally, and in an effort to select only

[10] Following Neilson (2017), I assume that two municipalities are contiguous if and only they are 5 km. or less apart from each other, when measured by their two closest points.

predominantly urban markets, I drop all markets with less than 10,000 elementary education students. I end up with 29 non-overlapping markets across the country. However, in this version of the paper, I use data from 28 of the 29 markets. For computational reasons, I leave out the market corresponding to the capital city, Santiago.

Table 3.2 presents summary statistics for the the 28 educational markets used in the empirical analysis. Three important markets' characteristics are worth mentioning. First, the educational markets in the sample are large, with an average of 23,651 students and 86 schools. The smallest market is comprised by 35 schools, whereas the largest market has 240 schools competing for attracting students. Second, 52% of the students in the average market are disadvantaged. And this number ranges from 30% to 69% in the entire sample, which highlights the broad impact that any policy change in the targeted voucher can have on students' school choices. Third, on average markets have 42 private-voucher schools competing with each other, and this number goes up to 138 in the largest market. Again, this markets' feature underscores the importance of any policy change in the voucher subisidies. On the other hand, a large number of private-voucher schools in a market represents an empirical challenge when trying to model and estimate schools' behavior in an oligopolistic context, as I show in section 3.4.

Table 3.2: Educational Markets' Characterization

	mean	std. dev.	min	max
no. of students	23,651	13,810	10,082	59,316
% disadvantaged students	52	10	30	69
no. of schools	86	52	35	240
no. of public schools	38	19	14	87
no. of private-voucher schools	42	33	12	138
no. of private-non-voucher schools	6	7	0	35
% private-voucher schools in targeted program	62	17	21	86

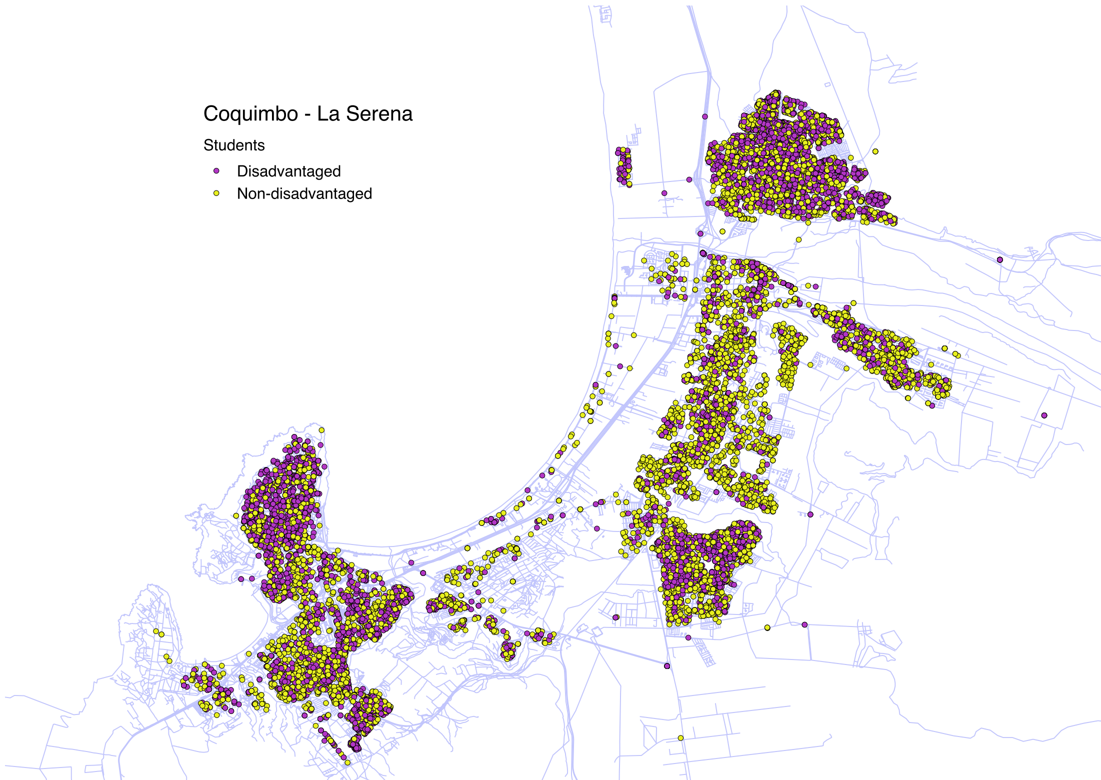
Notes: Summary statistics for all 28 geographic educational markets included in the empirical analysis. The data from the market corresponding to the capital city, Santiago, is not included.

Figures 3.1-3.4 present an example of an educational market created with the geocoded data. The market is formed by the municipalities of Coquimbo and La Serena, in Northern Chile. Figure 3.1 displays the streets and roads layout for the market. Figure 3.2 displays the spatial distribution of students' homes within the market. It distinguishes between disadvantaged (in purple) and non-disadvantaged (in yellow) students. Notice that it is possible to identify neighborhoods with high and low concentrations of disadvantaged students. Figure 3.3 displays the spatial distribution of schools within the market, distinguishing between public (in yellow), private-voucher (in blue), and private-non-voucher (in red) schools. Here, we can also identify areas with different concentrations of privately managed schools. Finally, Figure 3.4 displays the spatial distribution of private-voucher schools, distinguishing between schools that do (in blue) and do not (in light blue) participate in the targeted voucher program. Not surprisingly, neighborhoods with high concentrations of disadvantaged students (in Figure 3.2) also present high concentrations of schools that opted to participate in the targeted voucher program. Nonetheless, both types of schools are found in all of the neighborhoods.

Figure 3.1: Educational Market: Coquimbo-La Serena

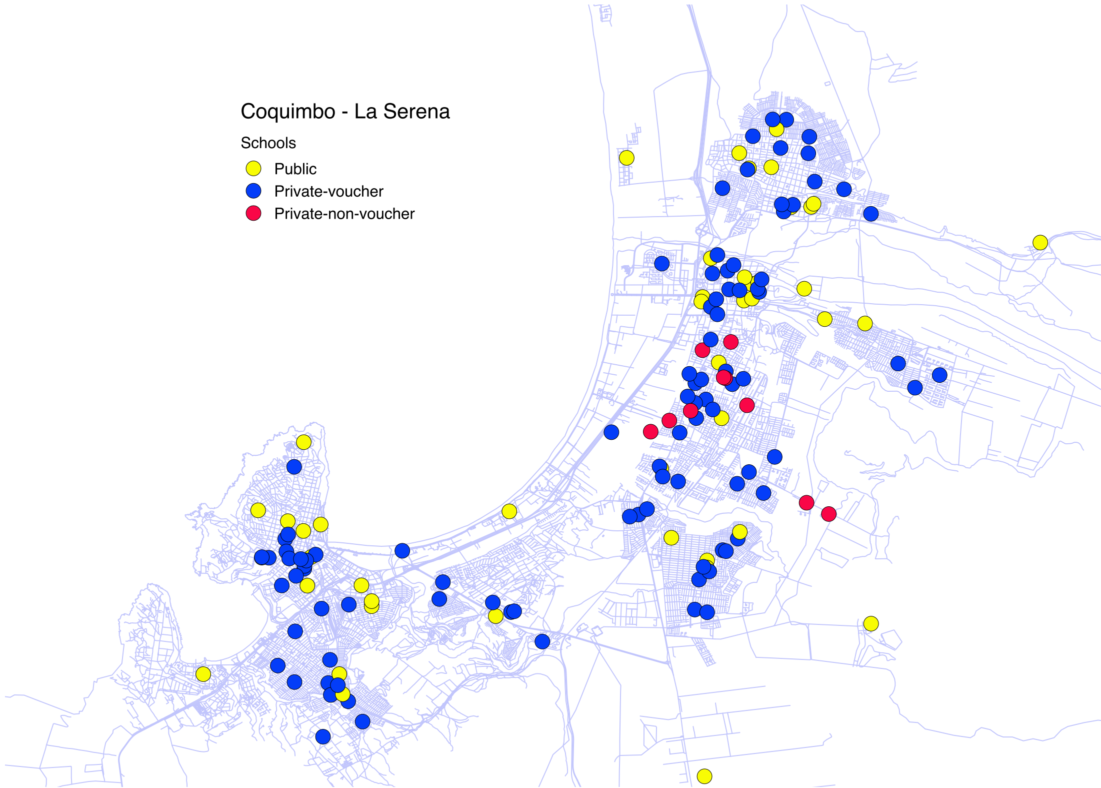
Notes: This figure shows the streets and roads layout for the educational market formed by the municipalities of Coquimbo and La Serena, in Northern Chile.

Figure 3.2: Educational Market: Coquimbo-La Serena - Students



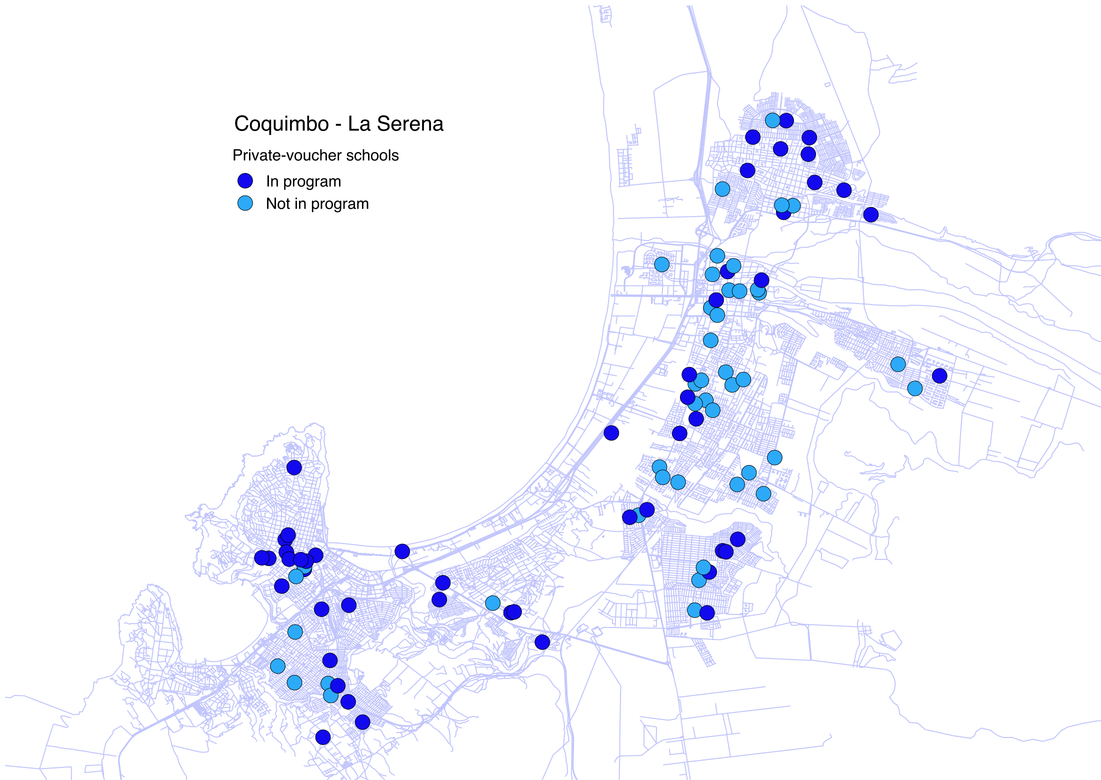
Notes: This figure shows the spatial distribution of students in the educational market formed by the municipalities of Coquimbo and La Serena, in Northern Chile. It distinguishes between disadvantaged (in purple) and non-disadvantaged (in yellow) students.

Figure 3.3: Educational Market: Coquimbo-La Serena - Schools



Notes: This figure shows the spatial distribution of schools in the educational market formed by the municipalities of Coquimbo and La Serena, in Northern Chile. It distinguishes between public (in yellow), private-voucher (in blue), and private-non-voucher (in red) schools.

Figure 3.4: Educational Market: Coquimbo-La Serena - Private-voucher Schools



Notes: This figure shows the spatial distribution of schools in the educational market formed by the municipalities of Coquimbo and La Serena, in Northern Chile. It distinguishes between schools that participate (in blue) and do not participate (in light blue) in the targeted voucher program.

3.3.3 Descriptive Statistics

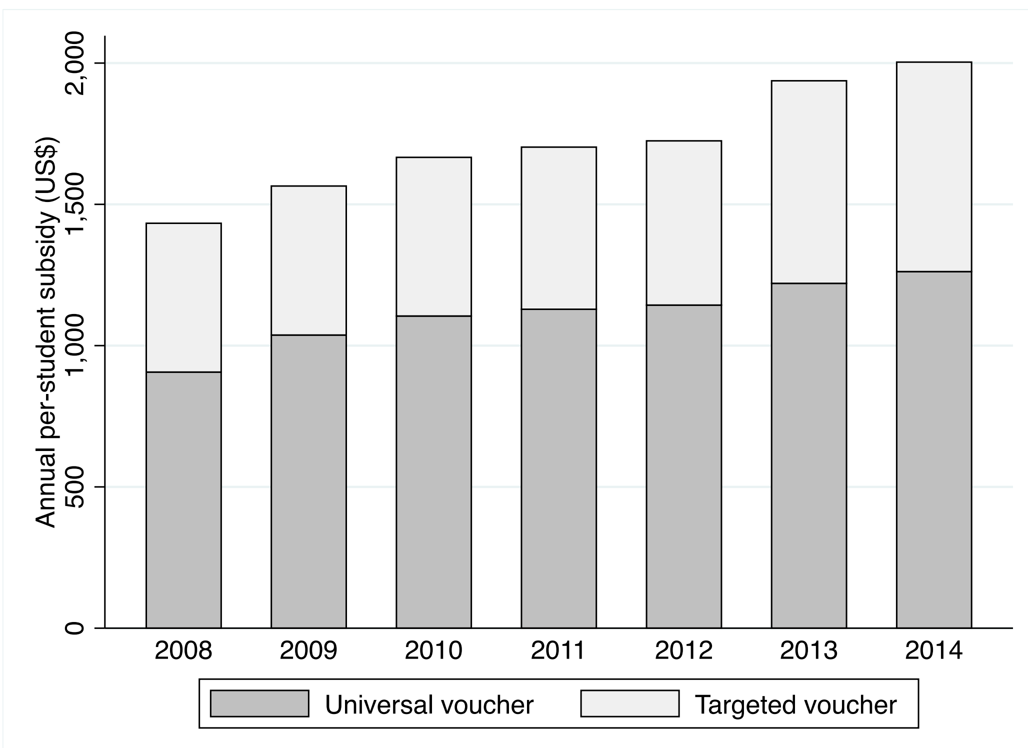
Table 4.1 displays the size of the annual voucher subsidies for the years 2008–2014. Figure 4.1 complements this analysis graphically. We observe that both the universal voucher and the targeted voucher have been slowly and steadily increasing over the years, with averages for the period of $1,114 and $604 for the universal and targeted vouchers, respectively. The targeted voucher amount is considerable, relative to the universal voucher, representing about 50%–60% the size of the universal voucher.

Table 3.3: Size of Annual Voucher Subsidies, by Category and Year

year	universal voucher	targeted voucher
2008	906	527
2009	1,037	527
2010	1,105	562
2011	1,129	574
2012	1,143	581
2013	1,220	717
2014	1,262	741

Notes: Voucher levels are in real prices using 2013 as the base year, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$). The universal voucher values correspond to those for students at schools with full school shifts.

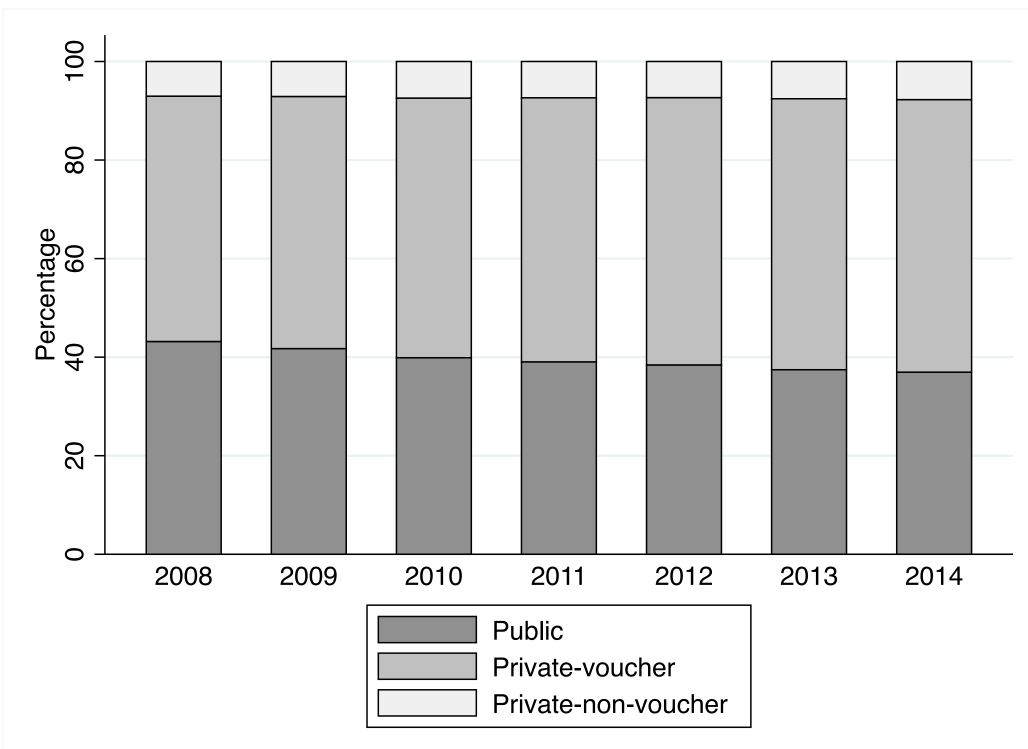
Figure 3.5: Size of the Voucher Subsidies by Category and Year



Notes: Voucher levels are in real prices using 2013 as the base year, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$). The universal voucher values correspond to those for students at schools with full school shifts.

Figure 3.6 displays the enrollment share distribution for first graders among the three broad types of schools for the years 2008–2014. Three important patterns emerge. First, public and private-voucher schools together enroll more than 90% of students. Second, the share of students in public schools has been slightly decreasing over time, going from a little more than 40% in 2008 to somewhat less than 40% in 2014. Third, such decline in public schools enrollment has translated in an almost one-to-one increase in the share of students attending private-voucher schools, while the private-non-voucher enrollment share has remained fairly constant over the period.

Figure 3.6: First Grade Enrollment Distribution Over Time



Notes: Calculated using administrative data from the Ministry of Education.

Table 3.4 summarizes the characteristics of elementary schools, distinguishing by whether the school is public, private-voucher, or private-non-voucher, and by whether the school participates in the targeted voucher program. Consistent with Figure 3.6, 92% of students attend subsidized schools, either public (40%) or private-voucher (52%).[11] Also, schools that participate in the targeted voucher program enroll about three quarters of the student population. When we disaggregate the student population into disadvantaged and non-disadvantaged groups, we observe that 90% of disadvantaged students attend schools that participate in the targeted voucher program (52% public, 38% private-voucher), which means that they forcefully pay zero tuition. For non-disadvantaged students, the enrollment distribution is somewhat different, with almost three quarters of students attending privately managed schools (57% private-voucher, 16% private-non-voucher). A fifth of public schools are located in rural areas, while less than 7% of private-voucher and none of private-non-voucher schools are considered to be rural. Public schools are mandated to be tuition-free. Private-voucher schools that participate in the targeted voucher program must charge zero tuition to disadvantaged students, and charge on average $121 per year to non-disadvantaged. Private-voucher schools that do not participate in the targeted voucher program charge on average $711 for annual tuition. Private-non-voucher schools charge much higher tuition than the rest of schools, with an average of almost $5,000 per year. The performance in standardized math tests of students in public schools is the lowest among the groups of schools. Students in private-voucher schools that participate in the targeted voucher program come in second. Students in private-voucher schools not participating in the tar-

[11] These numbers correspond to first grade enrollment in 2013.

geted voucher program outperform students in the former two groups of schools, and students in private-non-voucher schools obtain the highest scores. The same order is observed for the percentage of teachers with some kind of specialization, and the percentage of teachers with long-term work contracts, with public schools having the lowest concentrations, and private-non-voucher schools the highest ones.

Table 3.4: Schools' Characteristics, by School-type

school-type:	public	private-voucher		private-non-voucher
in targeted voucher program:	yes	yes	no	no
enrollment (%)	40	35	17	8
enrollment - disadv. (%)	52	38	10	1
enrollment - non-disadv. (%)	27	31	26	16
rural (%)	21	7	1	0
avg. annual tuition (US$)	0	0/121	711	4,960
avg. math scores	-0.25	-0.01	0.28	0.75
teachers with specialization (%)	41	46	55	57
teachers with long-term contracts (%)	44	59	64	81

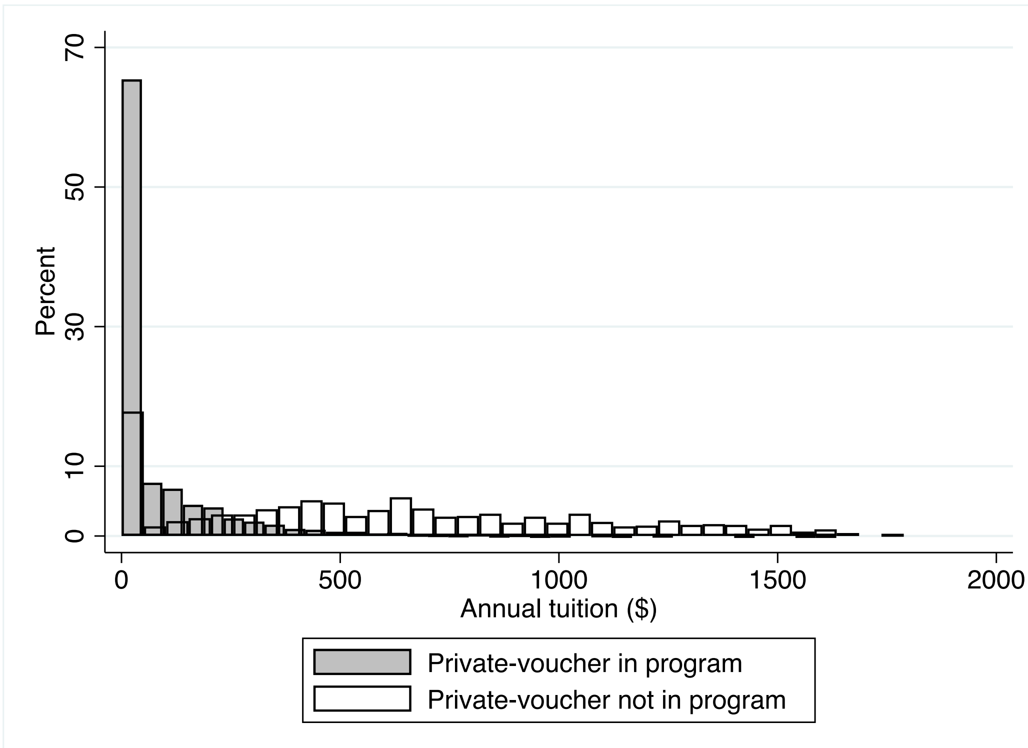
Notes: This table summarizes the characteristics of elementary schools, depending on whether the school is public, private-voucher, or private-non-voucher, and on whether it participates in the targeted voucher program. Tuition levels are in real prices using 2013 as the base year, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$). Test scores are standardized to have mean zero and standard deviation one at the student level. Enrollment shares correspond to 1st grade for the year 2013.

Figure 3.7 presents a more detailed picture of the heterogeneity in the tuition charged by private-voucher schools. It plots the distribution of annual full tuition charged by private-voucher schools, depending on whether the school participates in the targeted voucher program.[12] The tuition distribution for private-voucher schools participating in the targeted voucher program is highly right-skewed, with almost 70% of schools charging zero tuition (to non-disadvantaged students), and virtually no schools charging more than $500. In contrast, the tuition distribution

[12]Full tuition refers to the tuition paid by non-disadvantaged students.

for private-voucher schools not participating in the targeted voucher program is much more disperse. Only about 20% of schools don't charge tuition, and there is a high proportion of schools charging relatively high amounts.

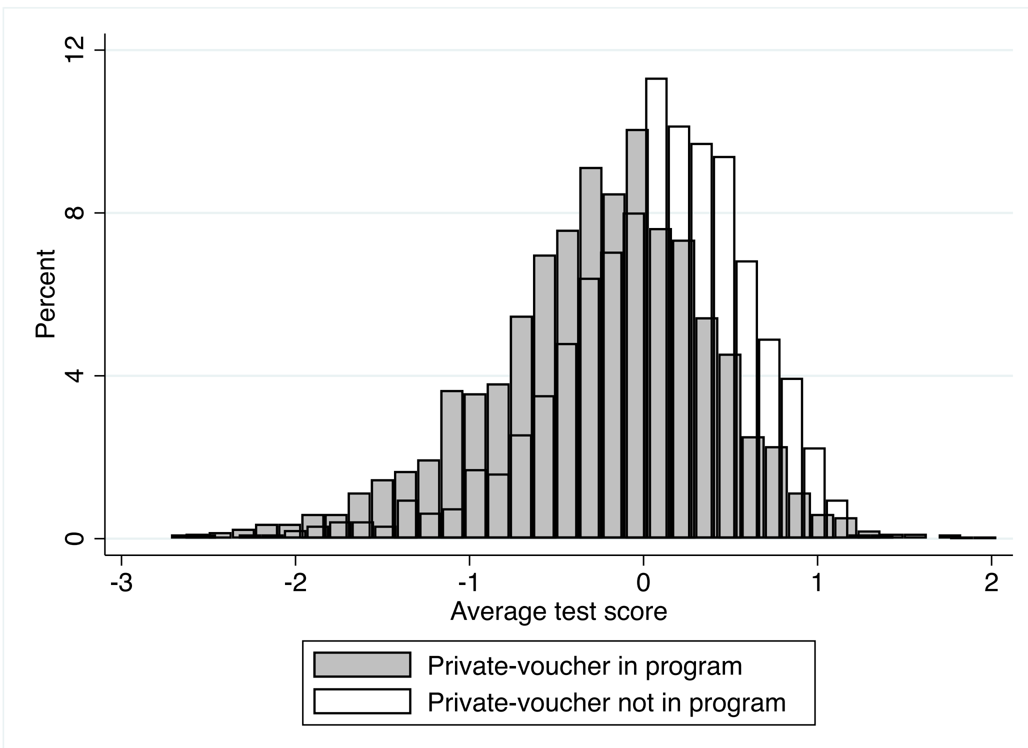
Figure 3.7: Annual (Full) Tuition Distribution for Private-voucher Schools



Notes: Full tuition refers to the tuition paid by non-disadvantaged students. Tuition levels are in real prices using 2013 as the base year, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

Figure 3.8 presents the distribution of private-voucher schools' average test scores in the 4th grade mathematics standardized exam, disaggregated by whether schools participate in the targeted voucher program or not. We observe three important patterns. First, there is high heterogeneity in average test scores among schools. This is true for the group of schools that participate in the targeted voucher program, as well as for the group of schools that opted out. Second, the distribution for schools that don't participate in the targeted voucher program is more left-skewed than the distribution for schools participating in the program, which translates into a higher proportion of schools with high test scores in the former group. Finally, there is a good amount of overlapping between the two distributions, suggesting that, even though, on average, students in schools not participating in the targeted voucher program achieve higher test scores than students in the other group of schools, this is not necessarily the case on a school-by-school basis.

Figure 3.8: Average Test Score Distribution for Private-voucher Schools



Notes: School's average test score is the average score in the mathematics standardized test for 4th grade students enrolled in the school. Test scores are standardized to have mean zero and standard deviation one at the student level.

3.4 A Demand and Supply Model of Elementary Schools

I develop and estimate a structural model of demand and supply of schools for Chile's elementary education. There exist several education markets that are geographically separated one from another. Each market is populated by households that live in different locations within the market, and that have children who are eligible for attending elementary school. Given its budget constraint, each household chooses among the schools available in the market.

There are three different types of schools: public, private-voucher, and private-non-voucher. In each market, schools are located in different geographic areas within the market. Location decisions are assumed to be exogenous. Public schools are mandated to be tuition free, private-voucher schools are allowed to charge tuition, and private-non-voucher schools charge relatively high levels of tuition. Public and private-voucher schools receive a flat per-student subsidy voucher (i.e. universal voucher). In addition, a complementary subsidy program is available for public and private-voucher schools: a targeted voucher to disadvantaged students. This targeted program is mandatory for public schools, and is optional for private-voucher schools. The targeted voucher program adds extra per-pupil funds of about 50% over the universal voucher for every disadvantaged student that the school enrolls, with the requirement of charging zero tuition to those students. Thus, each private-voucher school that chooses to participate in the targeted voucher program must charge zero tuition to disadvantaged students, but can charge any amount to non-disadvantaged. In contrast, private-voucher schools that opt out charge a unique level of tuition to all students, regardless of whether the student is disadvantaged or non-disadvantaged. Private-non-voucher schools do not receive any subsidy.

3.4.1 Demand

I assume that students have heterogeneous preferences over schools' tuition, geographical proximity (i.e. distance from home to school), a set of schools' fixed characteristics, such as whether the school is public or private, its religious orientation, etc., and a measure of schools' quality. I capture heterogeneity in preferences with a set of random coefficients that vary over students' observed demographic characteristics. Formally, in each market, student $i \in \{1, \ldots, I\}$ chooses the school $j \in \{1, \ldots, J\}$ that maximizes her utility. I specify the student's conditional indirect utility by:[13]

$$U_{ij} \quad = \quad \beta_{1i}^{\zeta} p_j^{\zeta} + \beta_2^{\zeta} d_{ij} + \beta_3^{\zeta\prime} X_j + \beta_4^{\zeta} q_j + \xi_j^{\zeta} + \varepsilon_{ij} \tag{3.1}$$

where p_j^{ζ} is school j's tuition charged to student i, d_{ij} is distance from student i's home to school j, X_j is a vector of school j's characteristics, q_j is school j's quality, and ε_{ij} is an i.i.d. preference shock. The superscript ζ refers to the type of the student, i.e. disadvantaged or non-disadvantaged. Also, for any $\beta^{\zeta} \in \{\beta_2^{\zeta}, \beta_3^{\zeta}, \beta_4^{\zeta}, \xi_j^{\zeta}\}$, we have $\beta^{\zeta} = D_i \beta^D + (1 - D_i)\beta^{nonD}$, where $D_i = \mathbb{1}[i \text{ is disadvantaged}]$. Similarly, $\beta_{1i}^{\zeta} = D_i \beta_{1i}^D + (1 - D_i)\beta_{1i}^{nonD}$, where $\beta_{1i}^D = \beta_1^D + \sum_r z_{ir} \beta_{1r}^D$ and $\beta_{1i}^{nonD} =$

[13] My model's demand specification follows the standard assumptions in the education literature, and in particular those in Gallego and Hernando (2009), Gazmuri (2015), Arcidiacono et al. (2016), Cuesta et al. (2017), Ferreyra and Kosenok (2017), and Neilson (2017).

$\beta_1^{nonD} + \sum_r z_{ir}\beta_{1r}^{nonD}$, with z_{ir} a demographic characteristic.

Note that the tuition that school j charges to student i, p_j^ζ, depends on whether the student is disadvantaged, and on whether the school participates in the targeted voucher program. Specifically,

$$p_j^\zeta = (1 - D_i\tau_j)p_j,$$

where $\tau_j = \mathbb{1}[j \text{ participates in targeted program}]$, and p_j is school j's full tuition level.

Let $V_{ij} = \beta_{1i}^\zeta p_j^\zeta + \beta_2^\zeta d_{ij} + \beta_3^{\zeta'} X_j + \beta_4^\zeta q_j + \xi_j^\zeta$. Then, $U_{ij} = V_{ij} + \varepsilon_{ij}$. Assuming $\varepsilon_{ij} \sim$ Type I Extreme Value, the probability that student i chooses school j is logistic:

$$P_{ij} = \frac{e^{V_{ij}}}{\sum_k e^{V_{ik}}}.$$

3.4.2 Supply

Public, private-voucher, and private-non-voucher schools are differentially affected by the institutional aspects of the voucher subsidies. I am interested in the effect that voucher policies have on schools' decisions to participate in the targeted voucher program, and on their tuition levels. Therefore, I focus only on private-voucher schools' decisions, given that all public schools participate in the targeted voucher program and are not allowed to charge tuition, and private-non-voucher schools are not directly affected by the vouchers.

I assume that private-voucher schools make decisions on whether to participate in the targeted voucher program, and on their tuition level, given their expectations of other schools' decisions, demand, and the realization of a cost structure, that consists of a marginal cost of educating a student and a fixed cost of participating in the targeted voucher program. I further assume that private-voucher schools are profit seekers, a reasonable assumption for the context, and common in the literature (Urquiola and Verhoogen, 2009; Barrera-Osorio et al., 2017; Neilson, 2017).

More formally, school j incurs in a marginal cost of c_j for delivering education to a student, which may vary depending on whether the student is disadvantaged or non-disadvantaged.[14] This marginal cost includes extra spending in teaching hours, staff remuneration, utilities' bills, etc., that are associated to the education of an additional student. I assume that schools observe each other's marginal costs when they make their choices, i.e. marginal costs are public information. In addition, school j incurs in a fixed cost of κ_j for participating in the targeted voucher program. This fixed cost includes administrative efforts related to dealing with an additional source of subsidy (i.e. bureaucracy), perceived costs associated to increased monitoring by the government, as well as school's own preference for serving (or not) disadvantaged students. Further, I assume that the fixed cost is observed only by the school itself, but not by its competitors, i.e. it is private information. In contrast to marginal costs, which are primarily driven by observable costs for homogeneous inputs, fixed costs may depend on the intrinsic efficiency of each school's processes, the strategic decisions it makes, as well as its own preference for participating in the

[14]It is reasonable to believe that educating a disadvantaged student, that is highly likely to come from a vulnerable and at-risk family, may involve more educational efforts than educating a non-disadvantaged student, who presumably enjoys of a richer and more stimulating environment at home.

program, all of which are generally unobserved to the other schools.

Thus, private-voucher school j chooses its program participation and tuition level to maximize expected profits:

$$\max_{\tau_j \in \{0,1\}, p_j \geq 0} \quad E[\Pi_j] \quad = \quad E_{\tau_{-j}} \Bigg[(p_j + v^u - c_j^{nonD}) \sum_i (1 - D_i) P_{ij}(\cdot) \\ + \tau_j (v^u + v^t - c_j^D) \sum_i D_i P_{ij}(\cdot) - \tau_j \kappa_j \\ + (1 - \tau_j)(p_j + v^u - c_j^D) \sum_i D_i P_{ij}(\cdot) \Bigg]$$

where τ_j is school j's decision to join the targeted voucher program, and v^u and v^t are the universal and targeted voucher subsidies, respectively. To simplify notation, I suppress $(p_1, \ldots, p_J; \tau_1 \ldots, \tau_J)$ as arguments of P_{ij}. Note, too, that the expectation is taken with respect to the other schools' program participation decisions, τ_{-j}.

The expression for school j's expected profits consists of three parts. The first part is the profits obtained for educating non-disadvantaged students, where for each of those students the school perceives the tuition they charge, p_j, the universal voucher, v^u, and incurs in a marginal cost c_j^{nonD}. The second part is the profits obtained for educating disadvantaged students in the case that the school joins the targeted program, where for each disadvantaged student the school perceives the universal and targeted vouchers, $v^u + v^t$, and incurs in a marginal cost c_j^D. Notice that c_j^D is generally different from c_j^{nonD}. The school also pays the fixed cost τ_j for participating in the targeted program. Finally, the third part is the profits obtained for educating disadvantaged students in the case that the school opts out of the targeted program, where for each disadvantaged student the school perceives the tuition it charges, p_j, the universal voucher, v^u, and incurs in a marginal cost c_j^D.

Implicit in my description of schools' objective function is the fact that schools do not present different marginal costs across regimes. That is, they do not become more or less efficient in the delivery of education by joining the program. The reason for making this assumption is that, if we assume that disadvantaged and non-disadvantaged students involve different education costs, then different marginal costs across regimes are not longer identifiable from the data, as I show below. On the contrary, if we assume that disadvantaged and non-disadvantaged students involve the same marginal costs, then different marginal costs across regimes can be identified. I find the former interpretation more plausible for the Chilean context, where there is a perceived higher cost of educating students from more vulnerable backgrounds (Fontaine and Urzúa, 2018); however, I do not rule out the latter.

The solution to schools' optimization problem is not trivial for several reasons. First, it involves both a discrete variable and a continuous variable to maximize over. Second, the continuous variable, p_j, is constrained to be non-negative, and therefore may result in a corner solution in the optimum. Third, the objective function depends on other schools' decisions through the $P_{ij}(\cdot)$ terms (i.e. it is a game).

Consider the optimality conditions for p_j, and ignore the expectation over other schools' participation decisions for a moment. If the school participates in the targeted program (i.e. $\tau_j = 1$), the Kuhn-Tucker first-order conditions for tuition are:

$$p_{j|\tau_j=1}(\tau_{-j}, p_{-j}) \quad \leq \quad c_j^{nonD} - v^u - \frac{\sum_i (1-D_i) P_{ij}(\cdot)}{\sum_i (1-D_i) \frac{\partial P_{ij}(\cdot)}{\partial p_j}},$$

$$p_{j|\tau_j=1}(\tau_{-j}, p_{-j}) \frac{\partial \Pi_{j|\tau_j=1}}{\partial p_j} = 0, \text{ and } p_{j|\tau_j=1}(\tau_{-j}, p_{-j}) \geq 0,$$

where the first equation is the profits' derivative with respect to tuition being less than or equal to zero, the second equation is the complementary slackness, and the last equation is the non-negativity constraint. Also, (τ_{-j}, p_{-j}) is the vector containing all other schools' program participation and tuition decisions. From the first equation, we observe that the universal voucher drives down the tuition charged by the school. In other words, the larger the universal voucher, the lower the level of tuition set by the school, all else equal. The last term on the right-hand side in the first equation represents the markup relative to the marginal cost and the universal voucher that schools can charge because of their market power. This markup is smaller the more price-sensitive the demand is. Notice that the markup term depends only on the demand of non-disadvantaged students. This is so because the school is required not to charge tuition to disadvantaged students in the case the school joins the targeted voucher program. This institutional feature allows the identification of school j's marginal cost for educating non-disadvantaged students, c_j^{nonD}.[15]

[15] Strictly speaking, c_j^{nonD} is identified only for schools charging positive tuition. In the empirical implementation of the model, I make functional assumptions that allow me to infer costs for schools with a binding non-negativity constraint. Same rationale applies to the identification of $c_j^{D\&nonD}$ below.

The Kuhn-Tucker first-order conditions for tuition, in the case that the school opts out of the targeted voucher program (i.e. $\tau_j = 0$) are:

$$p_{j|\tau_j=0}(\tau_{-j}, p_{-j}) \leq c_j^{D\&nonD} - v^u - \frac{\sum_i P_{ij}(\cdot)}{\sum_i \frac{\partial P_{ij}(\cdot)}{\partial p_j}},$$

$$p_{j|\tau_j=0}(\tau_{-j}, p_{-j}) \frac{\partial \Pi_{j|\tau_j=0}}{\partial p_j} = 0, \text{ and } p_{j|\tau_j=0}(\tau_{-j}, p_{-j}) \geq 0.$$

Here, the markup term in the first equation depends on the demand of all students, because school j's tuition is charged to everybody, regardless of whether the student is disadvantaged or non-disadvantaged. For this reason, I can identify school j's marginal cost of educating both disadvantaged and non-disadvantaged students, $c_j^{D\&nonD}$.

Notice that I emphasize the dependency of the optimal tuition on the program participation decisions of all schools in the market, $\tau = (\tau_1, \ldots, \tau_J)$. This implies that there is potentially a different set of optimal tuition levels for every different market configuration.

Now, consider the optimality conditions for school j's program participation decision, τ_j:

$$\tau_j = \mathbb{1}\left\{E_{\tau_{-j}}\left[\Pi_{j|\tau_j=1}(\tau_{-j}, p(\tau_{-j})) - \Pi_{j|\tau_j=0}(\tau_{-j}, p(\tau_{-j}))\right] - \kappa_j > 0\right\},$$

which simply states that school j joins the targeted program if and only if the expected profits of joining the program net of the program participation costs are greater than the expected profits of not joining the program.

As it is, this problem is theoretically solvable. However, in practice, it proves to be computationally intractable. The main reason for this intractability comes from the need of computing a different equilibrium set of tuitions for each possible market configuration. And, considering that urban education markets in Chile include tens, and sometimes hundreds of private-voucher schools, the problem quickly becomes computationally expensive as the number of schools grows. For instance, in a market with 10 private-voucher schools, there are 1,024 different market configurations. In a market with 20 private-voucher schools, there are 1,048,576 different market configurations.[16]

To overcome such practical difficulties, I adapt the concept of *Oblivious Equilibrium* (Weintraub et al., 2008) to my setting.

3.4.2.1 Oblivious Equilibrium

Oblivious equilibrium (OE) was initially introduced by Weintraub et al. (2008) to facilitate the computation of equilibria in dynamic games of imperfect competition in industries with a large number of firms. It constitutes an approximation to full-solution equilibria (i.e. Markov perfect equilibria), but it has been shown to accurately mimic the full-solution results, with approximation errors that quickly decay as the number of firms in the industry grows (Weintraub et al., 2008, 2010; Xu, 2008; Qi, 2013). OE in dynamic settings assumes that firms make their decisions by taking into account the long-run equilibrium of the game, in lieu of the period-

[16] More generally, in a market with J private-voucher schools, there is a total of 2^J different possible market configurations.

by-period equilibrium. Thus, firms ignore the contemporaneous effect of their own actions on their competitors' actions, as well as the contemporaneous effect of their competitors' actions on the firms' own actions.

I adapt the concept of OE to my setting as follows. I assume that each school makes decisions based only on its own type (i.e. realization of its fixed cost) and a belief of the expected equilibrium in the market. This is different from a full-solution equilibrium, in this context a Bayesian Nash equilibrium, in that the assumption implies that schools' competitors actions do not directly affect schools' own actions, but only through the expected equilibrium's belief, and likewise schools' own actions only affect their competitors' actions through their competitors' belief about the expected equilibrium.

I further define a sufficient statistic that summarizes the market's expected equilibrium, which I assume schools use to base their decisions on. I denote this sufficient statistic as γ_{ij}, where γ_{ij} is such that,

$$\tilde{P}_{ij} = \frac{e^{V_{ij}}}{e^{V_{ij}} + E_{\tau_{-j}}\left[\sum_{k \neq j} e^{V_{ik}(\tau_k)}\right]} = \frac{e^{V_{ij}}}{e^{V_{ij}} + \gamma_{ij}}.$$

Thus, school j's belief of the expected equilibrium consists in the vector $\gamma_j = (\gamma_{1j}, \ldots, \gamma_{Ij})$.

A vital criterion for an OE is that schools' beliefs be *consistent*. In other words, when schools have consistent beliefs about the expected equilibrium, the choices they make result in an equilibrium that is consistent with those beliefs. More formally,

$$\bar{\gamma}_{ij} \;=\; \sum_{k\neq j}\left\{u_k(\bar{\gamma})e^{V_{ik}(\tau_k=1)}+\left(1-u_k(\bar{\gamma})\right)e^{V_{ik}(\tau_k=0)}\right\}, \tag{3.2}$$

where $\bar{\gamma}=(\bar{\gamma}_1,\ldots,\bar{\gamma}_J)$ is the set of schools' consistent beliefs, and $u_j(\bar{\gamma})=Pr(\tau_j=1;\bar{\gamma})$ is school j's oblivious program participation probability when it has consistent beliefs $\bar{\gamma}$.

Equation (3.2) defines a fixed-point for $\bar{\gamma}$, i.e. $\bar{\gamma}=\Gamma(\bar{\gamma})$. I solve for this fixed-point by using the following iterative algorithm:

1. Start with an initial value, $\bar{\gamma}^0$.

2. Compute the optimal tuition levels and profits for both the cases when the school joins the program and when the school opts out, given the school's beliefs.

3. Compute the probability that the school joins the program, using the calculated profits and the realization of the fixed cost.

4. Compute a new value for the schools' beliefs, $\bar{\gamma}^1$, following equation (3.2).

5. Compare $\bar{\gamma}^1$ with $\bar{\gamma}^0$. If $\bar{\gamma}^1$ is sufficiently close to $\bar{\gamma}^0$, stop. Otherwise, update $\bar{\gamma}^0=\bar{\gamma}^1$, and go back to step 2.

Alogirthm 1 below describes the algorithm in more detail.

Algorithm 1 Oblivious Equilibrium Solver

$\gamma_{ij}^0 = 0$; $\gamma_j^0 = (\gamma_{1j}^0, \ldots, \gamma_{Ij}^0)$
$\Delta = 100$
$tol = 1e - 6$
while $\Delta > tol$ **do**
  $p^*_{j|\tau_j=1} = \text{argmax}_p\, \Pi_{j|\tau_j=1}(p, \gamma_j^0)$; $\quad p^*_{j|\tau_j=0} = \text{argmax}_p\, \Pi_{j|\tau_j=0}(p, \gamma_j^0)$
  $u_j(\gamma_j^0) = Prob\left(\Pi_{j|\tau_j=1}(p^*_{j|\tau_j=1}, \gamma_j^0) - \Pi_{j|\tau_j=0}(p^*_{j|\tau_j=0}, \gamma_j^0) > \kappa_j\right)$
  $\gamma_{ij}^1 = \sum_{k \neq j} \left\{u_k(\gamma_k^0) e^{V_{ik}(\tau_k=1)} + (1 - u_k(\gamma_k^0))\, e^{V_{ik}(\tau_k=0)}\right\}$; $\quad \gamma_j^1 = \left(\gamma_{1j}^1, \ldots, \gamma_{Ij}^0\right)$
  $\Delta = \max_{(ij)} |\gamma_{ij}^1 - \gamma_{ij}^0|$
  $\gamma_j^0 = \gamma_j^1$
end while

Note that uniqueness of equilibrium in this game is not guaranteed. However, I investigate the prevalence of multiple equilibria numerically, by computing the number of oblivious equilibria that arise from a large grid of starting values for $\bar{\gamma}$. At the estimated parameters, I find that there is always a unique equilibrium.

With all this in hand, I define an *Oblivious Equilibrium* for this static game as a set of oblivious participation probabilities, $(u_1(\bar{\gamma}), \ldots, u_J(\bar{\gamma}))$, and tuitions, $(p_1(\bar{\gamma}), \ldots, p_J(\bar{\gamma}))$, such that schools' profits are maximal given their beliefs about the expected equilibrium, and that schools' beliefs are consistent.[17]

3.4.3 Estimation and Identification

I estimate the model's parameters sequentially. First, I obtain the demand parameters. Then, given the demand parameters, I estimate the parameters that enter the marginal cost and the fixed cost of participating in the targeted voucher program.

[17] Notice that, despite the desirable properties of OE, this application of the concept of OE consists in one of the very few in the literature (see, e.g., Xu, 2008; Qi, 2013).

3.4.3.1 Demand

A key school characteristic in the demand model is school's quality. This variable is essentially unobservable, and is usually captured by the school fixed effects, ξ_j, in standard models. However, in an effort to be able to say something about students' preferences for quality, I follow Arcidiacono et al. (2016), and use test scores data to recover a proxy measure of schools' quality (or schools' test scores productivity). Specifically, I estimate the following regression model:

$$y_{ij} = \alpha_1' x_i + \alpha_2' X_j + q_j + \upsilon_{ij}, \tag{3.3}$$

where y_{ij} is the test score of student i in school j, x_i is a vector of student's observed characteristics, X_j is a vector of school's observed characteristics, q_j is school j's unobserved quality, and υ_{ij} is an idiosyncratic error term. I proceed in two steps for estimation. In the first step, I estimate

$$y_{ij} = \alpha_1' x_i + \rho_j + \upsilon_{ij}.$$

In the second step, I use the estimated $\hat{\rho}_j$ to recover α_2 and q_j, by estimating

$$\hat{\rho}_j = \alpha_2' X_j + q_j.$$

The residual of this second step equation is my estimated measure for the unobserved quality of the school, $\hat{q}_j = \hat{\rho}_j - \hat{\alpha}_2' X_j$. I additionally use a measure of school's "teachers quality", which I define by the cross product of the subset of school's observed characteristics that relate to teachers (e.g. teachers' experience, % teachers with specialization, % female teachers, etc.) and the corresponding subset of $\hat{\alpha}_2$ estimated coefficients.

With the estimated measures of schools' quality in hand, I proceed to estimate demand parameters following Goolsbee and Petrin (2004) and Hackmann (2015). The estimation is done in two steps. First, I use Maximum Likelihood to estimate distance and preference parameters capturing taste heterogeneity in mother's education. In the second step, I recover the remaining "average" preference parameters by two stages least squares (2SLS).

First Step.

I use Maximum Likelihood to estimate preference for proximity, taste heterogeneity in mother's education level, and mean utilities, δ_j^{ζ}. Note that mean utilities vary at the school-student type level, and absorb the remaining preference components from the indirect utility function:

$$\delta_j^{\zeta} = \beta_1^{\zeta} p_j^{\zeta} + \beta_3^{\zeta'} X_j + \beta_4^{\zeta} q_j + \xi_j^{\zeta}$$

The corresponding log-likelihood function is:

$$LL(\beta) = \sum_i \sum_j e_{ij} \ln \left(\frac{\exp\left(\beta_{1i}^{\zeta} p_j^{\zeta} + \beta_2^{\zeta} d_{ij} + \delta_j^{\zeta}\right)}{\sum_k \exp\left(\beta_{1i}^{\zeta} p_k^{\zeta} + \beta_2^{\zeta} d_{ik} + \delta_k^{\zeta}\right)} \right),$$

where e_{ij} is the choice indicator.

Second Step.

I use the estimated $\hat{\delta}_j^\zeta$ terms from the first step to estimate the remaining mean preference parameters in a linear regression of the form:

$$\hat{\delta}_j^\zeta \quad = \quad \beta_1^\zeta p_j^\zeta + \beta_3^{\zeta\prime} X_j + \beta_4^\zeta q_j + \xi_j^\zeta. \tag{3.4}$$

As is usual in demand models, I assume that X_j is uncorrelated with ξ_j. However, p_j^ζ is potentially endogenous. Thus, I estimate equation (3.4) by 2SLS, using BLP-type of instruments for tuition (Berry et al., 1995).

Identification is ensured as long as the variables used to instrument for tuition are valid instruments (i.e. are correlated with the endogenous variable, but not with the preference shock). I follow Berry et al. (1995) and use non-price attributes of all other schools in the market. The intuition behind these instruments is that we believe (and according to the supply side of the model) that schools make their program participation and tuition decisions by taking into account their competitors' characteristics, but that the utility that a student gets from attending a given school does not depend on the other schools' characteristics. In practice, I use the sum of other schools' pupil-teacher ratio, the sum of other schools' quality measures, and the percentage of public schools in the market to create the instruments.[18]

[18]Results using means instead of sums for the instruments are similar to the ones I report below. Conceptually, instruments using sums incorporate variation coming from both other schools' characteristics and markets' size, whereas instruments using means incorporate variation coming only from other schools' characteristics.

3.4.3.2 Supply

I use the demand estimates and schools' optimality conditions to estimate the marginal and fixed costs parameters. I parameterize the marginal cost c_j as follows:

$$c_j = X_j\omega_1 + \epsilon_j,$$

where ϵ_j is an idiosyncratic shock . I can then write down the latent tuition function to be estimated as:

$$p_j^* \;\; = \;\; c_j(\omega) - v^u - m_j(\hat{\beta}; d_j) + \epsilon_j,$$

where $m_j(\hat{\beta}; d_j)$ corresponds to the (estimated) markup term in the first-order conditions.[19] Observed tuition is,

$$p_j = \begin{cases} p_j^* & \text{if } p_j^* > 0 \\ 0 & \text{if } p_j^* \leq 0. \end{cases}$$

I assume $\epsilon_j \sim N(0, \sigma_\epsilon^2)$, which implies the model is a Type 1 Tobit (Tobin, 1958; Amemiya, 1985).

Similarly, I parameterize $\kappa_j = W_j\lambda + \nu_j$, where W_j is a vector of variables affecting the fixed cost, and $\nu_j \sim N(0, \sigma_\nu^2)$. This allows me to specify a probit model for the decision to participate in the targeted voucher program.

[19] Specifically, $m_j(\hat{\beta}; \tau_j) = \tau_j \frac{\sum_i (1-D_i) P_{ij}(\cdot;\hat{\beta})}{\sum_i (1-D_i) \frac{\partial P_{ij}(\cdot;\hat{\beta})}{\partial p_j}} + (1-\tau_j) \frac{\sum_i P_{ij}(\cdot;\hat{\beta})}{\sum_i \frac{\partial P_{ij}(\cdot;\hat{\beta})}{\partial p_j}}$.

I estimate the costs parameters using a GMM procedure coupled with a nested fixed-point (NFXP) algorithm that solves for markets' equilibria at every iteration of the parameters in the optimization routine. The moments I use are the difference between schools' predicted and actual program participation and tuition decisions.[20]

3.5 Results

I present evidence for 28 geographic markets from Chile for the year 2013, which consists in data for 662,327 elementary school students and 2,224 schools (959 public, 1,110 private-voucher, 155 private-non-voucher).[21]

Tables 3.5 and 3.6 present summary statistics for the variables used in estimation. Table 3.5 describes variables at the student level. On average, a student travels 3.05 km. to her school of choice. 53% of students are disadvantaged, and 51% are male. Almost two thirds of students have a computer at home, while half of them have internet connection. More than a quarter of students have less than 9 books at home, while only 15% of them have more than 51 books at home. The majority of students attended some form of preschool education. More than a quarter of students' mothers don't have a secondary education degree, and only 16% of students' mothers have a college degree. A similar pattern is observed for fathers' education. Finally, more than half of students live in households with a total monthly income below $740.02, and only 7% of students live in households with a total monthly

[20] A proper correction for standard errors should be used to account for the fact that demand estimates are used as inputs in the supply estimation procedure. Bootstrap is an option. The results I show below do not include corrected standard errors.

[21] For the moment, I am not using data from the market that corresponds to Santiago, the nation's capital city.

income of $1,902.91 or higher.

Table 3.5: Summary Statistics - Student Level

	mean	std. dev.	median
distance to school of choice (km.)	3.05	9.49	1.39
disadvantaged	0.53	0.50	1.00
male	0.51	0.50	1.00
computer at home	0.64	0.48	1.00
internet at home	0.49	0.50	0.00
no. of books at home: 0	0.03	0.17	0.00
no. of books at home: 1–9	0.25	0.43	0.00
no. of books at home: 10–50	0.39	0.49	0.00
no. of books at home: 51–100	0.10	0.30	0.00
no. of books at home: 100 or more	0.05	0.21	0.00
no. of books at home: missing	0.18	0.39	0.00
attended day care	0.13	0.34	0.00
attended pre-kindergarten level 1	0.53	0.50	1.00
attended pre-kindergarten level 2	0.73	0.44	1.00
attended kindergarten	0.82	0.39	1.00
mother's education: none	0.08	0.26	0.00
mother's education: primary	0.20	0.40	0.00
mother's education: secondary	0.39	0.49	0.00
mother's education: college	0.16	0.36	0.00
mother's education: missing	0.18	0.38	0.00
father's education: none	0.07	0.26	0.00
father's education: primary	0.20	0.40	0.00
father's education: secondary	0.36	0.48	0.00
father's education: college	0.15	0.35	0.00
father's education: missing	0.22	0.41	0.00
household's monthly income: $317.15 or less	0.23	0.42	0.00
household's monthly income: $317.15–$740.02	0.31	0.46	0.00
household's monthly income: $740.02–$1,902.91	0.22	0.41	0.00
household's monthly income: $1,902.91 or more	0.07	0.25	0.00
household's monthly income: missing	0.18	0.38	0.00

Notes: All variables are at the student level, for the sample used in estimation. Income levels are in real prices using 2013 as the base year, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

Table 3.6 presents summary statistics for variables at the elementary school level. On average, private (voucher and non-voucher) schools charge $943.15 per year. Two thirds of private-voucher schools participate in the targeted voucher program. 43% of schools are public, half of schools are private-voucher, and only 7% of schools are private-non-voucher. Also, a fifth of schools are located in a rural area, and half of schools are considered to follow a secular orientation. The average years of experience of teachers in schools is, on average, 12.69 years. Schools tend to hire teachers with both a degree in education and a college degree. Teachers with specialization or with a 10 or more semesters degree are relatively scarce in schools. Finally, schools hire mainly female teachers.

Table 3.6: Summary Statistics - School Level

	mean	std. dev.	median
annual tuition (private schools)	943.15	1805.32	182.24
participates in targeted voucher program (private-voucher schools)	0.66	0.47	1.00
public	0.43	0.50	0.00
private-voucher	0.50	0.50	0.00
private-non-voucher	0.07	0.25	0.00
rural	0.20	0.40	0.00
secular	0.50	0.50	0.00
average teachers' experience	12.69	5.67	12.35
% teachers with a degree not in education	0.03	0.06	0.00
% teachers with a college degree	0.92	0.11	0.94
% teachers with a long-term contract	0.51	0.25	0.50
% teachers with specialization	0.48	0.20	0.47
% teachers with a 10+ semesters degree	0.38	0.29	0.33
% female teachers	0.75	0.16	0.76

Notes: All variables are at the school level, for the sample used in estimation. Tuition levels are in real prices using 2013 as the base year, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

3.5.1 Demand Estimates

Tables 3.7 and 3.8 present the results of estimating the test scores equation (3.3). Table 3.7 shows the estimated coefficients for the first step, in which the student level test scores are regressed on a set of student characteristics and school fixed-effects.[22] The results are in line with the existing related evidence (see, for example, Neilson, 2017, and Rau et al., 2018). In particular, male students perform worse than females.[23] Disadvantaged students score lower than non-disadvantaged. More resources at home (e.g. computer, internet, books) generally increases students' test scores. Surprisingly, attending preschool lowers students' test scores. The higher the level of parents' education, the higher the test score of the student. Similarly, more financial resources in the household increase students' academic performance.

[22]The test score variable used as dependent variable in this regression corresponds to the average of student's math and verbal scores. As I mentioned above, this variable is normalized to have mean zero and standard deviation one.

[23]Rau et al. (2018) show that the gender effect varies depending on the subject tested. More precisely, 8th grade Chilean females outperform males in verbal, but the opposite occurs in math, social sciences, and natural sciences. They also show that the female effect in verbal is significantly stronger than the male effect in any of the other three subjects, which may explain the negative effects for males that Neilson (2017) and this paper find when averaging math and verbal scores.

Table 3.7: Test Scores Regressions - Step 1

variable	coef.	std. err.
male	-0.057***	0.005
disadvantaged	-0.053***	0.005
computer at home	0.024***	0.008
computer at home: missing	-0.052***	0.017
internet at home	-0.006	0.007
internet at home: missing	-0.076***	0.011
no. books at home: 0	0.044***	0.014
no. books at home: 10–50	0.111***	0.014
no. books at home: 51–100	0.180***	0.016
no. books at home: more than 100	0.253***	0.017
no. books at home: missing	0.160***	0.027
attended day care	-0.018***	0.007
attended day care: missing	-0.007	0.023
attended prekindergarten level 1	-0.049***	0.005
attended prekindergarten level 1: missing	-0.107***	0.026
attended prekindergarten level 2	0.002	0.008
attended prekindergarten level 2: missing	-0.017	0.031
attended kindergarten	0.047*	0.026
attended kindergarten: missing	0.047	0.043
mother's education: primary	0.029***	0.010
mother's education: secondary	0.129***	0.010
mother's education: college	0.151***	0.012
father's education: missing	0.040*	0.021
father's education: primary	0.039***	0.010
father's education: secondary	0.098***	0.010
father's education: college	0.145***	0.012
father's education: missing	0.091***	0.014
household's monthly income: $317–$740	0.025***	0.007
household's monthly income: $740–$1,903	0.051***	0.008
household's monthly income: $1,903 or more	0.082***	0.012
household's monthly income: missing	0.097***	0.023
constant	-0.305***	0.030
R-squared	0.272	

Notes: Estimated coefficients from test scores regressions at the student level. School fixed-effects are included. * denotes significance at the 90% level, ** denotes significance at the 95% level, *** denotes significance at the 99% level.

Table 3.8 shows the results for the second step of the estimation procedure of the test scores equation (3.3), which uses the school fixed-effects estimated in the first step, and regresses them on a set of schools' observed characteristics. Public and private-voucher schools are associated with a low contribution to test scores, relative to private-non-voucher schools. The coefficients for rural and secular are positive and negative, respectively, but they are both statistically insignificant. Finally, the results for the set of variables that relate to schools' teacher resources suggest that having a staff of teachers that are more qualified, have better work contracts, and are majority female, increases schools' contribution to test scores.

Table 3.8: Test Scores Regressions - Step 2

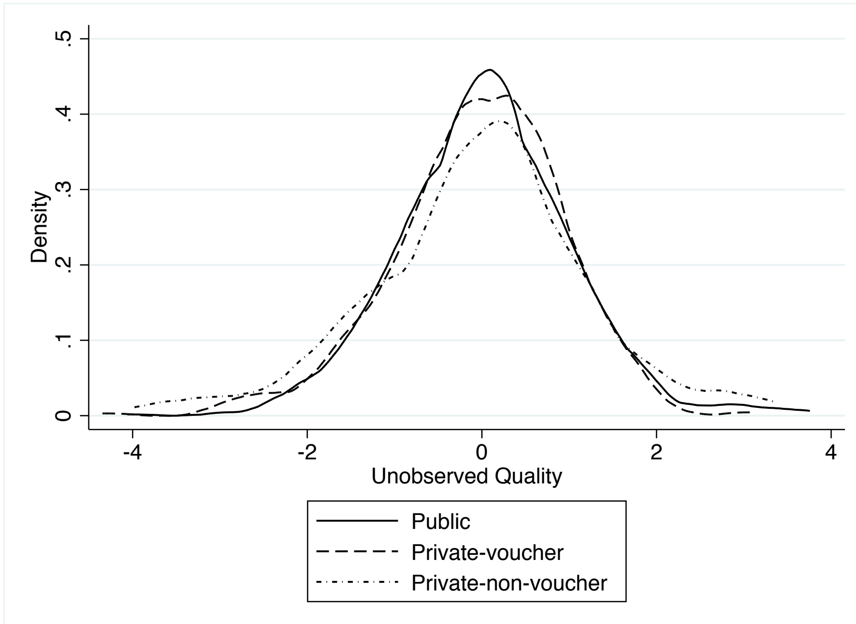
variable	coef.	std. err.
rural	0.014	0.025
public	-0.551***	0.032
private-voucher	-0.437***	0.027
secular	-0.023	0.015
average teachers' experience	-0.003*	0.002
% teachers with a degree not in education	-0.264*	0.145
% teachers with a college degree	0.218***	0.076
% teachers with a long-term contract	0.338***	0.041
% teachers with specialization	0.192***	0.041
% teachers with a 10+ semesters degree	0.182***	0.029
% female teachers	0.253***	0.049
constant	-0.430***	0.107
R-squared	0.245	

Notes: Estimated coefficients from second step of test scores regressions (at the school level). Market fixed-effects are included. * denotes significance at the 90% level, ** denotes significance at the 95% level, *** denotes significance at the 99% level.

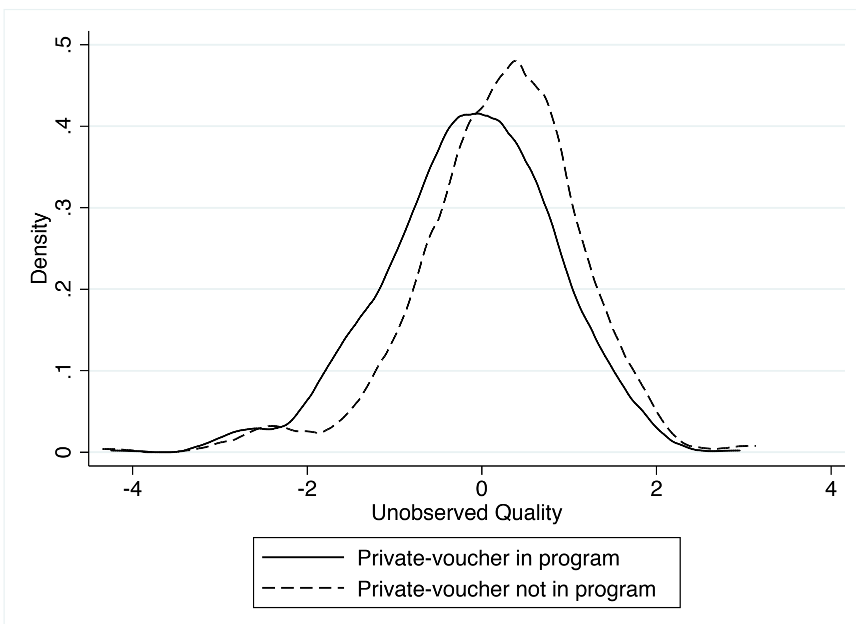
Following the analysis from section 3.4.3.1, I use the estimates from the test scores regressions to construct a measure of schools' unobserved quality. In addition, I construct a measure of schools' teachers quality, which is simply the cross-product of schools' teacher resources and the corresponding estimated coefficients. Figures 3.9 and 3.10 display the distributions of the estimated schools' unobserved and teacher quality, respectively. Panel A in Figure 3.9 presents schools' unobserved quality distribution by schools' administrative type. Unsurprisingly, given the way the unobserved quality was constructed, all school-types present the same distribution mean. This is expected, given that the unobserved quality is the residual of a regression that has the school-types as regressors. A considerable level of heterogeneity is also observed. Panel B supplements this information by showing schools' unobserved quality distribution for private-voucher schools only, distinguishing between schools that do and do not participate in the targeted voucher program. The quality distributions differ one from another, with schools participating in the targeted voucher program presenting a more right-skewed distribution than schools that are not in the program. Figure 3.10 presents schools' estimated teachers quality distributions. Panel A shows the distributions by schools' administrative type. Private-non-voucher schools present the distribution associated to the highest levels of teachers quality, which is followed by private-voucher schools' distribution, and lastly by public schools' distribution. Panel B presents schools' teacher quality distributions for private-voucher schools only, distinguishing between schools that do and do not participate in the targeted voucher program. Consistent with what was observed in Figure 3.9, schools that participate in the program have a teacher quality distribution that is more right-skewed than schools that do not participate in the program.

Figure 3.9: Schools' Unobserved Quality Distribution

A. All Schools



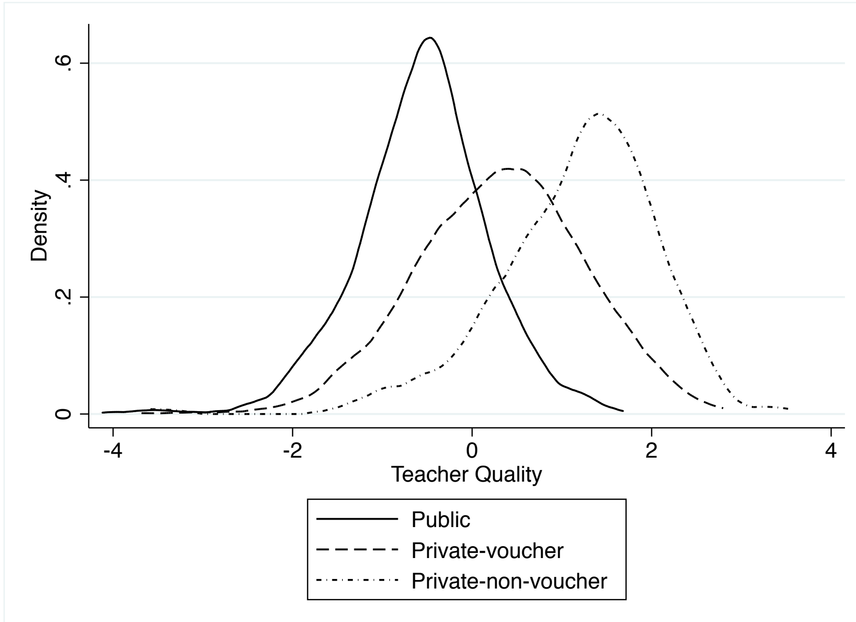
B. Private-voucher Schools



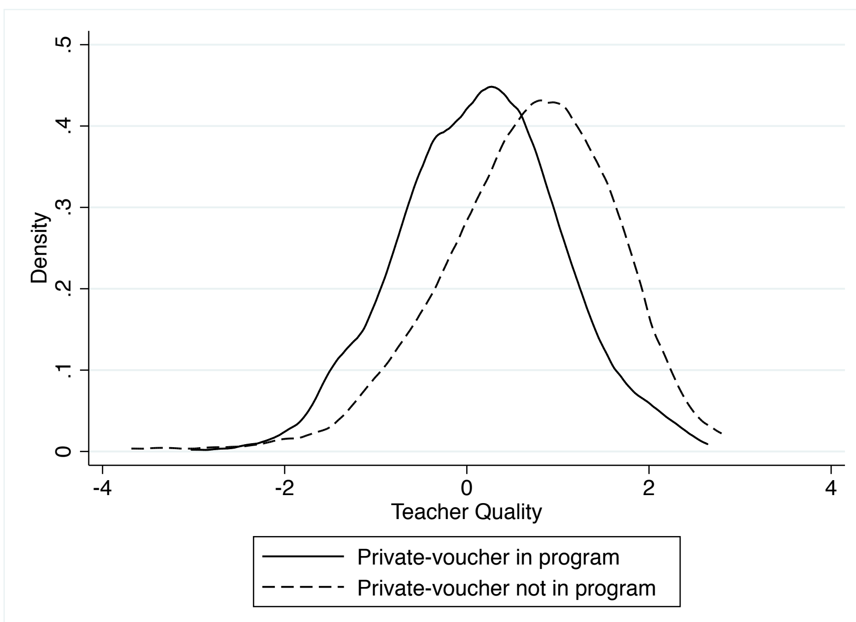
Notes: This figure plots kernel density estimates for the distribution of schools' estimated unobserved quality.

Figure 3.10: Schools' Teacher Quality Distribution

A. All Schools



B. Private-voucher Schools



Notes: This figure plots kernel density estimates for the distribution of schools' estimated teacher quality.

Table 3.9 displays the estimated parameters for the demand model. The table combines estimates from the first (maximum likelihood) and second (2SLS) steps. The omitted mother's level of education category is "not formal education". My estimates are in line with the related literature (e.g. Gallego and Hernando, 2009, Gazmuri, 2015, Cuesta et al., 2017, Neilson, 2017). The estimated "average" parameters for tuition, that correspond to the omitted mother's level of education category of "not formal education", are negative and statistically significant. The preference heterogeneity parameters suggest that children with highly educated mothers are more likely to attend schools with high levels of tuition.[24] Also, disadvantaged students have in general more negative coefficients for tuition, suggesting a greater dislike for higher prices for this group of students.[25] The coefficients on the distance variables suggest an important dislike for long travels from home to school. They also show that preferences are convex with respect to distance. Public schools are less preferred than private schools in both groups of students, as is the case of rural schools relative to urban schools. The opposite is observed for secular schools, relative to religious schools. Finally, students prefer schools of higher quality, although non-disadvantaged students may have stronger preferences for quality than disadvantaged students.

[24]The correct reading of the tuition coefficients for each mother's education group is obtained by adding the "average" coefficient to the coefficient that correspond to the group of interest. For instance, the tuition coefficient for non-disadvantaged students whose mothers have primary education is $-0.177 - 0.095 = -0.272$.

[25]Gazmuri (2015), unlike Gallego and Hernando (2009), Cuesta et al. (2017), Neilson (2017), and this paper, finds positive coefficients in tuition for some groups of students. Her results may be explained by the fact that she does not instrument for tuition, but rather assumes exogeneity of that variable after controlling for other schools' characteristics.

Table 3.9: Estimates for Demand Model

	non-disadvantaged		disadvantaged	
	coef.	std. err.	coef.	std. err.
annual tuition/100	-0.177	0.004	-0.055	0.007
annual tuition/100 × mother's education: primary	-0.095	0.011	-0.196	0.008
annual tuition/100 × mother's education: secondary	0.083	0.010	-0.037	0.002
annual tuition/100 × mother's education: college	0.138	0.010	0.003	0.002
annual tuition/100 × mother's education: missing	0.164	0.010	-0.062	0.004
distance to school/10	-5.023	0.051	-5.267	0.048
distance to school squared/10	0.026	0.002	0.050	0.001
public	-0.631	0.055	-0.073	0.071
rural	-0.657	0.068	-0.988	0.124
secular	0.096	0.046	0.116	0.060
unobserved quality	0.790	0.059	0.336	0.075
teachers quality	3.529	0.285	1.544	0.331
constant	-2.102	0.212	-1.025	0.235

Notes: Results from maximum likelihood estimation of distance and preference heterogeneity by mother's education, and from 2SLS estimation of remaining mean preference parameters. Omitted mother's level of education category is "not formal education". Tuition is instrumented with non-price attributes of other schools in the market in the 2SLS estimation. Tuition amounts are in real prices for the year 2013, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

3.5.2 Supply Estimates

Table 3.10 displays the estimated marginal cost and program participation fixed cost parameters. The results for the marginal cost parameters are the following. Higher quality schools present higher marginal costs. This is true for both measures of quality. More precisely, one standard deviation of higher unobserved quality translates into $27.9 of higher marginal costs. Likewise, one standard deviation of higher teachers quality increases marginal costs by $29.6. Secular schools have on average $12.8 higher marginal costs than religious schools, although the corresponding estimate is not statistically significant. Rural schools have on average \$169.9 lower marginal schools than schools located in urban areas. This is an intuitive result if we believe that rural schools invest less in amenities per student, and that staff and teachers' wages are lower in rural areas than in the city.[26] Lastly, schools that participate in the targeted program have on average \$315.8 lower marginal costs. In other words, the marginal cost of educating non-disadvantaged students is about three hundred dollars lower than the marginal cost of educating both disadvantaged and non-disadvantaged students.[27]

The results for the program participation cost parameters are the following. Higher levels of unobserved and teachers quality are associated with higher levels of participation cost, suggesting that higher quality schools find it more costly to join the targeted voucher program. Specifically, an increase in one standard deviation in schools' unobserved quality increases the cost of participating in the program by \$9,271, although this difference is not statistically significant. Similarly, a one standard deviation increase in schools' teachers quality increases the program participation cost by \$40,578. Secular schools find it more costly to join the targeted voucher program than religious schools, by approximately \$36,337.[28]

[26] There is a long literature that documents the high wages advantage of cities relative to rural areas. See, for instance, Bryan et al. (2014) for a study that investigates the migration behavior of individuals in Bangladesh, motivated by the higher returns to labor found in the cities.

[27] Recall from section 3.4.2 that the marginal cost of educating non-disadvantaged students is identified from schools participating in the targeted program, whereas the marginal cost of educating both disadvantaged and non-disadvantaged students is identified from schools that do not participate in the program.

[28] These results correspond to the interpretation of the program participation cost representing perceived increase in bureaucracy associated to participation and/or school's own preference for participation described in section 3.4.2.

Table 3.10: Estimates for Supply Model

	coef.	std. err.
marginal cost ($100):		
unobserved quality	0.279	0.056
teachers quality	0.296	0.062
secular	0.128	0.103
rural	-1.699	0.284
participates in targeted program	-3.158	0.106
constant	6.123	0.225
σ^2	2.199	0.119
participation cost ($1,000):		
unobserved quality	9.271	6.980
teachers quality	40.578	7.089
secular	36.337	13.005
constant	-146.977	12.241
$\log(\sigma)$	1.650	0.144
no. of private-voucher schools	1,110	

Notes: The first panel reports estimates of marginal cost parameters of a Tobit model for tuition. The model includes market fixed-effects, but those estimates are not reported. The second panel reports estimates of fixed cost parameters of a probit model for participation in the targeted voucher program. The tuition function for the case the school participates in the targeted program differs from the tuition function for the case the school opts out of the program only by the intercept, which is equal to the coefficient for the participation in the program dummy plus the constant for the case the school participates in the program, and only to the constant for the case the school opts out. All marginal and fixed cost parameters were estimated using a GMM procedure coupled with a nested fixed-point algorithm. Costs are in real prices for the year 2013, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

Table 3.11 presents the predicted mean and median marginal and program participation costs for schools, which were constructed using the estimates presented in Table 3.10. The average (median) marginal cost of educating a non-disadvantaged student is $237 ($279), about half as much as the average (median) marginal cost of educating both disadvantaged and non-disadvantaged students, $553 ($595). Also, the average (median) private-voucher school has negative program participation costs, of about $-\$158,000$ ($-\$156,000$), meaning that it finds it attractive to join the targeted program even if it incurs in some loss in profits by doing so. Negative participation costs may be interpreted as the result of the existence of non-monetary benefits associated to the participation in the program (e.g. preference for attracting disadvantaged students), or to efficiency gains associated to participation. Other interpretations may also be possible, and I remain agnostic about which interpretation is more plausible, as my model does not allow me to identify the sources and motivations that underlie the participation cost.

Table 3.11: Predicted Costs

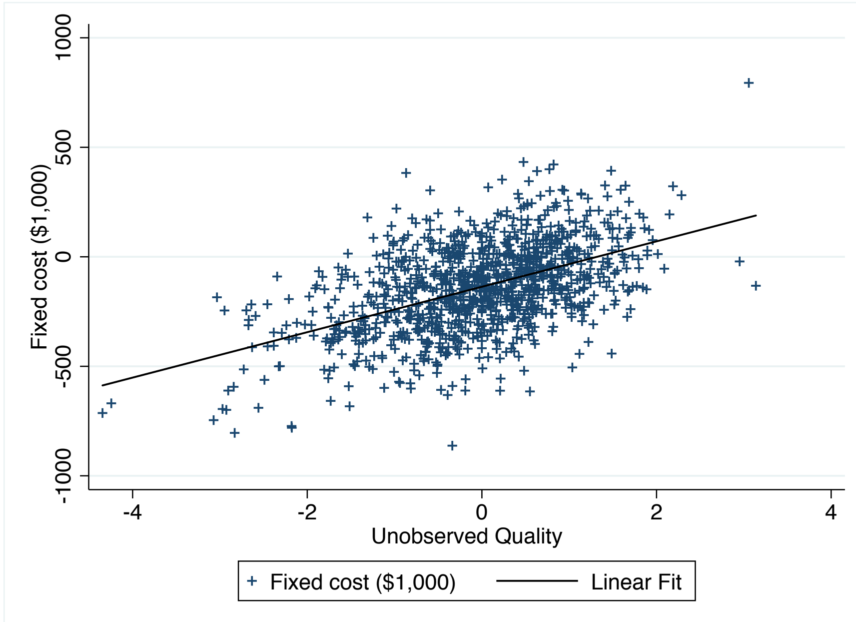
	mean	median
marginal cost ($):		
c_j^{nonD}	237	279
$c_j^{D\&nonD}$	553	595
participation cost ($1,000):		
κ_j	-158	-156

Notes: This tables presents the mean and median of predicted schools' marginal and program participation costs' distributions, which were constructed by using the estimated costs' parameters from the GMM-NFXP procedure. Costs are in real prices for the year 2013, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

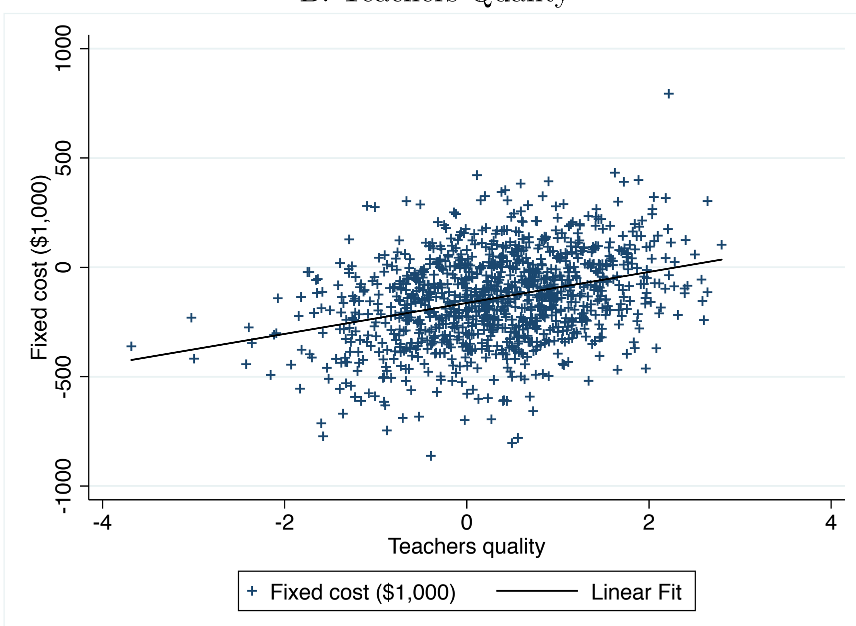
Figure 3.11 complements the results for the program participation cost from Table 3.11. Panel A plots the relationship between schools' predicted participation cost (y-axis) and unobserved quality (x-axis). Analogously, Panel B displays the relationship between schools' predicted participation cost (y-axis) and teachers quality (x-axis). There exists a positive correlation between schools' program participation cost and both measures of quality, suggesting that higher quality schools find it more costly to participate in the targeted program than lower quality schools, all else equal. Put differently, for the same gain in profits, a low-quality school is more likely to decide to join the targeted voucher program than a high-quality school. This is an important empirical result, that has not been documented in other studies, and that speaks directly to the evidence reported in Abdulkadiroglu et al. (2018) for the Louisiana Scholarship Program (LSP), a targeted voucher program currently in operation in the state of Louisiana. Abdulkadiroglu et al. (2018) document large negative effects of attending private-voucher schools on test scores (of about 0.4 standard deviations for math), and suggest that such finding may be explained by the fact that the private schools that are part of the LSP are predominantly low-quality. In fact, they show that, among all the private schools that were invited to participate in the LSP, the ones that joined the program were schools that had been continuously failing and losing students in the years that preceded the program. This result is also important because it can help policymakers to have and idea of which are the schools that may choose to participate in a targeted voucher program given a particular design (e.g. amount of the subsidy).

Figure 3.11: Schools' Program Participation Cost vs. Quality

A. Unobserved Quality



B. Teachers Quality



Notes: This figure displays the relationship between schools' predicted program participation cost and two measures of schools' quality. Panel A plots the relationship between schools' participation cost (y-axis) and unobserved quality (x-axis), whereas Panel B plots the relationship between schools' participation cost (y-axis) and teachers quality (x-axis). Schools' predicted participation costs were constructed using the estimated costs' parameters from the GMM-NFXP procedure. Costs are in real prices for the year 2013, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

3.6 Policy Analysis and Counterfactuals

I use the model and its estimated parameters to study the economic consequences of a variety of counterfactual policy scenarios. I am mostly interested in understanding whether and how schools respond to changes in the voucher subsidies. I focus on schools' program participation and tuition setting responses to policies. I also investigate whether and how such responses affect students' school choices.

My counterfactual policy analyses are motivated by actual policies that have recently been implemented in Chile. In 2016, and as part of a series of major reforms to all levels of the education system, the *Ley de Inclusión Escolar* law began to operate. This law introduced various changes to the regulations applicable to schools, including important increases to the voucher subsidies.[29] These increases include a rise in the universal subsidy, a new per-student voucher for schools that do not charge tuition, an increase in the targeted voucher, and a new per-disadvantaged student voucher to students in the third and fourth quintiles in the household income distribution (also for schools not charging tuition). The ultimate goal of these voucher increases is to end up with a system where no school charges top-up fees. The introduction of reform has been gradual, both in terms of the voucher increases, and geographically, with smaller regions entering first to the new regime. When fully implemented, it is estimated that the reform will increase the total government

[29] Overall, the law has three major pillars: 1) the end of copayment, implemented via increases in the vouchers; 2) the end of selection from the part of schools when oversubscribed, implemented via the introduction of lotteries to assign seats at schools; and 3) the end of the profit-seeking motive in private-voucher schools. In this paper, I focus on the increase-in-vouchers part of the law.

spending by about 20–30%.

As is usual with important reforms in education, proponents and detractors abound. Proponents argue that the goal of no tuition in schools is key to transform the current system into a more equitable one, and that the changes are in line with that objective. Detractors, in turn, argue that the reform is is too complex, and that it involves too many changes and additions to the voucher system without paying attention to schools' responses, which could lead to undesirable and unintended consequences.[30]

My goal with the policy simulations is to study the consequences of particular changes in the vouchers, and the mechanisms through which those consequences occur, paying special attention to schools' responses to policies. I do not aim to predict the consequences of the reform that is actually being implemented, because it involves aspects other than the voucher changes, which my model is silent about. I instead intend to inform policymakers about whether and how schools respond to particular changes in the voucher policies, and how such responses affect students' school choices.

I perform two series of counterfactual exercises. First, I study schools' program participation response to a set of different targeted voucher amounts, that range between 30% and 200% the 2013 subsidy level. I examine whether higher subsidy amounts attract more schools to participate in the targeted program, and whether the response of low-quality schools is different from the response of high-

[30] These and other arguments can be found in the transcript of the 120th session of Chile's Chamber of Deputies, January 26, 2015.

quality schools. The targeted program constitutes an important policy tool to bring tuition costs to zero for disadvantaged students, and therefore the study of schools' participation decisions is central to understand the capabilities of governments to lower tuition costs through the targeted voucher.

Second, I study the economic consequences of a 20% increase in the total budget that the government spends in vouchers, and that is implemented either as an increase in the level of the universal voucher, or as an increase in the level of the targeted voucher. I investigate the responses of schools to these policies, and the corresponding effect on students' school choices. 20% is about the percentage increase in government's spending induced by the actual reform being implemented in Chile. As stated above, instead of mimicking the actual policy, I choose to analyze separate increases in each of the vouchers, which can help to disentangle the mechanisms through which each of the vouchers operate.

3.6.1 Targeted Voucher Policies

I simulate the estimated model under seven different policy scenarios, where in each of them I keep the universal voucher fixed to its actual value ($1,220 for the year 2013), and set the level of the targeted voucher to either $200, $400, $600, $800, $1,000, $1,200, or $1,400.[31] I study schools' program participation decisions in each of the counterfactuals.

Table 3.12 presents schools' program participation behavior in each of the seven counterfactual scenarios. The first column presents the level of the targeted

[31] The actual value of the targeted voucher for the year 2013 is $717 (see Table 4.1).

voucher with which the model was simulated and the results obtained. The second column presents the total number of private-voucher schools that participate in the targeted program at each level of the targeted voucher. The third column presents the total number of private-voucher schools that opt out of the targeted program at each level of the targeted voucher. The fourth column presents the number of additional private-voucher schools that join the program at each level of the targeted voucher, relative to the number of private-voucher schools that are part of the program when the level of the targeted voucher is $200 lower. For example, the number of additional schools that join the program when the targeted voucher level is $400 is equal to the total number of schools that participate in the program at the targeted voucher level of $400 minus the total number of schools that participate in the program at the targeted voucher level of $200. For the targeted voucher level of $200, the number of additional schools joining the program is set to be the same as the total number of schools that participate in the program.

At the lowest level of the targeted voucher analyzed, $200, there are 606 private-voucher schools that decide to participate in the targeted program. These schools represent about 55% of all private-voucher schools.[32] This high response of schools to the positive but relatively small targeted voucher amount of $200 is somewhat expected, considering that many private-voucher schools are predicted to have negative program participation costs (see Figure 3.11), meaning that they find it optimal to participate in the program even if that results in a reduction in profits (before accounting for the program participation cost). For higher levels of

[32]The total number of private-voucher schools in the sample is 1,110.

the targeted voucher, larger sets of schools choose to join the targeted program. For instance, 62 additional private-voucher schools join the program when the targeted voucher is increased from $200 to $400. Likewise, 60 additional schools join the targeted program when the targeted voucher is increased from $400 to $600. Even more schools join the program when the targeted voucher is further increased, although the number of new schools joining the program is smaller the higher the level of the targeted voucher.[33] At the targeted voucher level of $1,400, which is about twice as large as the actual level ($717), 875 private-voucher schools decide to participate in the targeted program, which represents about 79% of all private-voucher schools in the sample. This result shows that, even for relatively high levels of the targeted subsidy, there is still a non-negligible group of schools that find it unattractive to join the targeted voucher program. However, possibly more important than the number of schools that stay out of the program is the identity (i.e. characteristics) of those schools. Put differently, a policymaker is likely to be less concerned of a targeted voucher program not being able to attract a set of schools if those schools are predominantly low-quality than if they are high-quality.

[33] Note, too, that the percentage of new schools joining the program is always around 10-14% relative to the set of schools that do not participate in the program. For instance, of the 504 schools that are not part of the program at the targeted voucher level of $200, 62 of them (12.3%) decide to join the program when the targeted voucher level is increased to $400.

Table 3.12: Schools' Program Participation Responses to Targeted Voucher Policies

subsidy amount	schools in program	schools not in program	additional schools joining program
$200	606	504	606
$400	668	442	62
$600	728	382	60
$800	772	338	44
$1,000	812	298	40
$1,200	849	261	37
$1,400	875	235	26

Notes: This table presents the program participation responses of private-voucher schools to seven different levels of the targeted voucher. The first column displays the targeted voucher level with which the model was simulated and the results obtained. The second column displays the total number of private-voucher schools that participate in the targeted program for each level of the targeted voucher. The third column displays the total number of private-voucher schools that do not participate in the targeted program for each level of the targeted voucher. The fourth column displays the number of additional schools that join the targeted program for each level of the targeted voucher, relative to the number of schools that participate in the targeted program when the targeted voucher level is $200 lower. For instance, for the targeted voucher level of $400, there are 668 private-voucher schools that participate in the program, which exceeds in 62 the number of private-voucher schools that are part of the program when the level of the targeted voucher is $200 (606). Therefore, there are 62 additional schools that join the program at the targeted voucher level of $400. For the targeted voucher level of $200, the number of additional schools joining the program is the same as the total number of private-vouchers schools in the program. Voucher amounts are in real prices for the year 2013, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$). The total number of private-voucher schools is 1,110.

Figure 3.12 complements the results from Table 3.12. It displays average quality measures for the set of additional schools that join the targeted program at each of the seven levels of the targeted voucher analyzed. Panel A plots additional schools' average unobserved quality, while panel B does analogously for schools' teachers quality. At the targeted voucher level of $200, schools' average quality measures are calculated for all private-voucher schools that participate in the program, and serve as a reference to compare against schools' quality measures at higher levels of the targeted voucher. At higher levels of the targeted voucher, the average quality measures are calculated only for the additional schools joining the program.[34] Two important patterns emerge. First, the average quality of the schools that are part of the program when the targeted voucher is $200 is considerably lower than the average quality of every set of new schools joining the program at higher levels of the targeted voucher. This is true for both unobserved and teachers quality measures. Second, the average teachers quality of the new schools in the program is higher the higher the level of the targeted voucher. This observed pattern is not exactly the same for the unobserved quality measure, but every set of additional schools is of higher unobserved quality (on average) than the reference set of schools that participate in the program at the targeted voucher level of $200. This finding is consistent with the estimation results for schools' program participation costs (see Figure 3.11), and suggests that higher quality schools find it particularly costly to participate in the program, and are therefore less likely to be part of the program than lower quality schools. A policy implication of this finding is that policymakers need to be sufficiently generous if they want to attract high-quality schools to participate in a targeted voucher program. That is, they should set a relatively high targeted voucher amount.[35] Once again, this result is directly related to the evidence in Abdulkadiroglu et al. (2018), where one could argue that the negative effects of attending voucher schools may well be mitigated by increasing the subsidy offered to participating schools, thus making more attractive the option of participating in

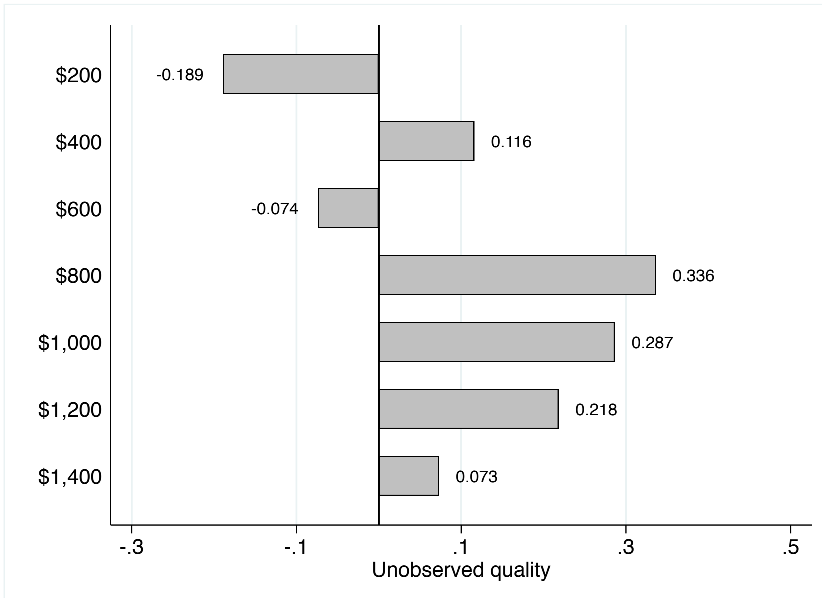
[34]For each targeted voucher level of $400 and higher, additional schools are schools that participate in the program at the corresponding targeted voucher level, but that do not participate in the program at lower levels of the targeted voucher.

[35]Another policy implication is to somehow lower the costs of joining the program, especially for high-quality schools. This could be achieved by, for example, cutting down bureaucracies in the joining process.

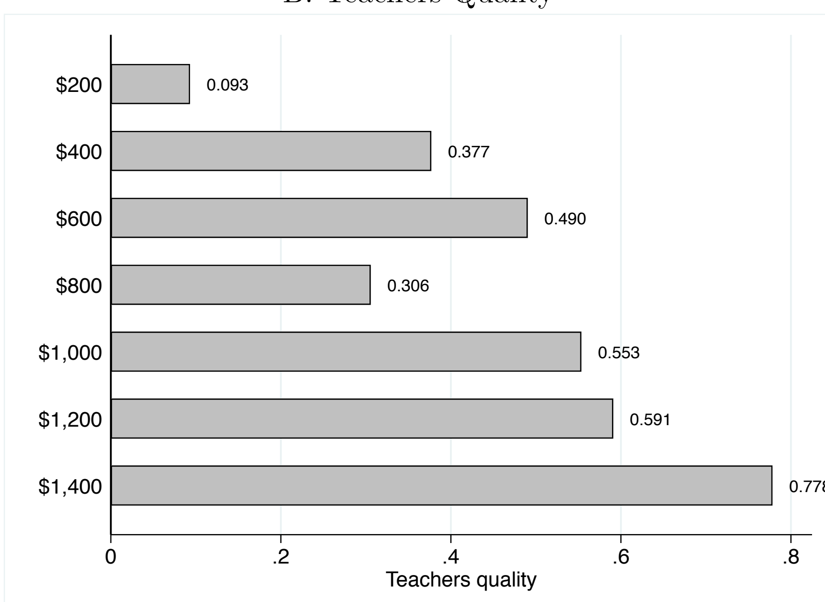
the program to higher quality schools.

Figure 3.12: Average Quality of the Additional Schools Joining the Targeted Voucher Program

A. Unobserved Quality



B. Teachers Quality



Notes: This figure plots the average unobserved and teachers quality of the additional private-voucher schools the join the targeted program at each level of the targeted voucher, relative to the private-voucher schools that are part of the program when the level of the targeted voucher is $200 lower. For the targeted voucher level of $200, the average quality of the additional private-voucher schools is the same as the average quality of all private-voucher schools that participate in the program. Voucher amounts are in real prices for the year 2013, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

3.6.2 Expansion in Government Spending

I study the economic consequences of expanding the total budget that the government spends in vouchers by 20%. I am interested in studying schools' responses to and equilibrium effects of two specific policies, that represent different ways of allocating the extra funding and therefore of implementing the budget expansion. Specifically, I investigate schools and students' responses when all the extra funding is allocated to increase the universal voucher, as well as their responses when all the extra funding is allocated to increase the targeted voucher. For a reference, I also look at responses in a baseline scenario where both the universal and targeted vouchers remain unchanged at their actual levels (as of 2013). Table 3.13 displays the exact voucher amounts used in each of the counterfactual scenarios. In the baseline scenario, the universal and targeted vouchers are kept at their actual levels of $1,220 and $717, respectively. In the scenario where the universal voucher is increased, its amount is set to $1,562, and the amount of the targeted voucher is kept at $717. Finally, in the scenario where the targeted voucher is increased, the universal voucher is kept at $1,220, and the targeted voucher is set to $1,256. The increases in the voucher amounts are such that they effectively result in a 20% increase in government's spending, and were calibrated using simulations of the model.

Table 3.13: Voucher Amounts in Counterfactual Scenarios

	baseline	increase in universal voucher	increase in targeted voucher
universal voucher ($)	1,220	1,562	1,220
targeted voucher ($)	717	717	1,256

Notes: This table presents the exact voucher amounts used in each of the counterfactual scenarios. The increases in the voucher amounts are such that they approximately result in a 20% increase in government's spending, and were calibrated using several simulations of the model.

Table 3.14 presents schools' responses in program participation under each policy scenario. These responses are analyzed relative to the baseline scenario of no increase in the voucher amounts. The table reports the number of private-voucher schools that join the program after an increase in each of the vouchers, as well as the number of private-voucher schools that leave the program after the voucher changes. For a reference, it also presents the total number of private-voucher schools that are part of the program in the baseline scenario, as well as the total number of private-voucher schools that are not part of the program in the baseline scenario. An increase in the universal voucher induces some schools to leave the targeted voucher program. More precisely, 98 of the 752 private-voucher schools that participate in the program in the baseline decide to leave the program after an increase of $342 in the universal voucher. These schools represent 13% of the group that participate in the program in the baseline. No new school is attracted to join the program. The response from schools is sizable, although it does not constitute a massive flight out of the program, as even after accounting for the leaving schools, more than half of all private-voucher schools still participate in the program. A simple rationale for explaining this result (some schools leaving, no school joining the program) comes from the fact that a rise in the universal voucher increases the importance of the universal voucher relative to the targeted voucher in schools' profits, and therefore the targeted program becomes less attractive for schools.

An increase of \$539 in the targeted voucher attracts an important number of additional schools to join the program. Specifically, 104 of the 358 private-voucher schools that do not participate in the program in the baseline decide to join the program after the rise in the targeted voucher. These schools represent 29% of the private-voucher schools that were not part of the program in the baseline. The response is sizable (as is the increase in the voucher), and its rationale is in that a higher targeted voucher makes the targeted program to be a more attractive option for many private-voucher schools, since it directly increases their profits for the case they join the program.

Table 3.14: Schools' Program Participation Responses in Counterfactual Scenarios

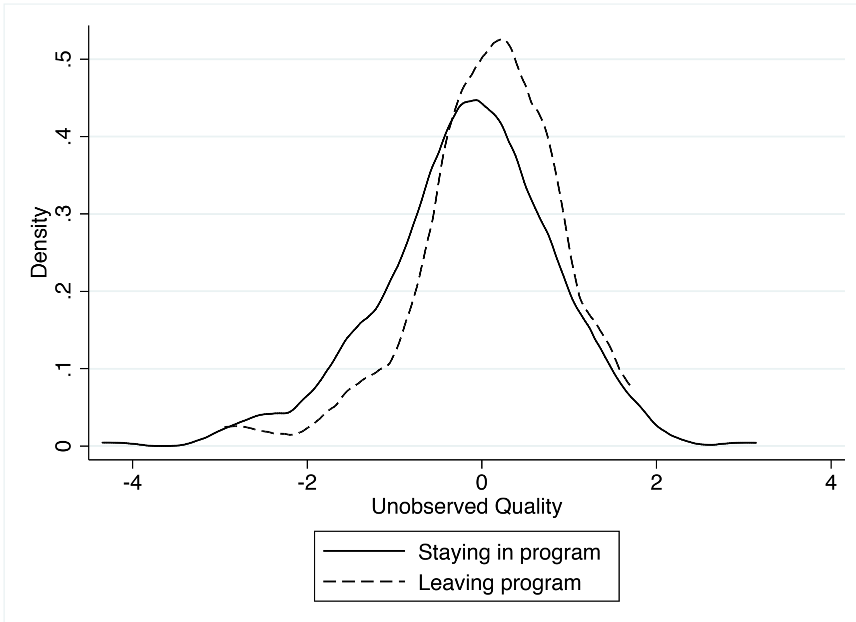
	increase in universal voucher	increase in targeted voucher
joining program	0	104
leaving program	98	0
in program (baseline)	752	
not in program (baseline)	358	

Notes: This table presents schools' program participation responses in the two counterfactual scenarios studied (increase in the universal voucher, and increase in the targeted voucher). The table reports the number of private-voucher schools that join the program, as well as the number of private-voucher schools that leave the program, in each policy scenario. It also presents the number of private-voucher schools that do and do not participate in the program in the baseline scenario.

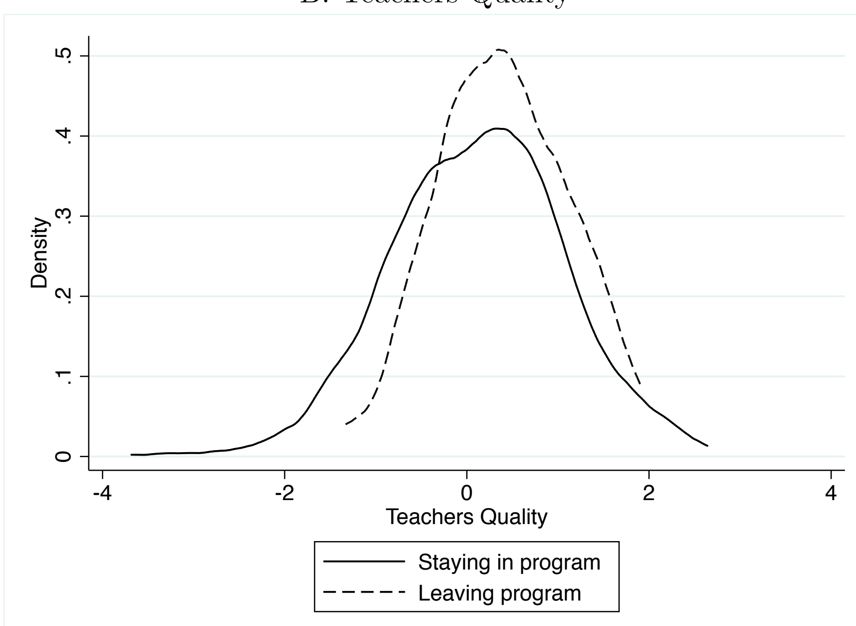
It is also important to look at the characteristics of the schools that either join or leave the program after increases in the vouchers. In a program evaluation language, these schools are the compliers; that is, they are the schools that respond to changes in exogenous parameters (i.e vouchers) by changing their program participation behavior. Figures 3.13 and 3.14 display the unobserved and teachers characteristics of the complier schools in each of the counterfactuals. Figure 3.13 plots the quality distributions of the private-voucher schools that leave the program after an increase in the universal voucher, and compare them with the quality distributions of the schools that remain in the program after the policy change. Panel A presents schools' unobserved quality distributions, while Panel B does analogously for schools' teachers quality. Though there is substantial overlap between compliers' and non-compliers' quality distributions, the schools leaving the program are in general of higher quality than the schools staying in the program. This is especially true for schools' teachers quality. Thus, an increase in the universal voucher not only results in a number of schools leaving the targeted program, but also in that the program loses some of its highest quality schools.

Figure 3.13: Increase in Universal Voucher - Quality Distribution of Schools Leaving Program

A. Unobserved Quality



B. Teachers Quality

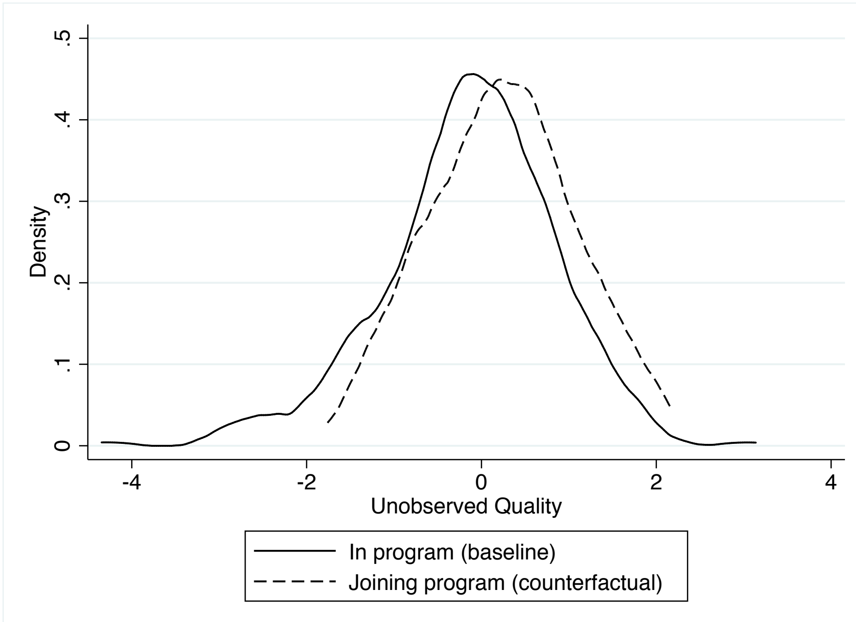


Notes: This figure plots the unobserved and teachers quality distributions of the private-voucher schools that decide to leave the targeted program after an increase of $342 in the universal voucher, and compare them with the quality distributions of the private-voucher schools that choose to remain in the program after the same increase in the universal voucher. Panel A displays schools' unobserved quality distributions, while Panel B does analogously for schools' teachers quality distributions.

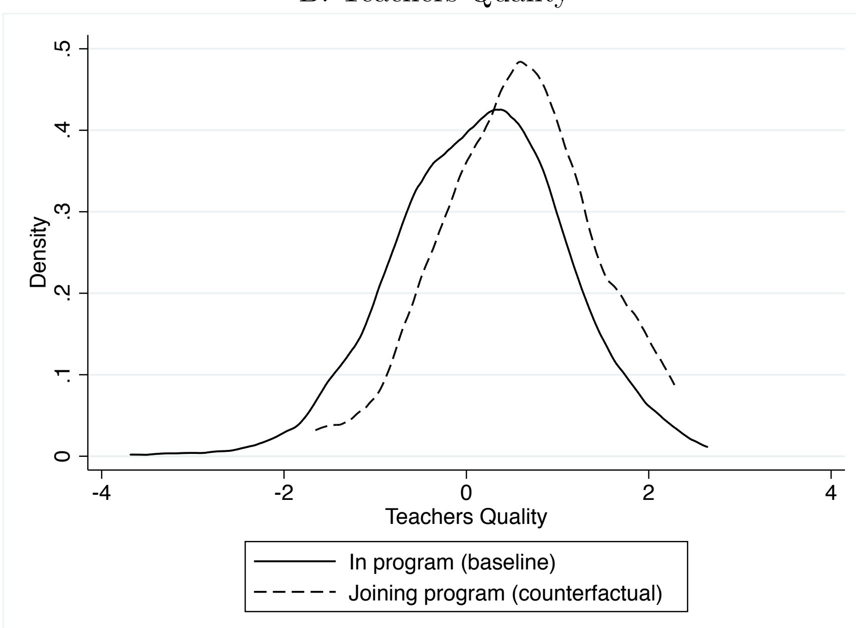
Figure 3.14 presents the unobserved and teachers quality distributions of the schools that decide to join the targeted program after an increase of $539 in the targeted voucher (and that do not participate in the program absent the voucher increase), and compare them with the quality distributions of the schools that participate in the program absent the policy change. Panel A plots schools' unobserved quality distributions, while Panel B does analogously for schools' teachers quality distributions. There exists an important overlap between the distributions of the two groups of schools. Nonetheless, the schools joining the program after the increase in the targeted voucher are in general of higher quality than their counterparts in the program. Thus, an increase in the targeted voucher not only attracts more schools to participate in the targeted program, but it also tends to attract schools of higher quality than the ones that participate absent the voucher increase.

Figure 3.14: Increase in Targeted Voucher - Quality Distribution of Schools Joining Program

A. Unobserved Quality



B. Teachers Quality

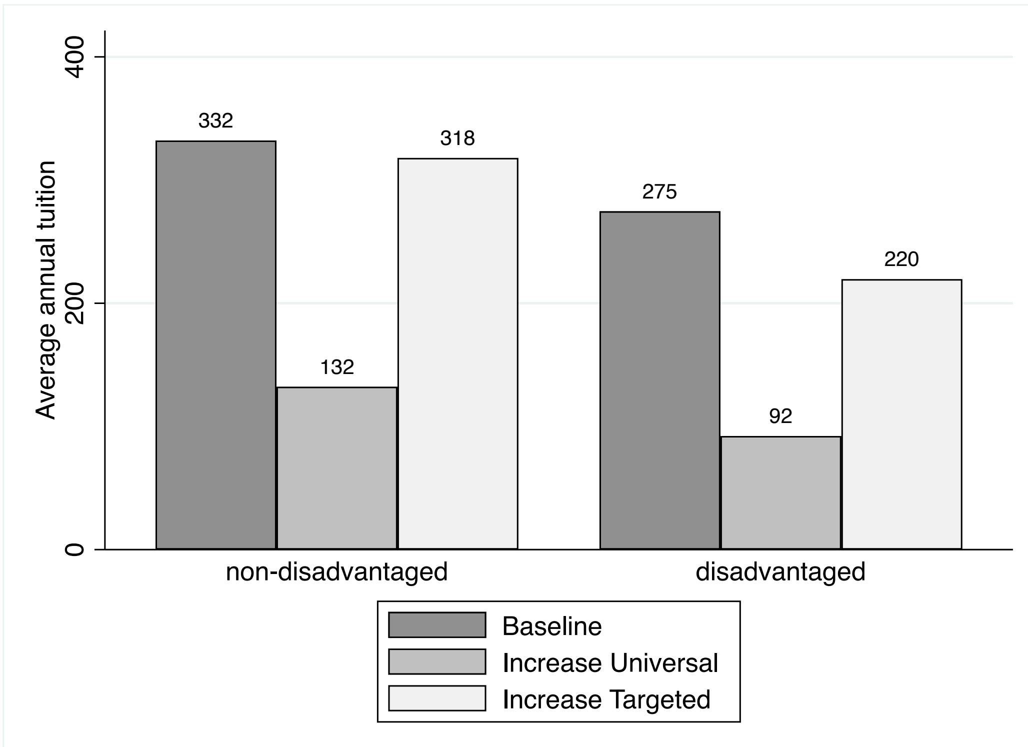


Notes: This figure plots the unobserved and teachers quality distributions of the private-voucher schools that decide to join the targeted program after an increase of $539 in the targeted voucher (and that do not participate in the program absent the policy change), and compare them with the quality distributions of schools that participate in the targeted program absent the increase in the targeted voucher. Panel A displays schools' unobserved quality distributions, while Panel B does analogously for schools' teachers quality distributions.

The results presented in Table 3.14 and Figures 3.13 and 3.14 describe two important supply responses to voucher policies. The implications of the changes in each of the vouchers are sizable and go in opposite direction. In particular, an increase in the universal voucher leaves the targeted program with less but also lower quality participating schools. Conversely, an increase in the targeted voucher increases the number of schools that participate in the program, but also the new participating schools are in general of higher quality than the rest of the participating schools.

Another channel through which schools respond to changes in the vouchers is via tuition. According to schools' optimality conditions (see Section 3.4.2), the universal voucher plays both a direct and an indirect role in determining tuition levels, whereas the targeted voucher's role in tuition setting is only indirect (through schools' demand). Therefore, it is reasonable to expect that schools' tuition levels be more sensitive to changes in the universal voucher than to changes in the targeted voucher. Figure 3.15 displays average tuition levels under each counterfactual scenario. It shows both average tuition charged to non-disadvantaged students (i.e. full tuition) and average tuition charged to disadvantaged students. An increase of $342 in the universal voucher lowers the average tuition charged to non-disadvantaged students from $332 to $132. Put differently, a $1 increase in the universal voucher translates into a $0.58 decrease in average full tuition. The fall in average tuition charged to disadvantaged students is also important, going from $275 to $92. On the other hand, the targeted voucher has a much smaller effect in tuition. Specifically, a $539 increase in the targeted voucher decreases the average tuition charged to non-disadvantaged students by only \$14, going from \$332 to \$318. Similarly, it decreases the tuition charged to disadvantaged students by \$55, going from \$275 to \$220.[36]

Figure 3.15: Schools' Tuition Setting Responses in Counterfactual Scenarios



Notes: This figure presents average tuition levels of private-voucher schools under each of three counterfactual scenarios: baseline, increase of \$342 in the universal voucher, increase of \$539 in the targeted voucher. It distinguishes between tuition charged to non-disadvantaged students and tuition charged to disadvantaged students. Voucher amounts are in real prices for the year 2013, and were transformed from Ch\$ to US\$ according to the exchange rate as of March 1, 2013 (472.96 Ch\$/US\$).

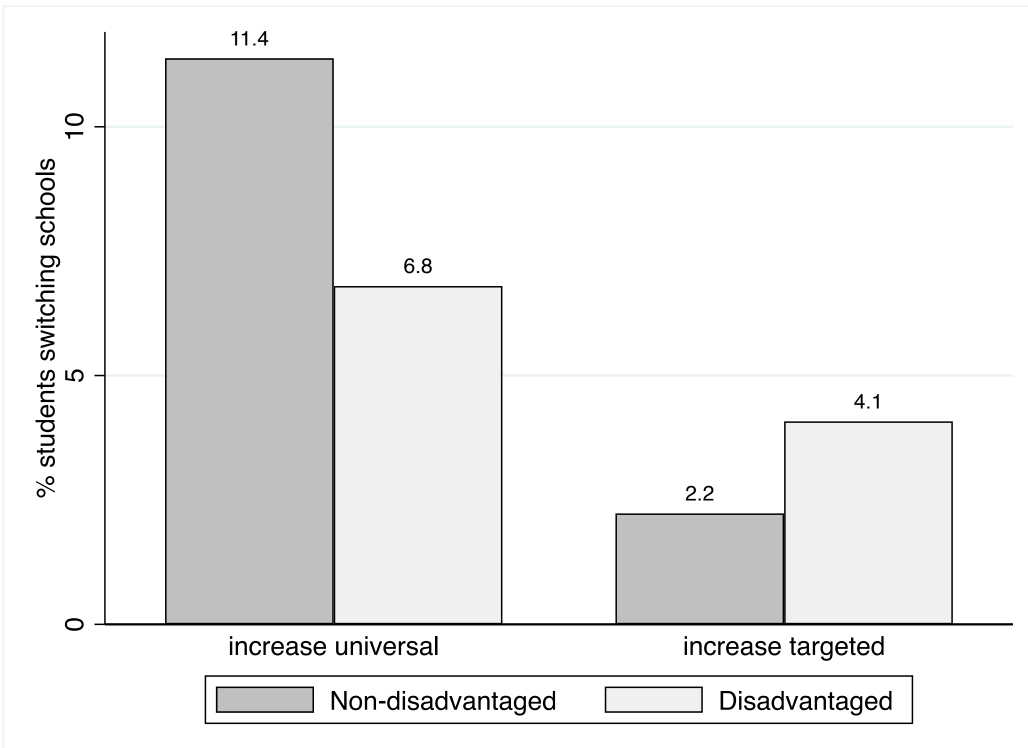
Table 3.14 and Figures 3.13-3.15 have shown two different mechanisms through which schools respond to changes in the vouchers: program participation and tuition setting. A careful evaluation of a voucher policy needs to account for both types of responses. Failure to do so, may lead policymakers to make inaccurate conclusions.

[36] All results account for the program participation response of schools to the voucher increases.

For instance, if a policymaker considers only the program participation response of schools, it may be led to prefer an increase in the targeted voucher over an increase in the universal voucher, because the former increases the quantity and quality of the schools that predominantly serve disadvantaged students. On the contrary, if the same policymaker considers only the tuition response of schools, it may prefer to increase the universal voucher over increasing the targeted voucher, as the former has a steeper effect in driving down tuition for all students.

More importantly, supply responses are of interest because they have consequences on students' choices and welfare. For example, more schools participating in the targeted voucher program may induce some disadvantaged students to switch to a new participating school. Similarly, lower tuitions may give some financially constrained students access to otherwise high-tuition schools. Figure 3.16 gives a picture of the school switches that occur under each counterfactual, relative to the baseline scenario of no voucher increase. It displays the percentage of students that switch to a different school than the one they attend in the baseline, and distinguishes between non-disadvantaged and disadvantaged students. 11.4% of non-disadvantaged and 6.8% of disadvantaged students choose a different school when the universal voucher is increased. Likewise, 2.2% of non-disadvantaged and 4.1% of disadvantaged students choose a different school when the targeted voucher is increased. These results can be interpreted as an increase in mobility for students, where supply responses in the form of lower prices allow some financially constrained individuals to choose schools that would otherwise be too expensive for them to attend.[37] Note also that the universal voucher policy produces a higher share of students switching schools than the targeted voucher policy. However, in relative terms, a higher share of non-disadvantaged students switch schools relative to disadvantaged students under the universal voucher policy, while the opposite occurs under the targeted voucher policy.

Figure 3.16: Students Switching Schools in Counterfactual Scenarios



Notes: This figure displays the percentage of students that switch to a different school under each of the counterfactual scenarios, relative to the school they choose in the baseline. It distinguishes between non-disadvantaged and disadvantaged students.

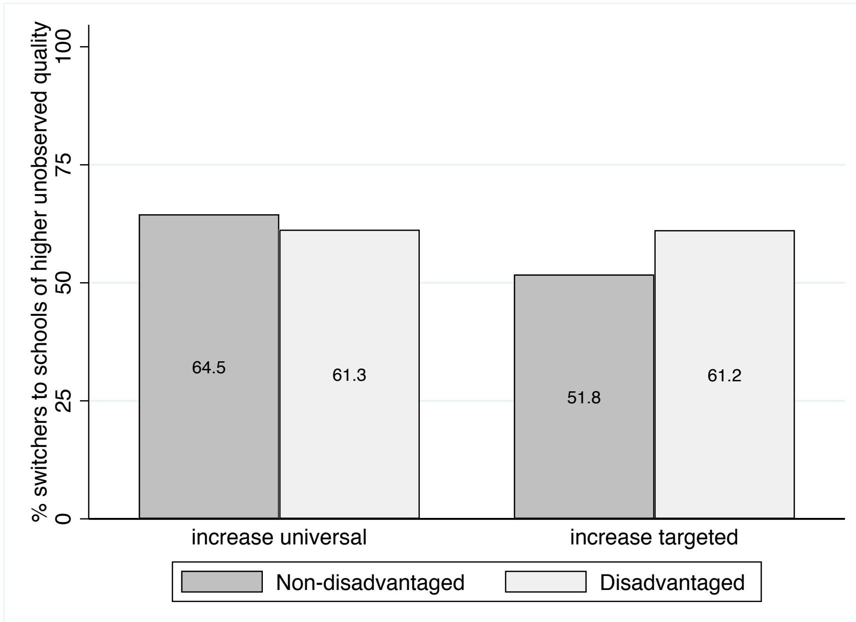
It is also important to examine whether students that switch schools are

[37]Note that the two types of supply responses I study in this paper, i.e. program participation and tuition setting, are essentially two different mechanisms that schools use to price-respond to voucher policies. By choosing to participate in the targeted program, schools are actually choosing to (second degree) price discriminate among students, where they charge no tuition to disadvantaged students, and may charge a positive amount to non-disadvantaged. Tuition setting is, evidently, a price response as well.

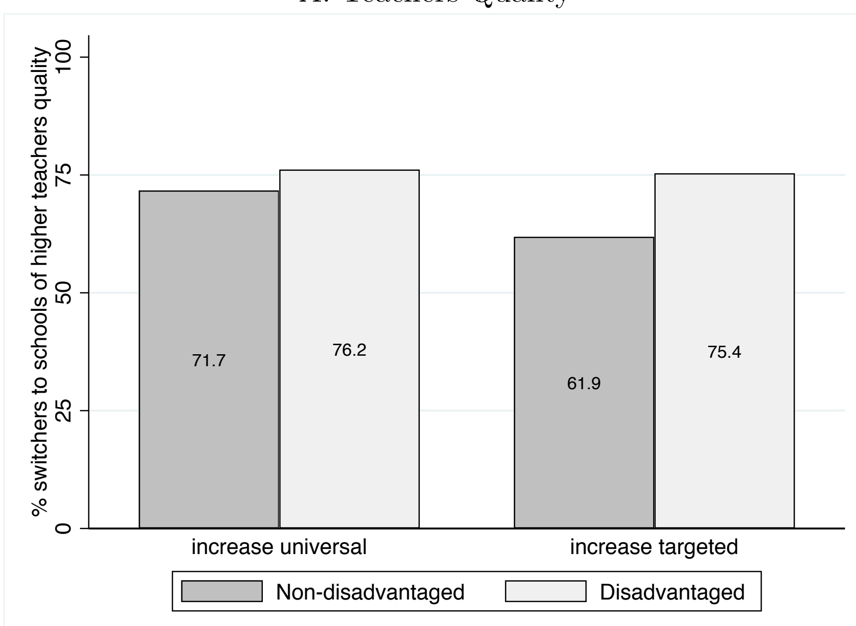
switching to schools of higher quality. From a policy perspective, this matters whenever a policymaker is interested in identifying policies that facilitate students' access to high quality schools. Figure 3.17 displays, for each counterfactual, the percentage of students that switch to a school of higher quality, given that they switch at all. It distinguishes between non-disadvantaged and disadvantaged students. Panel A shows results for schools' unobserved quality measure, while Panel B does analogously for schools' teachers quality. Under each of the policies, the majority of students switch to schools of higher quality. This is true for both non-disadvantaged and disadvantaged students, and when looking at either of the quality measures. Specifically, 64.5% of non-disadvantaged and 61.3% of disadvantaged switcher students switch to a school of higher unobserved quality when the universal voucher is increased, while 51.8% of non-disadvantaged and 61.2% of disadvantaged switchers do so when the targeted voucher is increased. Similarly, 71.7% of non-disadvantaged and 76.2% of disadvantaged switcher students switch to a schools of higher teachers quality when the universal voucher is increased, while 61.9% of non-disadvantaged and 75.4% of disadvantaged switchers do so when the targeted voucher is increased. These results are in line with the demand estimates from Table 3.9, where we noted that students have strong preferences for schools' quality, but dislike high tuition levels. As such, any policy that is able to drive down tuition levels is likely to increase demand for high quality schools.

Figure 3.17: Percentage of Switchers Choosing Schools of Higher Quality in Counterfactual Scenarios

A. Unobserved Quality



A. Teachers Quality



Notes: This figure displays, for each counterfactual scenario, the percentage of students that switch to a school of higher quality, given that they switch at all, and relative to the quality of the school they choose in the baseline. It distinguishes between non-disadvantaged and disadvantaged students. Panel A shows results for schools' unobserved quality measure, while Panel B does analogously for schools' teachers quality.

Table 3.15 complements the analysis from Figures 3.16 and 3.17. It shows the average difference in characteristics between the schools chosen by the switchers in each counterfactual scenario and the schools chosen by the switchers in the baseline scenarios. It includes the unobserved and teachers quality measures, distance travelled, and the probabilities that the school is private-voucher, rural, and secular as school characteristics. The table also distinguishes between non-disadvantaged and disadvantaged students. As shown in Figures 3.16 and 3.17, switchers, both non-disadvantaged and disadvantaged, switch to schools of higher quality on average. More precisely, switchers choose schools that are about 0.22–0.65σ higher in the quality measures. The only exception is non-disadvantaged students under the policy that increases the targeted voucher, where on average switchers choose a school that is 0.05σ lower in unobserved quality. However, that same group of students choose schools that are on average 0.22σ higher in teachers quality.

Table 3.15 also shows that the increase in the universal voucher policy induces non-disadvantaged (disadvantaged) students to switch to schools that are on average 2.5 (2.9) meters farther away than the baseline school. Conversely, the increase in the targeted voucher policy induces non-disadvantaged (disadvantaged) students to switch to schools that are on average 26.5 (3.4) meters closer than the baseline school. A priori, it is not obvious whether lower prices that result from the counterfactual policies should induce students to switch to schools that are farther away or closer to the students' home. It depends on the spatial distribution of the schools that are responding to the policies, as well as on the location of the residences of the switching students, among other things. For instance, if a high-quality school lowering its tuition due to a policy is located far away from a student's residence, then one might expect that student to be more likely to attend the high-quality school after the implementation of the policy. And the opposite is expected to occur if the high-quality school lowering its tuition is located closer to the student's home.

Switchers are also more likely to choose schools that are private-voucher, urban, and religious under each of the counterfactual policies. The results for the private-voucher and urban characteristics follow a similar intuition than the results found for the quality measures, which is that we expect that students be more likely to attend schools with the characteristics they enjoy after a reduction in the tuition levels due to a policy, whenever those characteristics are priced higher in the absence of the policy (see Tables 3.4, 3.9 and 3.10). The result found for the secular/religious characteristic of schools is likely to be due to the positive correlation between high-quality schools and their likelihood of being religious. For instance, if a high-quality school is also religious, and the student cares more about quality than whether the school is secular (see Table 3.9), then a fall in tuition levels due to a policy should increase the likelihood that a student attends a religious school (that is also high-quality).

Table 3.15: Characteristics of Schools Chosen by Switchers in Counterfactual Scenarios

students:	non-disadvantaged		disadvantaged	
counterfactual:	universal	targeted	universal	targeted
unobserved quality (std. dev.)	0.397	-0.050	0.299	0.313
teachers quality (std. dev.)	0.495	0.220	0.649	0.289
distance (km)	0.025	-0.265	0.099	-0.034
private voucher (p.p.)	0.410	0.176	0.502	0.438
rural (p.p.)	-0.018	-0.015	-0.018	-0.022
secular (p.p.)	-0.137	-0.412	-0.095	-0.270

Notes: This table displays the average difference in the characteristics of the schools chosen by the switchers in each of the counterfactual scenarios and the characteristics of the schools chosen by the switchers in the baseline scenario. It distinguishes between non-disadvantaged and disadvantaged students.

Finally, I analyze students' welfare changes associated to each voucher policy. To do so, I take advantage of the logit specification assumed for the error term in the indirect utility, and note that student i's expected utility is,

$$w_i = \ln\left(\sum_j e^{V_{ij}}\right).$$

Thus, the change in welfare associated to a particular counterfactual policy can be written as,

$$\Delta w_i = \ln\left(\sum_j e^{V_{ij}(counterfactual)}\right) - \ln\left(\sum_j e^{V_{ij}(baseline)}\right),$$

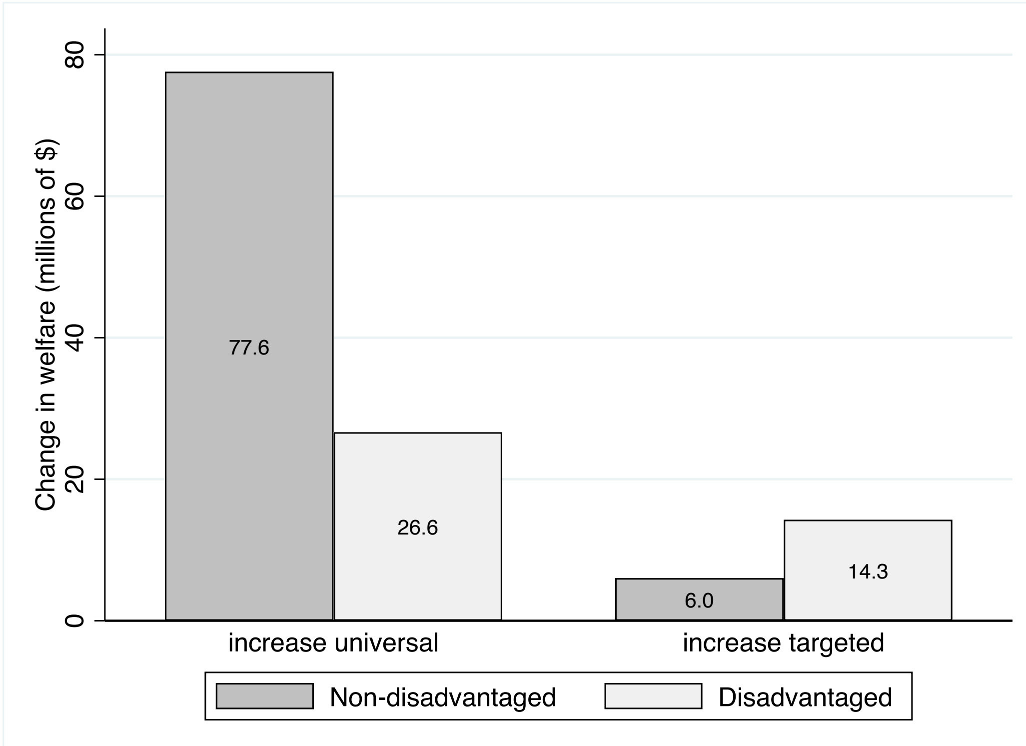
which, in turn, can be used to compute a measure of the aggregate welfare change in dollar terms,

$$\Delta w = \sum_i \frac{\Delta w_i}{-\hat{\beta}_{1i}},$$

where $\hat{\beta}_{1i}$ is student i's estimated coefficient for tuition in the indirect utility.

Figure 3.18 displays the aggregate welfare changes associated to each counterfactual voucher policy, relative to the baseline scenario. It distinguishes between non-disadvantaged and disadvantaged students' welfare changes. Both policies produce sizable welfare gains, for both types of students. More precisely, increasing the universal voucher by \$342 produces aggregate welfare gains of about \$77.6 million and \$26.6 million for non-disadvantaged and disadvantaged students, respectively. On the other hand, increasing the targeted voucher by \$539 produces aggregate welfare gains of about \$6 million and \$14.3 million for non-disadvantaged and disadvantaged students, respectively.

Figure 3.18: Change in Students' Welfare in Counterfactual Scenarios



Notes: This figure displays changes in aggregate students' welfare associated to each counterfactual voucher policy, relative to the baseline scenario of no voucher increase. It distinguishes between non-disadvantaged and disadvantaged students. Welfare measures are in real prices for the year 2013, and were transformed from Ch$ to US$ according to the exchange rate as of March 1, 2013 (472.96 Ch$/US$).

When comparing the welfare results of the two voucher policies, we have that the increase in the universal voucher policy produces larger aggregate welfare gains than the increase in the targeted voucher policy, overall and for each type of student. However, the universal voucher policy produces more gains for non-disadvantaged than for disadvantaged students, thus widening the welfare gap between the two groups.[38] On the contrary, the targeted voucher policy produces larger welfare

[38]Recall from Section 3.5 that the student population is approximately evenly distributed between disadvantaged and non-disadvantaged students. Specifically, in my sample, 53% of students are classified as being disadvantaged, while the remaining 47% are considered to be non-disadvantaged.

gains for disadvantaged than for non-disadvantaged students, therefore narrowing the gap in welfare between the groups. Thus, a policymaker that is interested in maximizing aggregate welfare among students would tend to prefer increasing the universal voucher, while a policymaker that is more concerned about welfare inequality results would tend to prefer increasing the targeted voucher.

3.7 Conclusions

This paper empirically studies the program participation and tuition setting behavior of Chilean elementary private-voucher schools in a context in which they are eligible to receive a universal voucher and a targeted voucher, and investigates how such behavior determines students' school choices. To that aim, I build and estimate a model of demand and supply of schools that approximates the Chilean elementary education system. I use the model and its estimated parameters to produce counterfactuals and learn about schools' and students' responses to different policy scenarios. I show that schools respond substantially to changes in the voucher amounts, and that the mechanisms through which they respond greatly depend on whether the change in policy affects the universal or the targeted vouchers. In particular, I find that a higher targeted voucher attracts more schools to join the targeted voucher program, but that high quality schools join only if the subsidy is sufficiently high. I also find that a higher universal subsidy induces schools to lower their tuition. Specifically, a $1 increase in the universal subsidy translates into a $0.58 decrease in average tuition. Finally, I quantify the consequences that these supply responses to policies have on students' mobility and welfare. I show that policies that favor the universal voucher are more mobility- and welfare-enhancing in the aggregate, but that policies favoring the targeted voucher are more effective in narrowing the welfare gap between low- and high-income students.

This paper's analysis captures schools' program participation and pricing behavior relatively well, and is able to generate intuitive predictions for different counterfactual voucher policies. To the best of my knowledge, this a novel feature for models that combine demand and supply decisions in elementary school markets. Nevertheless, my model has some limitations. For instance, I do not allow for voucher policies to affect schools' productivity or quality levels. Other studies (Neilson, 2013; Correa et al., 2014; Murnane et al., 2017) have found important improvements in schools' productivity associated to the introduction of the targeted voucher in Chile. Although, more recent studies (e.g. Feigenberg et al., 2017; Sánchez, 2018a) have challenged such findings, arguing that a more careful analysis of the data shows smaller or no improvement in schools' productivity attributed to the targeted voucher. This paper's future agenda includes incorporating an economic and empirical channel that links changes in voucher policies to potential changes in school productivity.

Chapter 4: Skipping your Exam? The Unexpected Response to a Targeted Voucher Policy

4.1 Introduction

The educational literature that studies education markets that include voucher subsidies and school choice often focuses its attention on the demand side of these markets (i.e. students, parents).[1] They typically answer important policy questions, such as what are the gains in academic performance and achievement of attending a private school versus a public one, or what are the factors that determine parental school choice. However, in most of the cases, voucher policies involve conditions and changes in regulation that also affect the supply side of the education markets. It thus becomes crucial to understand how schools react to changes in policies if we want to have a clear picture of all the effects of such policies.[2] In this paper, I study how schools responded to a recent targeted voucher reform in Chile that considerably increased the funding per-student, but that also required a rapid increase in schools'

[1]See Angrist et al. (2002), Angrist et al. (2006), Hsieh and Urquiola (2006), Hastings and Weinstein (2008), Gallego and Hernando (2009), Rouse and Barrow (2009), Bravo et al. (2010), Bettinger (2011), and Carneiro et al. (2013), among others.

[2]See Bau (2014), and Dinerstein and Smith (2014) for two recent studies that effectively account for schools responses to policy changes when investigating the consequences of policies on educational outcomes.

performance to secure the receipt of the subsidy.

In 2008, the Chilean government introduced a new subsidy in the form of a targeted voucher for disadvantaged students, that supplemented the existing per-student flat voucher. Schools participating in the new program receive extra funds for every disadvantaged student that they enroll, in addition to the base voucher common to all students. The size of the new funds are considerable, representing about 60% the amount of the base voucher. A novelty of this reform is that, for the first time, the payment of the subsidy is contingent on the school improving its performance on standardized tests. This condition is closely monitored and regularly enforced by the government. The idea that motivates this condition is to make sure that participating schools exert enough effort to improve the quality of the education they provide.

Neilson (2013) and Correa et al. (2014) have recently documented large impacts of this targeted voucher reform on the performance of students and schools affected by the program. Specifically, Neilson (2013) finds that disadvantaged students increased their performance on standardized test scores by 0.2σ due to the targeted voucher reform.[3] Similarly, Correa et al. (2014) find that the program had an impact of 0.12–0.18σ on schools' performance on standardized test scores four years after the introduction of the reform. Though encouraging, this evidence is not in line with audit studies and papers that document large inefficiencies in the use of the new subsidies from the part of schools, and that only few institutions were able to effectively take advantage of the increased funds received through the program

[3] σ denotes standard deviation units.

(de la Republica, 2012; Raczynski et al., 2013). Thus, it remains unclear what were the actions that participating schools took in order to increase their performance on standardized test scores.

I investigate a potential mechanism that schools can use to effectively and rapidly increase their performance on standardized test scores. National standardized exams in Chile are taken simultaneously by all students in the country in two specific days, usually in November. To take the tests, students have to attend school as they normally do in a regular day of class. Thus, an inexpensive mechanism that schools can use to increase their average performance is to strategically select a subgroup of high-performing students to take the exams. They can do so by asking some low-performing students to stay home during the exam days. Whether this behavior actually occurs remains an empirical question. What is clear is that schools that participate in the targeted voucher program have strong incentives to engage in such strategic behavior whenever such action is less costly than actually increasing the quality of education they provide, and effectively translating that higher quality into higher test scores. The large literature on education policies suggests that the latter is very costly.[4]

By exploiting rich administrative data on students' and schools' characteristics, performance, and test-taking rates, I use a difference-in-differences strategy to show that the targeted voucher reform significantly decreased the likelihood that low-performing students take the national standardized tests. Specifically, low-performing students are about 15 percentage points (20%) less likely to take the tests

[4]See Glewwe (2014), and Evans and Popova (2016a,b).

due to the program. Furthermore, the introduction of the program did not have an effect on high-performing students' likelihood of taking the tests. As a consequence, this specific strategic response of schools to the targeted voucher program introduced a bias in the representativeness of the test score distribution, where high-performing students are over-represented relative to the period before the implementation of the targeted program. Apart from being novel, this result is important for the implementation and evaluation of public policies for two main reasons. First, the results on the national standardized tests are used both by the government to allocate many of its educational policies (Cuesta et al., 2017), and by families to make their school choices (Gallego and Hernando, 2009; Cuesta et al., 2017). Therefore, a test score distribution that is not representative of the true underlying distribution may lead to inefficiencies in the allocation of resources. Second, this result may invalidate many of previous studies that use the national standardized test scores as an input in their analyses (see Neilson, 2013, and Correa et al., 2014, among others).

I also show that the targeted program had somewhat positive effects on schools' investment in educational inputs, especially those related to the hiring of new teachers, and that it reduced students' chronic absenteeism.

The paper is organized as follows. After this brief introduction, Section 2 describes the Chilean school system and the targeted voucher reform. Section 3 describes the data. Section 4 presents the identification strategy and shows the results of the paper. Section 5 concludes.

4.2 The Chilean School System and the Targeted Voucher Program

Schools in Chile can be organized within three main groups according to their management and financing scheme: public schools, private-voucher schools, and private-fee-paying schools. Both public and private-voucher schools are financed by a per-student voucher subsidy paid by the government directly to the schools. Private-fee-paying schools are financed by fees charged to parents, and serve the country's richest families. Today, 40% of students in elementary grades attend public schools, 52% attend private-voucher schools, and 8% attend private-fee-paying schools.

In 2008, the government introduced a new source of subsidy to complement the existing flat voucher in the form of a targeted voucher to disadvantaged students. On February of that year, the *Ley de Subvención Escolar Preferencial (SEP)* law that regulates this new subsidy was enacted, and was immediately put into practice for the 2008 academic year.[5] The law mandates that each school that participates in the program receives an additional subsidy per every disadvantaged student that they enroll. In addition, they also receive a per-disadvantaged student subsidy that depends on the share of disadvantaged students enrolled in the school, called *Subvención por Concentración (SC)*. Participation in the program is voluntary from the part of schools, and only public and private-voucher schools are eligible to join. Monitoring from the government is also an important aspect of the reform. At the moment of joining the program, each school is classified into one of three categories, that determines the level of monitoring the school receives from the government. The

[5]The academic year in Chile goes from March through December.

classification is based on schools' past standardized test scores and on an poverty index for the population that is served by the school. A higher classification implies less monitoring. In addition, all schools are required to set short- and long-term learning goals (i.e. test score achievements), which are evaluated by the government at the end of the period. Failing schools are reclassified one level down, and/or temporally suspended to receive the subsidy, with an eventual permanent exit of the system.

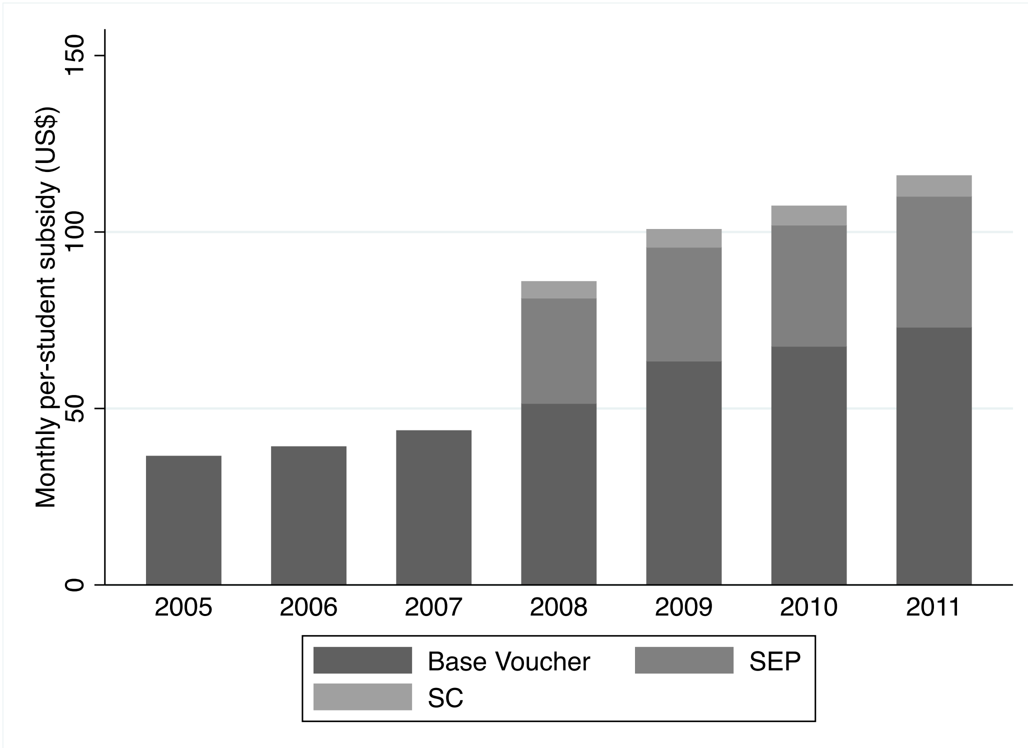
Table 4.1 displays the evolution of the monthly per-student voucher subsidy corresponding to elementary grades 1st-4th, decomposed by its different categories, for the years 2005-2011. Figure 4.1 complements this analysis graphically. The targeted voucher represents a considerable increase from the original flat voucher, of about 50–60% the base amount. The SC subsidy, in contrast, is almost negligible, representing only about 1% the base amount. The base voucher has experienced slight yearly increases during this period, with the largest increase occurred in 2009. A similar pattern is observed for the different targeted voucher categories since the introduction of the reform in 2008.

Table 4.1: Monthly Voucher Subsidy Decomposition for Students in 1st-4th Grades

	subsidy (US$)						
category	2005	2006	2007	2008	2009	2010	2011
base voucher	36.52	39.21	43.76	51.38	63.40	67.57	72.97
targeted voucher (SEP)	–	–	–	29.85	32.23	34.35	37.10
subsidy by concentration (SC):							
15–30%	–	–	–	2.09	2.26	2.40	2.60
30–45%	–	–	–	3.58	3.87	4.12	4.45
45–60%	–	–	–	4.78	5.16	5.50	5.94
more than 60%	–	–	–	5.37	5.80	6.18	6.68

Notes: SEP is the Spanish acronym for the targeted voucher program. SC is the Spanish acronym for the additional voucher subsidy that depends on the percentage of disadvantaged students in the school. All values are real, and are converted from Chilean pesos to US dollars according to the exchange rate of Ch$686.52 per US dollar, as of May 16, 2016. The base voucher values correspond to those for students at schools with full school shifts.

Figure 4.1: Size of the Vouchers for Students in 1st-4th Grades, by Category and Year



Notes: SEP is the Spanish acronym for the targeted voucher program. SC is the Spanish acronym for the additional voucher subsidy that depends on the percentage of disadvantaged students in the school. All values are real, and are converted from Chilean pesos to US dollars according to the exchange rate of Ch$686.52 per US dollar, as of May 16, 2016. The base voucher values correspond to those for students at schools with full school shifts. The SC values correspond to those for students in schools with 45–60% of disadvantaged students.

4.3 Data

I combine various administrative data sets of Chilean students and schools for the years 2005-2011 to form a seven-year (unbalanced) panel sample for schools, and a seven-year repeated cross-section sample for 4th grade students. I ignore private-fee-paying schools and their students, as the targeted voucher reform applies only to public and private-voucher schools. The data were obtained from the Ministry of

Education and the Agencia de Calidad de la Educación, the government's agency in charge of conducting all national standardized examinations in the primary and secondary levels. The data sets include the censuses of students and schools, the census of teachers, and the annual national standardized exams for 4th graders. See appendix A for a more detailed description of each of the data sets I use.

Table 4.2 displays summary statistics for selected variables from this sample. Panel A shows means and standard deviations for variables at the student level. Boys and girls are almost equally represented in the data. GPA, on a scale of 1.0–7.0, is fairly constant at 5.8 across years. Average class attendance is also constant at 93–94% across years. Both verbal and math scores increase over time, especially after the implementation of the targeted voucher reform. Test-taking rates are constant for the pre-reform period, and decrease right after that. The proportion of students that are recipients of the targeted voucher starts at 29% in 2008, increases to 45% in 2009, and stays constant at 42% thereafter. A similar pattern is observed for the proportion of disadvantaged students. Total enrollment for 4th graders slowly decreases over time, going from 253,223 in 2005 to 224,868 in 2011.

Panel B in Table 4.2 presents means and standard deviations for selected variables at the school level. The share of public schools decreases over the period studied, going from 63% in 2005 to 58% in 2011.[6] A similar pattern is observed for the proportion of rural schools. School inputs such class size, proportion of multigrade classes, average teacher experience, and pupil-teacher ratio show a common pattern,

[6]This pattern has been shown before in other studies that analyze the Chilean school system. See, for example, Bravo et al. (2010).

staying fairly constant in the pre-reform period, and decreasing thereafter. This is consistent with SEP schools spending the extra funds in performance-enhancing activities.[7] The proportion of SEP schools slightly increases over time, going from 79% in 2008 to 86% in 2011. Lastly, the total number of schools that offer 4th grade decreases from 7,963 in 2005 to 7,517 in 2011.

[7]The decrease in average teacher experience goes in the opposite direction (whenever we believe that more years of experience implies better quality of teaching), but that could be explained by the fact that hiring new teachers necessarily implies hiring less experienced teachers if all experienced teachers are already under a contract in a school.

Table 4.2: Summary Statistics for 4th graders

	2005	2006	2007	2008	2009	2010	2011
A. students							
male	0.51	0.51	0.51	0.51	0.51	0.51	0.51
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
GPA	5.79	5.78	5.77	5.77	5.77	5.77	5.75
	(0.63)	(0.62)	(0.62)	(0.61)	(0.59)	(0.58)	(0.57)
avg. class attendance	0.94	0.94	0.94	0.93	0.93	0.93	0.93
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.07)
verbal score	252.5	250.3	251.4	257.4	258.8	268.1	264.2
	(52.6)	(53.2)	(52.7)	(52.9)	(52.8)	(50.1)	(50.2)
math score	244.2	244.3	242.2	243.3	248.9	249.0	255.3
	(54.5)	(55.1)	(55.4)	(53.7)	(53.9)	(52.5)	(49.6)
test-taking rate	0.91	0.90	0.90	0.90	0.85	0.88	0.86
	(0.29)	(0.31)	(0.30)	(0.30)	(0.36)	(0.32)	(0.34)
SEP recipient	–	–	–	0.29	0.45	0.42	0.42
	–	–	–	(0.45)	(0.50)	(0.49)	(0.49)
disadvantaged student	–	–	–	0.33	0.53	0.49	0.48
	–	–	–	(0.47)	(0.50)	(0.50)	(0.50)
observations	253,223	249,344	241,006	238,196	231,074	234,353	224,868
B. schools							
public	0.63	0.62	0.61	0.60	0.60	0.59	0.58
	(0.48)	(0.49)	(0.49)	(0.49)	(0.49)	(0.49)	(0.49)
rural	0.51	0.50	0.49	0.49	0.48	0.47	0.46
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
class size	24.0	23.9	23.7	23.5	23.3	22.8	22.2
	(11.3)	(11.2)	(11.2)	(11.3)	(11.2)	(11.4)	(11.8)
share of multigrade classes	0.36	0.35	0.34	0.33	0.32	0.30	0.23
	(0.45)	(0.45)	(0.45)	(0.44)	(0.44)	(0.43)	(0.40)
avg. teacher experience	18.9	19.5	19.6	18.7	18.0	18.0	15.9
	(8.2)	(8.3)	(8.5)	(8.3)	(8.2)	(8.3)	(7.9)
pupil teacher ratio	17.7	17.7	17.3	17.1	16.9	16.3	15.2
	(8.2)	(8.2)	(8.4)	(8.6)	(15.4)	(11.1)	(11.1)
SEP school	–	–	–	0.79	0.83	0.84	0.86
	–	–	–	(0.41)	(0.38)	(0.37)	(0.35)
observations	7,963	7,888	7,810	7,783	7,734	7,700	7,517

Notes: SEP is the Spanish acronym for the targeted voucher program.

4.4 Empirical Analysis

4.4.1 Identification Strategy and Preliminary Results

Despite the fact that Chile's educational system is a school choice one, where students can freely choose schools regardless of their location of residence, time and travel costs allow for the existence of differentiated local school markets. In fact, previous research has found that primary school students avoid traveling long distances to go to school, with the average student traveling less than 2.78 km (1.7 mi) (Gallego and Hernando, 2009; Chumacero et al., 2011).[8] In addition, about 90% of students attend a school that is located in the same municipality of their residence.[9] This makes of municipalities a good candidate to define local school markets.[10][11]

The particular design of the targeted voucher reform implies that some municipalities are more affected by the program than others, depending on their share of disadvantaged students that are eligible to participate in the program. To make this point clear, take the extreme case of a municipality in which no disadvantaged student lives. The targeted voucher reform has zero effect in this municipality, in terms

[8] Chumacero et al. (2011) calculate an average distance from home to school in the metropolitan area of Santiago of 2.57 km (1.6 mi) for 4th grade students that attend public schools, and of 2.78 km (1.7 mi) for students that attend private-voucher schools.

[9] This is the case for the sample of 4th graders that I use in my empirical analysis.

[10] See Topel (1986) and Card (2001) for other papers that use political and administrative boundaries to define local markets.

[11] Notice that my definition of a school market in this chapter is different from the definition I use in chapter 3 of this dissertation. I choose the current definition because it involves smaller geographical areas, and it therefore provides somewhat greater variation for the identification strategy. Either way, for most of the markets, both definitions coincide. Hsieh and Urquiola (2006) also use municipalities to define local school markets in the Chilean context.

adding new funds, because no student is eligible to participate in the program. On the contrary, a municipality in which all students come from disadvantaged families has the maximum potential of receiving additional funds.[12] Thus, it is possible to argue that different municipalities have different intensities of treatment, and that these intensities depend on the share of disadvantaged students that reside in the municipalities.

To avoid endogeneity issues when conducting my empirical analysis, I use students' municipality of residence the year before the targeted voucher program was introduced.[13] This variable is highly correlated with the current municipality of residence (88.4% of 4th graders in 2008-2011 live in the same municipality than they did in 2007), and is free of endogeneity issues because the residential decision was taken before the program was announced and implemented. Figure 4.2 displays the distribution of municipalities according to their share of disadvantaged students the year before the targeted voucher reform took place. Panel A presents the distribution at the municipality of residence level. The support of the distribution is complete in the [0,1] range.[14] Also, about half of the municipalities have between 20% and 50% of disadvantaged students, and only few have less than 10% or more than 90% of disadvantaged students. Panel B presents the same distribution but weighted by each municipality's student population. The municipalities with the highest shares

[12] I am careful to say that this increase in the funding is only "potential", because it primarily depends on the schools deciding to participate in the program. However, as I show below, the share of disadvantaged students in the municipality highly predicts the likelihood that a school chooses to participate in the targeted voucher.

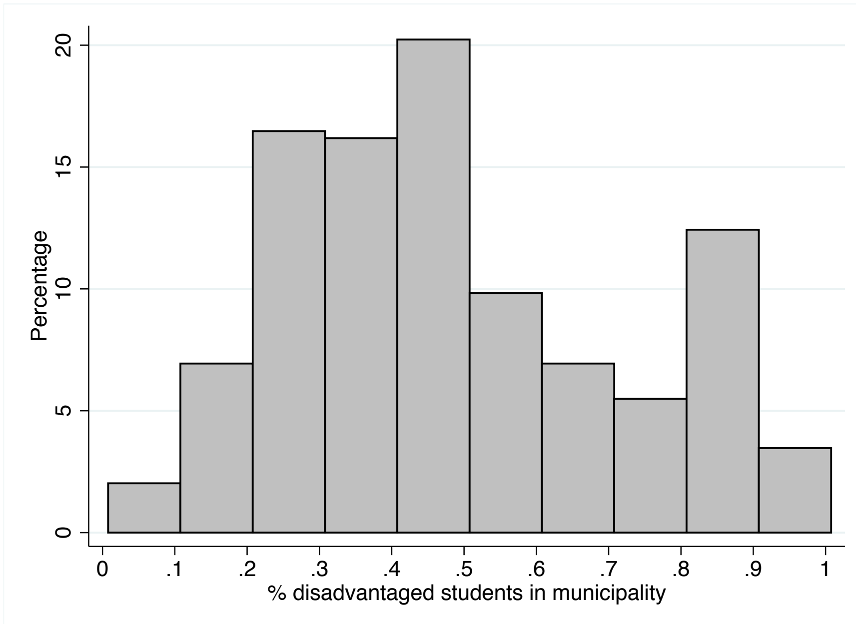
[13] As opposed to the municipality of residence before the introduction of the program, the current municipality of residence is subject to endogeneity issues via, for example, endogenous migration (Rosenzweig and Wolpin, 1988).

[14] The exact support of the distribution is [0.008,1].

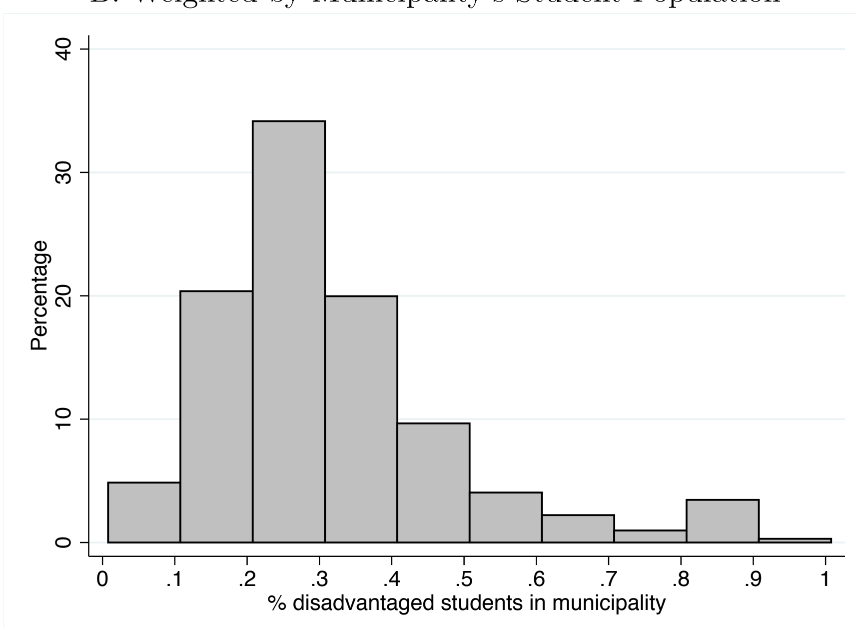
of disadvantaged students are also those with the least number of students. Also, more than half of students live in municipalities that had a share of disadvantaged students before the introduction of the reform within the range [0.1,0.4]. All in all, it is possible to argue the distribution of this "intensity of treatment" variable is well suited for my statistical analysis.

Figure 4.2: Distribution of Municipalities According to their Share of Disadvantaged Students Before the Reform

A. Unweighted



B. Weighted by Municipality's Student Population



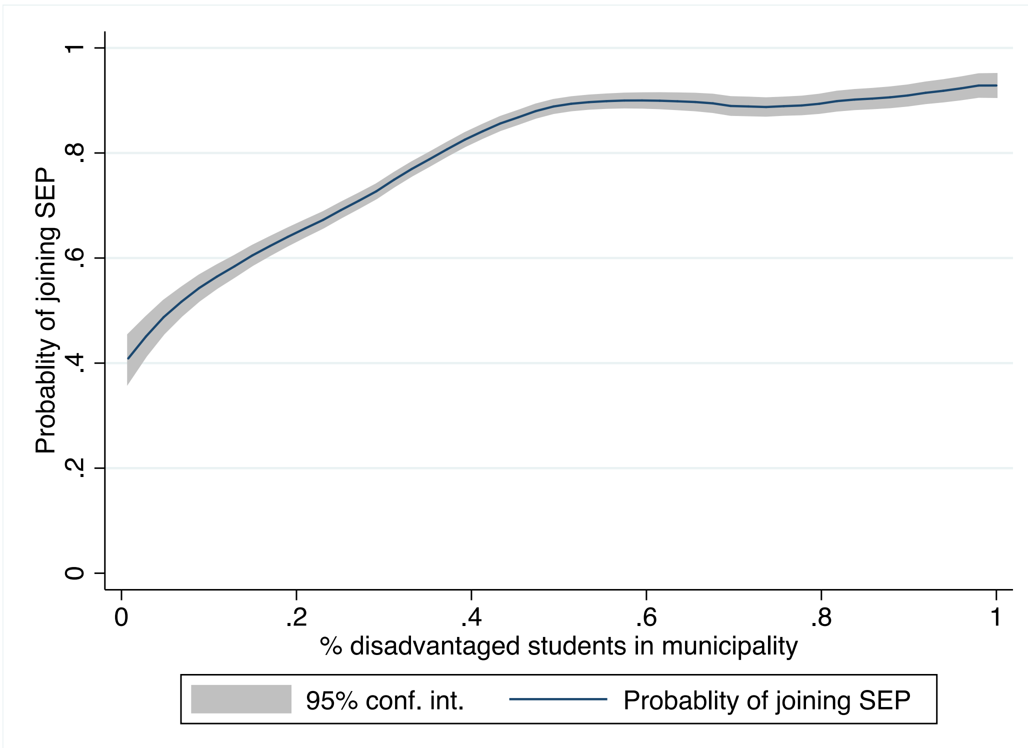
Notes: Panels A and B display histograms for the distribution of municipalities according to their share of disadvantaged students one year before the introduction of the targeted voucher reform (2007). Panel A displays the distribution at the municipality level, and Panel B presents the distribution weighted by each municipality's population of 4th grade students in the first year of the program (2008).

The basic idea of the identification strategy can be illustrated by using a standard diff-in-diff rationale. Adopting a similar strategy as in Card (1992) and Duflo (2001), I use the evidence from Figures 4.3 and 4.4 to define three categories for the share of disadvantaged students in the municipality of residence one year before the introduction of the reform.[15] Figure 4.3 displays a nonparametric estimation of the probability that a school joins the targeted voucher program in the first year of its implementation (2008) with respect to the municipality's share of disadvantaged students before the reform. The estimated function is monotonically increasing in the domain [0,0.5], going from 0.4 to about 0.9 in the probability, and remains fairly constant at 0.9 thereafter. Figure 4.4 plots a nonparametric estimation of the probability that a student attends a SEP school one year after the reform with respect to the municipality of residence's share of disadvantaged student one year before the reform. The estimated function is monotonically increasing in the domain [0,0.5], going from 0.4 to about 0.9 in the probability, remains stable in the domain (0.5,0.7], at 0.9 in the probability, and increases to almost 1 in the domain (0.7,1]. With this information at hand, I define the following three levels of intensity of treatment for local school markets (i.e. municipalities): *high*, for municipalities with more than 50% of disadvantaged students; *medium*, for municipalities with 20%-50% of disadvantaged students; and *low*, for municipalities with less than 20% of disadvantaged students. The choice of the levels responds to the fact that all students in a municipality with a high level of intensity of treatment are almost sure

[15] Neumark and Wascher (1992) also use a similar identification strategy to estimate the effects of minimum wage laws on employment in the U.S.

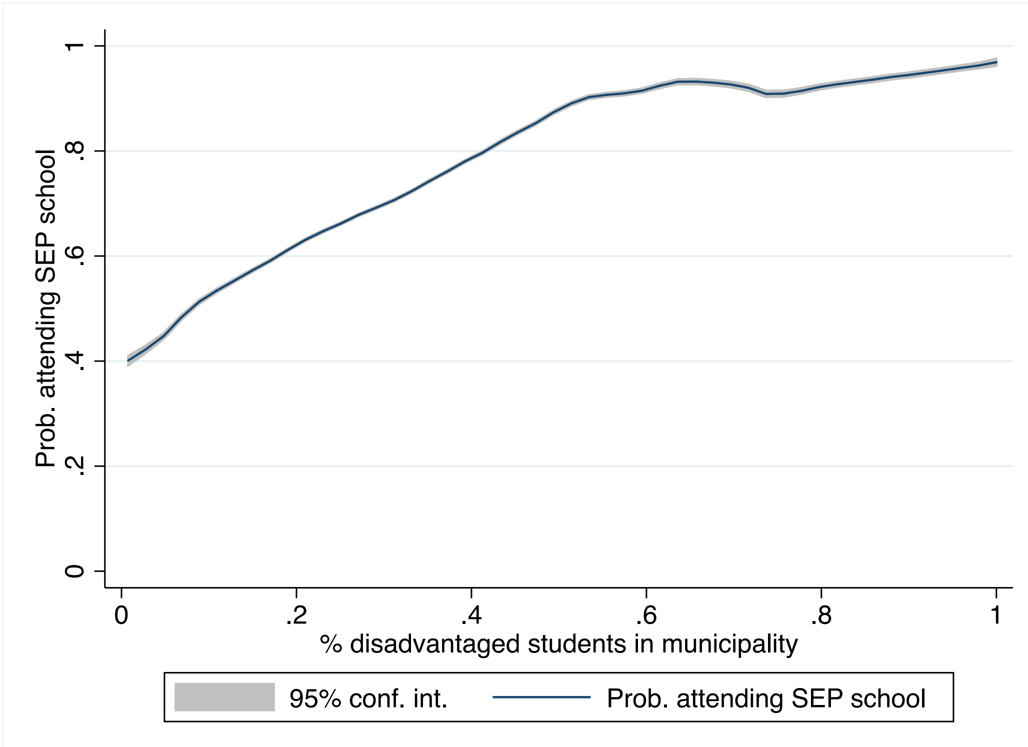
to attend a SEP school, and that the typical student in a municipality with a low intensity of treatment is as likely to attend a SEP school as to attend a non-SEP school. The rest of the municipalities are classified to be of medium level.

Figure 4.3: Probability that a School Joins the Targeted Voucher Program, by Municipality's Share of Disadvantaged Students



Notes: This figure displays a nonparametric estimation of the probability that a school joins the targeted voucher reform (SEP) in the first year of its implementation (2008), with respect to the percentage of disadvantaged students in the municipality one year before the introduction of the targeted voucher reform (2007).

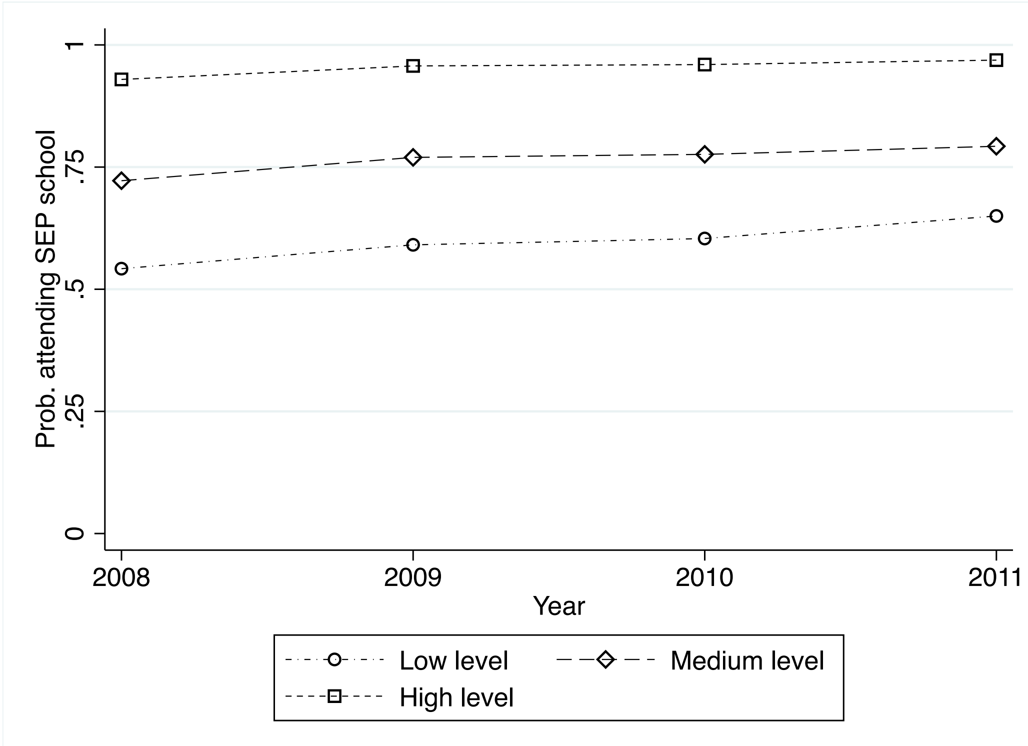
Figure 4.4: Probability that a Student Attends a SEP School, by Municipality's Share of Disadvantaged Students



Notes: This figure displays a nonparametric estimation of the probability that a student attends a SEP school in the first year of the targeted voucher reform (2008), with respect to the percentage of disadvantaged students in the municipality one year before the introduction of the targeted voucher reform (2007).

Figure 4.5 plots a dynamic version of Figure 4.4, where we observe that the probability that a student attends a SEP school is fairly constant over time and by intensity of treatment level, confirming the robustness of my choice for the definition of the three intensity levels.

Figure 4.5: Probability that a Student Attends a SEP School, by Municipality's Share of Disadvantaged Students Level Over Time



Notes: I define and use three different levels of concentration of disadvantaged students in the municipality one year before the introduction of the targeted voucher reform (2007): low, for municipalities with less than 20% of disadvantaged students; medium, for municipalities with more than 20% and less than 50% of disadvantaged students; and high, for municipalities with more than 50% of disadvantaged students. This figure displays the probability that a student attends a SEP school in the first four years of the targeted voucher reform (2008-2011), by municipality's concentration of disadvantaged students level one year before the introduction of the targeted voucher reform (2007).

Table 4.3 presents means and standard deviations for test scores one year before the introduction of the program (2007) and four years after the introduction of the program (2011), by intensity of treatment level. Test scores are standardized to have zero mean and standard deviation of one in 2007. Panel A presents means for verbal scores. In general, students in low-intensity municipalities have higher scores that students in medium-intensity municipalities, who in turn score higher than students in high-intensity municipalities. Average test scores increase in all three types of municipalities, but they increase more in high-intensity municipalities, followed by medium-intensity ones. Simple difference-in-difference estimators can be constructed by using the change in low-intensity municipalities as a base, and are shown in columns (4) and (5). The diff-in-diff estimate is 0.007σ (not statistically different from zero) for medium-intensity markets, and 0.091σ for high-intensity markets. In order to transform these estimates into effects attributed to the targeted voucher reform, I divide them by the differences in the share of disadvantaged students between medium/high-intensity markets and low-intensity markets. Such shares are 15%, 31.4%, and 68.7% for low-, medium-, and high-intensity markets, respectively. Combining these results, we obtain that the average treatment effect on the treated (Abadie, 2005) of the targeted voucher reform on verbal scores is 0.04σ for students in medium-intensity markets, and 0.16σ for students in high-intensity markets. A similar analysis can be done for math scores, by using the statistics displayed in Panel B. I obtain effects attributed to the targeted voucher reform of 0.27σ and 0.31σ for medium- and high-intensity markets, respectively. These results are in line with the findings in Neilson (2013).

Table 4.3: Test Scores Before and After the Targeted Voucher Reform, by Intensity of Treatment Level

	intensity of treatment level			difference	
	low	medium	high	medium - low	high - low
	(1)	(2)	(3)	(4)	(5)
A. verbal					
test score in 2007	0.070	-0.010	-0.083	-0.080	-0.153
	(0.004)	(0.003)	(0.006)	(0.005)	(0.008)
test score in 2011	0.297	0.225	0.235	-0.073	-0.062
	(0.004)	(0.003)	(0.007)	(0.005)	(0.008)
difference 2011 - 2007	0.228	0.234	0.319	0.007	0.091
	(0.006)	(0.004)	(0.009)	(0.007)	(0.011)
B. math					
test score in 2007	0.115	-0.008	-0.178	-0.123	-0.293
	(0.004)	(0.003)	(0.006)	(0.005)	(0.008)
test score in 2011	0.303	0.226	0.181	-0.077	-0.122
	(0.004)	(0.003)	(0.006)	(0.005)	(0.008)
difference 2011 - 2007	0.188	0.233	0.359	0.045	0.171
	(0.006)	(0.004)	(0.009)	(0.007)	(0.011)

Notes: The sample consists in all students in 4th grade in public and private-voucher schools for the years 2007 and 2011. Test scores are standardized with respect to the year 2007. Standard errors in parentheses. I define and use three different levels of intensity of treatment: low, for municipalities with less than 20% of disadvantaged students; medium, for municipalities with more than 20% and less than 50% of disadvantaged students; and high, for municipalities with more than 50% of disadvantaged students.

I also present difference-in-difference estimates for standardized test-taking rates. Standardized tests in Chile are mandatory for schools and are scheduled to be taken simultaneously by all 4th grade students in two specific days, usually in November, every year.[16] To take the tests, students have to normally attend class those days, just as they do in a regular day of class. Table 4.4 presents test-taking rates for the years 2007 and 2011, and by intensity of treatment level. Panel A displays such rates for all students. On average, test-taking rates are highest

[16]Students in 8th and 10th grades also take standardized tests, every other year.

in low-intensity school markets, followed by medium-intensity markets, and then by high-intensity school markets. Also, test-taking rates decreased in all three types of municipalities between 2007 and 2011. The reduced-form diff-in-diff estimated effects of the targeted voucher reform on students' test-taking rates, using low-intensity municipalities as benchmark, are -0.7 percentage points (p.p.) for medium-intensity municipalities, and -2.5 p.p. for high-intensity municipalities. These numbers imply a treatment on the treated effect attributed to the reform of -4.3 p.p. for medium-intensity municipalities, and -4.7 p.p. for high-intensity municipalities. Panel B presents an analogous diff-in-diff exercise as in Panel A, but only for low-performing students.[17] The implied treatment on the treated effects of the targeted voucher reform on the test-taking rates of low-performing students are -12.8 p.p. for students in medium-intensity municipalities, and -10.2 p.p. for students in high-intensity municipalities. These estimates represent considerable effects of -15.7% and -13.7% in the test-taking rates of low-performing students in medium- and high-intensity municipalities, respectively. Panel C presents the same diff-in-diff exercise in test-taking rate as in panels A and B, but for high-performing students. The implied effects of the targeted voucher program are 4.9 p.p. for students in medium-intensity municipalities, and 0.7 p.p. for students in high-intensity municipalities. The combined results from panels A-C in Table 4.4 show that the effect of the reform on test-taking rates is entirely driven by the decrease in the test-taking rate of low-performing students.

[17] I define low-performing students as students that belong to the lowest quartile in their schools' GPA distribution. Analogously, I define high-performing students as students that belong to the highest quartile in their schools' GPA distribution.

Table 4.4: Test-taking Rates Before and After the Targeted Voucher Reform, by Intensity of Treatment Level

	intensity of treatment level			difference	
	low	medium	high	medium - low	high - low
	(1)	(2)	(3)	(4)	(5)
A. all students					
test-taking rate in 2007	0.911	0.903	0.883	-0.008	-0.028
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
test-taking rate in 2011	0.880	0.866	0.827	-0.015	-0.053
	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)
difference 2011 - 2007	-0.031	-0.037	-0.056	-0.007	-0.025
	(0.002)	(0.001)	(0.003)	(0.002)	(0.004)
B. low-performing students					
test-taking rate in 2007	0.844	0.814	0.746	-0.030	-0.098
	(0.003)	(0.002)	(0.005)	(0.004)	(0.006)
test-taking rate in 2011	0.787	0.736	0.634	-0.050	-0.153
	(0.003)	(0.002)	(0.006)	(0.004)	(0.007)
difference 2011 - 2007	-0.057	-0.078	-0.112	-0.021	-0.055
	(0.005)	(0.003)	(0.008)	(0.005)	(0.009)
C. high-performing students					
test-taking rate in 2007	0.951	0.955	0.964	0.004	0.013
	(0.002)	(0.001)	(0.002)	(0.002)	(0.003)
test-taking rate in 2011	0.947	0.958	0.963	0.011	0.017
	(0.002)	(0.001)	(0.002)	(0.002)	(0.003)
difference	-0.005	0.003	-0.001	0.008	0.004
	(0.003)	(0.002)	(0.003)	(0.003)	(0.004)

Notes: The sample consists of all students in 4th grade in public and private-voucher schools for the years 2007 and 2011. Standard errors in parentheses. I define and use three different levels of intensity of treatment: low, for municipalities with less than 20% of disadvantaged students; medium, for municipalities with more than 20% and less than 50% of disadvantaged students; and high, for municipalities with more than 50% of disadvantaged students. Low-performing students are students that belong to the lowest quartile in their schools' GPA distribution. High-performing students are students that belong to the highest quartile in their schools' GPA distribution.

Two important remarks can be taken from the preliminary evidence just shown. First, the targeted voucher reform increased students' academic performance (measured by test scores). Second, the reform decreased the representativeness of low-performing students in the national standardized tests. The reasons for the latter effect are unknown and hard to identifiy, but could well relate to strategic actions taken by schools to the increased pressure from the government to rapidly increase test scores. More importantly, these results imply that the estimated effects that I and others studies find for test scores may be biased upwards.[18]

4.4.2 Main Results

To better exploit the variation in treatment intensity across municipalities, I generalize the strategy presented above to a regression framework. Specifically, I estimate the following equation:

$$y_{ist} = \gamma_s + \lambda_t + \delta(\text{post}_t \times \text{intensity}_s) + \varepsilon_{ist}, \tag{4.1}$$

where y_{ist} is the outcome of interest for student i in municipality of residence before the reform s in period t, γ_s is a fixed effect for municipality of residence before the reform, λ_t is a year fixed effect, post_t is a post-reform indicator, intensity_s is the intensity of treatment (i.e. share of disadvantaged students in the municipality of residence one year before the reform), and ε_{ist} is an error term. In the empirical implementation of this regression I cluster the standard errors at the municipality of residence before the reform level (Bertrand et al., 2004; Cameron and Miller, 2015). The coefficient of interest is δ, as it captures the effect of the targeted voucher reform. Note that the treatment parameter identified by this equation is

[18] See Neilson (2013) and Correa et al. (2014).

the average treatment effect on the treated (Abadie, 2005), which in this case of a continuous treatment represents the effect on students residing in municipalities with a 100% share of disadvantaged students before the reform.

I first estimate equation (4.1) on test scores and test-taking rates, and check whether the results from Section 4.4.1 are also found in this regression framework. Panels A and B in Table 4.5 present the results for test scores. Column (1) presents estimates from specifications not including controls, and column (2) includes the gender of the student and the share of public schools in the current municipality of residence as covariates. The estimated effect for verbal is 0.21σ, and the effect for math is 0.35σ, both statistically significant at all conventional levels. Panel A in Table 4.6 presents the results for test-taking rate. Columns (1) and (2) show estimates for all students, columns (3) and (4) do so for low-performing students, and columns (5) and (6) show results for high-performing students. The estimates indicate that the targeted voucher reform decreased in 7.9 p.p. students' test-taking rate. They also show that the targeted voucher reform decreased in 14.6 p.p. low-performing students' test-taking rate. The program had no significant effect on test-taking rate of high-performing students. This evidence confirms the negative effect that the reform had on the representativeness of low-performing students in the sample of students that take the national exams. In addition, it is no longer possible to claim that the estimated effects found for test scores in Table 4.5 and in other studies (Neilson, 2013; Correa et al., 2014) are free from representativeness bias.

To the question of why schools engage in such a strategic behavior, I return to the discussion from section 4.1. Schools that participate in the targeted program are required to meet specific academic goals in the form of average test scores at the school level. They need to comply with the academic goals in order to secure the receipt of the new subsidy. Schools are thus incentivized to increase the quality of the education they provide, and to transform that quality improvement into higher students' test scores. However, if schools find it difficult or costly to quickly raise test scores (Glewwe, 2014; Evans and Popova, 2016a,b), they may look for alternatives that may help them achieve their goals. One such alternative is to keep low-performing students to take the tests, thus automatically increasing the school's average test score without necessarily changing its quality of education. Moreover, in the current policy setting, this is an inexpensive way of increasing average test scores, as there is no penalty for schools engaging in this behavior.

Table 4.5: Effect of the Targeted Voucher Reform on Test Scores and Chronic Absenteeism

	(1)	(2)
A. verbal scores		
post × intensity	0.205***	0.205***
	(0.034)	(0.033)
observations	373,260	373,260
R^2	0.031	0.040
B. math scores		
post × intensity	0.352***	0.349***
	(0.038)	(0.038)
observations	373,332	373,332
R^2	0.038	0.039
C. chronic absenteeism		
post × intensity	-0.173***	-0.172***
	(0.024)	(0.024)
observations	414,299	414,299
R^2	0.029	0.030
controls	no	yes

Notes: All results come from estimation of generalized diff-in-diff regressions that use data for students one year before and four years after the introduction of the SEP reform. The intensity of treatment variable is the municipality's share of disadvantaged students. I report the estimated coefficient on the interaction between the dummy for the period after the introduction of the program and the treatment variable. Specifications with controls include the gender of the student and the share of public schools in the current municipality of residence. Standard errors are clustered at the municipality of residence before the program level. *** denotes statistically significance at 99% level.

Table 4.6: Effect of Targeted Voucher Reform on Test-taking Rate and Class Attendance

	students' performance group					
	all		low-performing		high-performing	
	(1)	(2)	(3)	(4)	(5)	(6)
A. test-taking rate						
post × intensity	-0.079***	-0.079***	-0.147***	-0.146***	-0.004	-0.004
	(0.013)	(0.013)	(0.023)	(0.022)	(0.012)	(0.012)
observations	414,299	414,299	108,477	108,477	99,938	99,938
R^2	0.011	0.013	0.032	0.032	0.007	0.007
B. class attendance						
post × intensity	0.028***	0.028***	0.040***	0.040***	0.019***	0.019***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)
observations	414,299	414,299	108,477	108,477	99,938	99,938
R^2	0.045	0.045	0.048	0.048	0.050	0.050

Notes: All results come from estimation of generalized diff-in-diff regressions that use data for students one year before and four years after the introduction of the SEP reform. The intensity of treatment variable is the municipality's share of disadvantaged students. I report the estimated coefficient on the interaction between the dummy for the period after the introduction of the program and the treatment variable. Low-performing students are students that belong to the lowest quartile in their schools' GPA distribution. High-performing students are students that belong to the highest quartile in their schools' GPA distribution. Specifications with controls include the gender of the student and the share of public schools in the current municipality of residence. Standard errors are clustered at the municipality of residence before the program level. *** denotes statistically significance at 99% level.

Next, I investigate whether the observed effect of the targeted voucher reform on students' test-taking rate responds to a decrease in general class attendance. Panel B in Table 4.6 presents results from estimating equation (4.1) for students' average annual class attendance rate. The estimates show a positive effect attributed to the reform. The point estimates are 2.8 p.p., 4 p.p., and 1.9 p.p. for all, low-performing, and high-performing students, respectively. Additional evidence supporting this finding is presented in Panel C in Table 4.5, that displays the estimated effect of the targeted voucher reform on students' chronic absenteeism. Chronic absenteeism is defined as missing ten percent of a school year for any reason (Balfanz and Byrnes, 2012), and is found to be strongly linked to low academic achievement and high dropout rates.[19] The results indicate that the targeted voucher reform reduced chronic absenteeism in 17.2 p.p., out of a base of 20.7% in 2007, a result that is both statistically significant and economically important. These two pieces of evidence highlight the positive effect that targeted voucher program had on attendance, an important input for academic achievement. However, such results do not help to explain the observed decrease in the test-taking rates attributed to the reform.

As a final empirical exercise, I estimate equation (4.1) for selected variables that measure educational inputs. I do so to investigate whether the targeted voucher reform had an effect on schools' incentive to invest in school quality. Table 4.7 reports the effect of the targeted voucher reform on class size, pupil-teacher ratio, % of multigrade classes, and average teacher experience in years, all measured at the school level. I weigh each observation by schools' 4th grade enrollment. Column (1) presents estimates from specifications not including controls, while column (2) includes a dummy for public school as a covariate. Class size, pupil-teacher ratio, and average teacher experience are transformed to logs, so the estimates should be interpreted as percent changes. The results suggest that schools used the extra funds

[19] See Balfanz and Byrnes (2012), and Gottfried (2014).

they received from the targeted voucher to invest in educational inputs. Specifically, the reform reduced class size in 8.1%, reduced the pupil-teacher ratio in 5.3%, and reduced the percentage of multigrade classes in 7.8 p.p. (out of a base of 19.2% in 2007). The program also reduced the average years of experience of teachers, in about 11.6%.

Table 4.7: Effect of the Targeted Voucher Reform on School Inputs

	(1)	(2)
A. class size		
post × intensity	-0.083***	-0.081***
	(0.017)	(0.016)
observations	12,071	12,071
R^2	0.274	0.290
B. pupil-teacher ratio		
post × intensity	-0.054**	-0.053**
	(0.025)	(0.024)
observations	11,991	11,991
R^2	0.261	0.266
C. % multigrade classes		
post × intensity	-0.078***	-0.078***
	(0.011)	(0.011)
observations	12,071	12,071
R^2	0.171	0.171
D. avg. teacher experience		
post × intensity	-0.104*	-0.116**
	(0.055)	(0.052)
observations	11,995	11,995
R^2	0.164	0.425
controls	no	yes

Notes: All results come from estimation of generalized diff-in-diff regressions that use data for schools one year before and four years after the introduction of the SEP reform. Each school observation is weighted by school's enrollment in 4th grade. The intensity of treatment variable is the municipality's share of disadvantaged students. I report the estimated coefficient on the interaction between the dummy for the period after the introduction of the targeted voucher program and the treatment variable. Specifications with controls include a dummy for public school. Standard errors are clustered at the municipality of residence before the program level. *** denotes statistically significance at 99% level. ** denotes statistically significance at 95% level. * denotes statistically significance at 90% level.

In summary, I find that the targeted voucher program had positive effects on test scores four years after its implementation. However, those results should be taken with caution, as I also find that the reform significantly decreased the likelihood that low-performing students take the national standardized tests, a result that cannot be explained by the observed increase in class attendance due to the program. I also find that schools invested in educational inputs, namely class size, pupil-teacher ratio, and % of multigrade classes. Both the test-taking rate and the school inputs effects can certainly help explain the large effects of the reform on test scores.

4.5 Conclusions

In this paper, I present evidence regarding the strategic response of schools to a targeted voucher reform in Chile. Specifically, I use a difference-in-differences strategy to document that schools in local markets that were most affected by the reform engaged in the strategic selection of high-performing students to take the national standardized exams, as a way of complying with the requirement of increasing the school's average performance on standardized test scores. My results show that the reform decreased the likelihood of taking the standardized tests for low-performing students in about 14.6 percentage points four years after the introduction of the reform. Moreover, the reform did not have a significant impact on the likelihood of taking the exams for high-performing students. I also show that the reform had a positive impact on schools' investment in educational inputs, especially in those related to the hiring of new teachers.

My findings highlight the importance of taking into account the supply responses to policy changes when evaluating educational programs. The general enthusiasm generated by recent studies documenting large impacts of the Chilean targeted voucher reform on students' performance in standardized test scores must be taken with caution, as those studies do not account for schools' reactions to the reform.

Appendix A: Data Sources

I conduct my empirical analyses using various administrative and survey data sets from Chile. Most of the data were obtained from the Ministry of Education and the Agencia de Calidad de la Educación, the government's agency in charge of conducting all national standardized examinations in the primary and secondary levels. The richness of the data is remarkable. It covers all students and schools in the country, and provides a large set of demographic variables for students and of educational inputs and management characteristics for schools. Among the data for school inputs is a detailed set of variables for teachers, that includes information on their education credentials and teaching specialization. The data allows researchers to track students from first grade until they finish their formal schooling, including higher education. It additionally provides information on the performance of students in every standardized test they take throughout their schooling years. Panel data samples for schools and teachers can also be constructed. The years spanned by these data sets are 1999-2016, where different variables are available for different years.

In addition to the data obtained from the government's education branches, in chapter 3 I also use data from the most important national household survey, CASEN (Encuesta de Caracterización Socioeconómica Nacional), and from the national standardized college admission exams, PSU (Prueba de Selección Universitaria). Chapter 4 also complements the base data with my own collection and construction of records for students' residence geographic coordinates and private schools' tuition. Each of these chapters elaborate on the importance of the added data to conduct the corresponding empirical analysis.

Below, I provide a list of each administrative and survey data set used in this dissertation, along with its corresponding description.

- *National standardized exams, SIMCE (Sistema de Medición de la Calidad de la Educación), student-level.*

  This data provides information on students' test scores in various primary and secondary grades and for various subjects, including verbal, mathematics, social sciences, and natural sciences. It also provides information on students' gender and grade.

- *SIMCE's questionnaire to parents and tutors.*

  This data consists in the responses to a survey that parents and tutors answer during the days when the national standardized tests are taken. The survey is voluntary, though about more than 90% of parents respond it. It provides information on students' household size, house amenities, and time use, total number of books available in the household, household total monthly income, parents and tutors' time use, education, indigenous identification, occupation, health insurance, participation in social programs, reasons for the choice of the school, beliefs on the student's future educational attainment, satisfaction with the school, knowledge of school's average performance in standardized tests, total monthly expenses related to the student's education other than tuition, and school's admission criteria, tuition, and fees.

- *National standardized exams, SIMCE, school-level.*

  This data provides information on schools' average test scores in various grades and for various subjects, including verbal, mathematics, and social and natural sciences. It also provides information on schools' municipality, management type, socio-economic category of the population served by the school, urban status, and number of students taking the tests.

- *Registry of students.*

  This data provides information on students' gender, date of birth, age, municipality of residence, type and level of education, grade, class, grade repetition status, special education status, and various characteristics of the school of attendance, such as municipality, management type, single/double shift schedule, and urban status.

- *Registry of schools.*

  This data provides information on schools' municipality, management type, urban status, address, and type and level of education offered.

- *National standardized college admission exams, PSU (Prueba de Selección Universitaria).*

This data provides information on students' college admission test scores for four different subjects: verbal, mathematics, social sciences, and natural sciences. These exams are not mandatory, but are essential in determining students' chances of attending college. The data also provides information on students' birth date, home address, level of education of the parents, occupation of the parents, high school attended, high school GPA, preference ranking of higher education institutions-majors, among others.

- *National household survey, CASEN (Encuesta de Caracterización Socioeconómica Nacional).*

  The CASEN series of household surveys corresponds to the most important piece of socio-economic information in Chile. It is used to inform public polices, and contains extensive information on individuals' education, health, employment, etc. It is nationally representative at the municipality level.

- *Registry of students in higher education institutions.*

  This data provides detailed information on students' enrollment in higher education institutions, including the institution's name, major of study, geographical location where the classes are held, and students' age, gender, and birth date.

- *Registry of individuals completing a higher education degree.*

  This data provides information for all students earning a higher education degree. It also contains detailed information on the degree (major and higher education institution), the time needed to complete the degree, the official duration of the degree, the exact date when the degree was completed, and students' age, gender, and birth date.

- *Registry of students that are eligible to participate in the targeted voucher program.*

  This data provides information on the characteristics of students that are eligible to participate in the targeted voucher program. It provides information on students' gender, date of birth, program participation status, level of education, grade, single/double shift schedule, and on the type of management, and urban status of the school attended by the student.

- *Registry of schools that participate in the targeted voucher program.*

  This data provides information on the characteristics of the schools that participate in the targeted voucher program. Information on schools' municipality, type of management, urban status, number of disadvantaged students that are eligible for the targeted voucher subsidy, and number of students that are beneficiary of the targeted voucher is available.

- *Registry of students' academic performance.*

  This data provides information on students' gender, date of birth, municipality of residence, type and level of education, grade, class, GPA, average class attendance, and various characteristics of the school of attendance, such as municipality, type of administration, and urban status.

- *Registry of schools' summary of enrollment.*

This data provides information on schools' municipality, type of management, urban status, male enrollment by education type and level, female enrollment by education type and level, total enrollment by education type and level, total enrollment, number of single-grade classes by education type and level, total number of single-grade classes, number of multigrade classes by education type and level, and total number of multigrade classes.

- *Registry of teachers.*

  This data provides information on teachers' gender, date of birth, education degree, subject specialization, institution attended, graduation year, and duration of the degree studied. It also provides information on the characteristics of all schools in which each teacher is hired (municipality, type of management, rural status), and on the teachers' primary and secondary roles (e.g. teacher, principal, supervisor), type of contract, hours contracted, teaching hours, experience, tenure, and teaching subject and level of education.

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