Understanding School Competition Under Voucher Regimes

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Abstract

I study the equilibrium consequences of educational voucher policies, explicitly accounting for both extensive and intensive margins competition in the supply side. Educational markets are commonly large, which heavily complicates solving for equilibria when schools compete in discrete and continuous strategies. I deal with the curse of dimensionality related to standard equilibrium concepts in large discrete-continuous games by adapting a simplified equilibrium notion that better captures the limited capability of players to store large dimensions of contingencies when forming their best responses. I apply this equilibrium concept to a structural model of demand and supply for primary education in markets that allow the use of vouchers. I model schools' program participation (extensive margin) as well as their pricing behavior (intensive margin). I estimate my model using data from Chile, and leverage its simultaneous implementation of universal (available to all students) and targeted (available only to low-income students) vouchers to study schools' behavior under a variety of policy designs. Results show that universal vouchers affect mostly the pricing strategy of schools, while targeted vouchers affects schools' program participation. Empirically, high-quality schools are attracted to join the voucher programs only if the subsidies are high enough. Also, low-income students benefit the most when vouchers increase.

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1 Introduction

In the past few decades, the education literature has made significant progress in understanding how vouchers affect the demand side of education markets (i.e. students) (Epple et al., 2017). Conversely, our knowledge on the effects of vouchers on the supply side of education markets is somewhat limited to date.[1] More importantly, understanding how schools respond to vouchers is critical, as vouchers consequences on markets' equilibria and on students' outcomes are greatly determined by schools' behavior. This paper contributes to filling this gap in the literature by explicitly studying schools' responses to a variety of voucher policies. It does so by rigorously 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 vouchers that they receive from the government. In addition, the system combines two different policy 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-low-income student subsidy paid to schools that choose to participate in the targeted voucher program. Thus, the Chilean case presents a unique opportunity to study various policies that combine universal and targeted subsidies.

This paper develops an equilibrium model of school choice and competition under simultaneous universal and targeted voucher programs. In the demand side of the model, families choose schools by taking into account a number of schools' characteristics, such as proximity, top-up fees, 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 simultaneously choosing whether they participate in a targeted voucher program, and the fees they charge to students.

The inherent characteristics of urban education markets, where a large number of schools compete for attracting students, and my explicit modeling of the demand proves 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 one or more equilibrium profiles of fees 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

[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 Sánchez (2018) focuses on other strategic responses to the same targeted voucher policy.

[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 instance, 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 $T' = (0, 1)$.

possible market configurations. Considering that Chilean educational markets are typically comprised by tens, and sometimes hundreds, of schools, the task of solving for equilibria quickly becomes computationally intractable. To overcome such difficulties, I adapt the concept of fully cursed equilibrium (Eyster and Rabin, 2005) to my setting. Such notion of equilibria recognizes that players have limited capabilities to evaluate counterfactual situations as the number of players and contingencies grows. Furthermore, it not only adds parsimony and computational tractability to the model, but also is a more realistic representation of the play in large discrete-continuous games (Kagel and Levin, 1986; Eyster and Rabin, 2005). In my setting, fully cursedness implies that each school correctly predicts the distribution of other schools' actions, but ignores the correlation between these actions and other schools' types.

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, with a focus on schools' responses. I perform two series of counterfactual exercises. First, I examine policies that allow the use of either universal vouchers or targeted vouchers, but not both simultaneously. These exercises allow the study of the effect that each type of program (in isolation) has on school competition.

The second series of counterfactual exercises studies markets' equilibria in scenarios where both the universal and the targeted vouchers are simultaneously implemented. These counterfactuals allow the study of existing synergies among both types of vouchers.

From the first counterfactual exercise, I find that the universal voucher operates mostly through schools' fee strategies. Higher universal subsidies imply lower equilibrium fees charged to students. The targeted voucher, in turn, changes equilibria mostly through schools' program participation decisions. A higher targeted voucher attracts more schools to join the targeted voucher program in equilibrium. More interestingly, such response is heterogeneous with respect to schools' quality. The first schools that decide to join the program are of low-quality. High quality schools, on the other hand, join the program only if the subsidy is sufficiently high. These results speak directly to the evidence in Abdulkadiroglu et al. (2018), that suggest that the negative achievement effects of the Louisiana Scholarship Program they estimate are mostly due to the program attracting only low-quality private schools.

The second series of counterfactual exercises shows that the highest gains in students' welfare are obtained when both the universal and the targeted vouchers are simultaneously in place. Different combinations of subsidy amounts provide policymakers with various routes to achieve their policy goals.

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 into 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.[4] 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: program participation, 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 industrial 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 unusually large number of players (i.e schools) making 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 describes the data used in the empirical analysis, defines the educational markets, and presents descriptive statistics and stylized facts. Section 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 6 presents the estimation results. Section 7 presents the policy and counterfactual analysis, where I study the economic consequences of a series of counterfactual voucher policy scenarios. Finally, section 8 concludes.

2 Educational 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).

[4] 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).

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 fees (i.e. copayment) on top of the voucher subsidies. *Private-non-voucher* schools, that are privately managed, do not receive vouchers, and charge relatively high levels of fees. In addition, private (voucher and non-voucher) schools operate under a more lenient regulation 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-low-income student subsidy paid to public and private-voucher schools that choose to participate in the targeted voucher program.[5]

Participation in the universal voucher program is mandatory for all public and private-voucher schools. In contrast, participation in the targeted voucher program is voluntary.[6] Private-non-voucher schools are not eligible to participate in any voucher program.[7] Schools that decide to participate in the targeted voucher program receive an additional subsidy per every low-income student that they enroll, that supplements the subsidy received from the universal voucher. They are also required to charge no top-up fees to low-income students, but they can charge any amount to high-income students.

Table 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 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 fees	✗	to high-income	✓	✓
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.

[5]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.

[6]While, in principle, public schools have the choice to participate in the targeted voucher program, in practice, virtually all of them opt in.

[7]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 Data, Educational Markets, and Descriptive Statistics

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, fees, 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. I observe students' grade and school of attendance, whether the student is low- or high-income, residential address, and other characteristics such as gender and date of birth.[8] 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 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' fees. 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 fee values for all private-non-voucher schools in the country.

3.2 Educational Markets

In the Chilean context, there is no clear definition of educational markets. Students face no geopolitical boundaries within which they are forced to choose schools. Thus, in theory, a student may attend a school that is hundreds of kilometers away from her home. In practice, however, students choose schools that are close to their homes. As a result, natural geographical constraints determining distance from home to school end up (endogenously) defining the relevant markets for students and schools. Facing similar challenges, Neilson (2017) develops an algorithm that identifies educational markets in Chile. I very closely follow Neilson (2017) to define the educational markets in my sample.[9] Specifically, I start with all students in an urban center. I join the starting urban center with all of the urban centers in which the schools chosen by (at least 5% of) the students are located. If all students attend schools in the same urban center, I stop. If other urban centers are included, then I take all students in these other urban centers and redo the exercise I did for the starting sample of students. This creates a network of urban centers that constitutes a market.

[8] 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.

[9] In a related paper, Gazmuri (2015) also follows Neilson (2017) when defining markets.

Finally, and in an effort to select only predominantly large markets, I drop all markets with less than 10,000 elementary education students. I end up with 29 non-overlapping markets across the country.[10] Figure 8 in Appendix B displays a geolocated map of all educational markets within the country's territory. Figures 9-12 in Appendix B present an example of an educational market created with the geocoded data.

Table 2 presents summary statistics for 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 classified as low-income. 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 potentially have on students. Third, on average markets have 42 private-voucher schools competing with each other, and this number is 138 in the largest market. Again, this markets' feature underscores the importance of any policy change in the voucher subsidies.

Table 2: Educational Markets' Characterization

	mean	std. dev.	min	max
no. of students	23,651	13,810	10,082	59,316
% low-income 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.

3.3 Descriptive Statistics

Table 3 displays the size of the annual voucher subsidies for the years 2008–2014. 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 sizable, relative to the universal voucher, representing about 50–60% the size of the universal voucher.

[10] In this version of the paper, I use data from 28 of the 29 markets. For computational reasons, I drop the market corresponding to the capital city, Santiago.

Table 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.

Table 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. 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 low- and high-income groups, we observe that 90% of low-income students attend schools that participate in the targeted voucher program (52% public, 38% private-voucher), which means that they forcefully pay zero fees. Almost three quarters of high-income 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 fees to low-income students, and charge on average $121 per year to high-income students. Private-voucher schools that do not participate in the targeted voucher program charge on average $711. Private-non-voucher schools charge much higher fees 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 targeted 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 for the percentage of teachers holding long-term contracts.

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

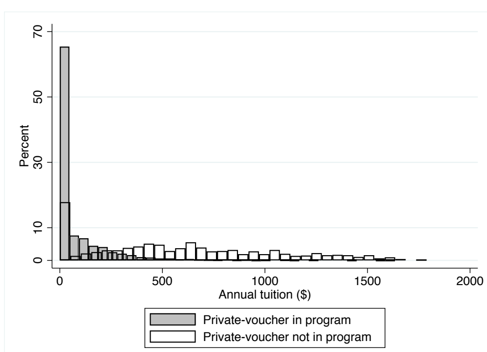
Table 4: Schools' Characteristics, by School-type

school-type:	public	private-voucher		private-non-voucher
in targeted voucher program:	yes	yes	no	no
enrollment (%)	40	35	17	8
enrollment - low-income. (%)	52	38	10	1
enrollment - high-income (%)	27	31	26	16
rural (%)	21	7	1	0
avg. annual fees (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. Fees 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 1 presents a more detailed picture of the heterogeneity in the fees charged by private-voucher schools. It plots the distribution of annual top-up fees charged by private-voucher schools, depending on whether the school participates in the targeted voucher program. The fee distribution for private-voucher schools participating in the targeted voucher program is highly right-skewed, with almost 70% of schools charging zero fees (to high-income students), and virtually no schools charging more than $500. In contrast, the fee distribution for private-voucher schools not participating in the targeted voucher program is much more disperse. Only about 20% of schools charge no fees, and there is a high share of schools charging relatively high amounts.

Figure 1: Annual Fee Distribution for Private-voucher Schools



Notes: Fee 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$/US$).

4 The Model

I develop and estimate a structural model of demand and supply of schools for Chile's elementary education. The model is static. 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, with children that are eligible for attending elementary school. Given its budget constraint, each household chooses among the schools available in the market.

In each market, schools are (exogenously) distributed within the market's area. There are three different types of schools: public, private-voucher, and private-non-voucher. Public schools are mandated to be tuition free, while both private-voucher and private-non-voucher schools are allowed to charge fees. Public and private-voucher schools receive a per-student subsidy for every student that they enroll, the universal voucher. In addition, a complementary subsidy program is available for public and private-voucher schools: a targeted voucher to economically 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 over the universal voucher for every eligible low-income student that the school enrolls, with the requirement of charging zero fees to those students. Private-voucher schools can still, however, charge a non-zero fee on the voucher to higher income students. Private-non-voucher schools do not receive any subsidy, and charge a uniform level of fees to all students.

4.1 Demand

Students have heterogeneous preferences over schools' fees, geographical proximity, a set of schools' observable (to the econometrician) characteristics, measures of school quality, and schools' unobservable (to the econometrician) characteristics. I capture heterogeneity in preferences with a set of coefficients that vary over students' observed demographic characteristics. Formally, in each market $m \in \{1, \ldots, M\}$, 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:[12][13]

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

where the superscript $\zeta \in \{L, H\}$ refers to the eligibility status of the student, i.e. low-income or high-income. Thus, p_j^ζ is school j's fees charged to students of type ζ, 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 a vector of school j's quality measures, ξ_j^ζ is the common preference that students of type ζ have for school j's unobservable (to the econometrician) characteristics, and ε_{ij} is an i.i.d. preference shock. Also, for any $\beta^\zeta \in \{\beta_2^\zeta, \beta_3^\zeta, \beta_4^\zeta, \xi_j^\zeta\}$, I let $\beta^\zeta = D_i \beta^D + (1 - D_i)\beta^{nonD}$, where $D_i = \mathbb{1}[i \text{ is low-income}]$. Similarly, $\beta_{1i} = D_i \beta_{1i}^D + (1 - D_i)\beta_{1i}^{nonD}$, where $\beta_{1i}^D = \beta_1^D + \sum_r z_{ir}\beta_{1r}^D$ and $\beta_{1i}^{nonD} = \beta_1^{nonD} + \sum_r z_{ir}\beta_{1r}^{nonD}$, with z_{ir} being student i's demographic characteristic r.

Note that the fees that school j charges to student i, p_j^ζ, depends on whether the student is low-income,

[12] My demand model builds on the demand models in Neilson (2017), Gazmuri (2015), Arcidiacono et al. (2016), Cuesta et al. (2017), and Ferreyra and Kosenok (2017).

[13] I suppress the market subscript m for ease of exposition.

and on whether the school participates in the targeted voucher program. Specifically,

$$p_j^{\zeta} = \tau_j(1 - D_i)p_j^1 + (1 - \tau_j)p_j^0,$$

where $\tau_j = \mathbb{1}[j \text{ participates in the targeted program}]$, p_j^1 is school j's counterfactual fees in the case the school participates in the targeted program, and p_j^0 is school j's counterfactual fees in the case the school does not participate in the targeted program.

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

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

4.2 Supply

Public, private-voucher, and private-non-voucher schools are differentially affected by the institutional aspects of the voucher subsidies. Public schools are mandated both to join the targeted program and to charge no fees. Private-voucher schools choose whether to participate in the program, as well as the top-up fees they charge. Private-non-voucher schools are not eligible to participate in the targeted program, and choose their fees.

I model private-voucher schools' decisions only.[14] I assume private-voucher schools make their strategic decisions in the context of a static game of incomplete information. Let $a_j = (\tau_j, p_j^1, p_j^0)$ denote the actions available to school j, where $\tau_j \in \{0, 1\}$ is school j's decision to participate in the targeted program, $p_j^1 \geq 0$ is the price the school sets if it joins the program, and $p_j^0 \geq 0$ is the price it sets if it does not join the program. Also, let κ_j be school j's fixed cost of participating in the targeted program. In addition, let c_j^1 and c_j^0 be the school's marginal costs of educating a student in the in-the-program and in the not-in-the-program regimes, respectively.[15] Collect all of the costs terms in $t_j = (\kappa_j, c_j^1, c_j^0)$. I assume t_j is private information. Finally, denote school j's pure strategy as $s_j(t_j) = \big(\tau_j(t_j), p_j^1(t_j), p_j^0(t_j)\big)$.

Private-voucher school j of type t_j chooses its actions to maximize expected profits (Urquiola and Verhoogen, 2009; Barrera-Osorio et al., 2017; Neilson, 2017). That is,

$$\max_{\tau_j \in \{0,1\}, p_j^1 \geq 0, p_j^0 \geq 0} \quad E_{t_{-j}}\left[\tau_j\left(\Pi_j^1(a_j, s_{-j}(t_{-j}); t) - \kappa_j\right) + (1 - \tau_j)\Pi_j^0(a_j, s_{-j}(t_{-j}); t)\right],$$

[14]Public schools do not make choices in either margin. Also, for simplicity, I abstract from modeling private-non-voucher schools' tuition decisions.

[15]As is noted below, c_j^1 is a vector that contains two elements, namely $c_j^1 = (c_j^{1,H}, c_j^{1,L})$, where $c_j^{1,H}$ is the marginal cost of educating a high-income student, and $c_j^{1,L}$ is the marginal cost of educating a low-incoe student, in the case the school joins the targeted program.

where,

$$\begin{aligned}
\Pi_j^1(a_j, s_{-j}(t_{-j}); t) &= (p_j^1 + v^u - c_j^{1,H}) \sum_i (1 - D_i) P_{ij}(a_j, s_{-j}(t_{-j}); t) \\
&\quad + (v^u + v^t - c_j^{1,L}) \sum_i D_i P_{ij}(a_j, s_{-j}(t_{-j}); t), \\
\Pi_j^0(a_j, s_{-j}(t_{-j}); t) &= (p_j^0 + v^u - c_j^0) \sum_i P_{ij}(a_j, s_{-j}(t_{-j}); t).
\end{aligned}$$

The expression for school j's expected profits consists of two parts. The first part, $(\Pi_j^1 - \kappa_j)$, is the net (of participation cost) profits obtained when deciding to join the program. In that regime, for each high-income student, the school perceives the tuition it charges, p_j^1, the universal voucher, v^u, and it incurs in a marginal cost $c_j^{1,H}$. For each low-income student, the school perceives the universal and targeted vouchers, $v^u + v^t$, and it incurs in a marginal cost $c_j^{1,L}$. The school also incurs in a fixed cost of participating in the program, κ_j. The second part of the school's objetive function, Π_j^0, is the profits obtained when deciding not to join the targeted program. In such case, for each student, regardless of her socioeconomic status, the school perceives the tuition it charges, p_j^0, the universal voucher, v^u, and it incurs in a marginal cost c_j^0.[16]

The standard equilibrium notion for this type of games is Bayesian Nash equilibrium (BNE). Such equilibrium concept assumes that schools do not observe the types of their opponents but know the probability distribution from which each type is drawn from. Moreover, schools expect that their opponents choose their actions according to their types. That is, schools anticipate a correlation between other schools' actions and types.

For large discrete-continuous game, BNE involves the computation of many counterfactual equilibria to form the expected utility function of each player. This procedure quickly becomes expensive, computationally but also in terms of players' cognition.

For illustration, note that in a BNE framework, school j's belief of the expected profits in the not-in-the-program regime is,

$$E_{t_{-j}}^{BN}\left[\Pi_j^0(a_j, s_{-j}(t_{-j}); t)\right] = \int_{\mathcal{S}_{t_{-j}}} (p_j^0 + v^u - c_j^0) \sum_i P_{ij}(a_j, s_{-j}(t_{-j}); t) dF(t_{-j}|t_j),$$

which, using iterated expectations, can be rewritten as,

$$E_{t_{-j}}^{BN}\left[\Pi_j^0(a_j, s_{-j}(t_{-j}); t)\right] = \sum_{\tau_{-j}} \left[\int_{\mathcal{S}_{t_{-j}}} (p_j^0 + v^u - c_j^0) \sum_i P_{ij}(a_j, s_{-j}(t_{-j}); t) dG(c_j^1, c_j^0|\tau_{-j}; t_j)\right] Pr(\tau_{-j}|t_j),$$

where the term inside the square brackets is the conditional expected profits in the not-in-the-program regime for a particular value of τ_{-j} (i.e. other schools' program participation decisions), and the summation takes the expectation of those profits over all possible values of τ_{-j}. Note that, for a given τ_{-j}, conditional expected profits are a function of equilibrium counterfactual prices, $\big(p^1(\tau_j = 0, \tau_{-j}), p^0(\tau_j = 0, \tau_{-j})\big)$. Thus, to compute the expected profits in the not-in-the-program regime, we first need to obtain the equilibrium prices and the corresponding conditional expected profits for each τ_{-j}. Then, we take the weighted sum of all conditional expected profits, where the weights are the probabilities of occurrence of each τ_{-j}. This

[16]See appendix D for a discussion on the supply side modeling assumptions.

is a complicated task for large games. For instance, in a market with $J-1=10$, 1,024 different sets of equilibrium prices need to be obtained. In a market with $J-1=20$, 1,048,576 different sets of equilibrium prices need to be obtained. And in a market of similar size to the ones I study in this paper, with $J-1=40$, $5.498e^{11}$ different sets of equilibrium prices need to be obtained.[17] This procedure becomes computationally intractable very fast.

I solve the computational intractability related to BNE by recognizing that it is unrealistic to assume that schools can store large dimensions of counterfactuals to form their best responses.[18] In fact, there is a large empirical literature showing that people do not understand the strategy of their opponents state by state.[19] As a result, standard equilibrium concepts, that assume that players are perfectly rational in their ability to form correct expectations about other players' behavior and in their ability to select best responses to their expectations, no longer apply.

I thus depart from the standard Bayesian Nash equilibrium framework, and instead assume that schools are fully cursed (Eyster and Rabin, 2005).[20] As a first step to defining fully cursed equilibrium in this game, let $\bar{s}_{-j}(t_j) \equiv \int_{\mathcal{S}_{t_{-j}}} s_{-j}(t_{-j})dF(t_{-j}|t_j)$, where $\mathcal{S}_{t_{-j}}$ is the space of other schools' types, and $F(t_{-j}|t_j)$ is the conditional probability distribution of other schools' types. That is, $\bar{s}_{-j}(t_j)$ is the average strategy of other players, averaged over other players' types, from the perspective of school j of type t_j.

When schools are fully cursed, they (mistakenly) believe that each type profile of the other players plays the same action profile, $\bar{s}_{-j}(t_j)$, whenever they play $s_{-j}(t_{-j})$. Consequently, fully cursed school j's beliefs are such that,

$$
\begin{aligned}
E^{FC}_{t_{-j}}\left[\Pi^1_j(a_j, s_{-j}(t_{-j}); t)\right] &= \Pi^1_j(a_j, \bar{s}_{-j}(t_j); t_j) \\
&= (p^1_j + v^u - c^{1,H}_j)\sum_i (1-D_i)P_{ij}(a_j, \bar{s}_{-j}(t_j); t_j) \\
&\quad + (v^u + v^t - c^{1,L}_j)\sum_i D_i P_{ij}(a_j, \bar{s}_{-j}(t_j); t_j), \\
E^{FC}_{t_{-j}}\left[\Pi^0_j(a_j, s_{-j}(t_{-j}); t)\right] &= \Pi^0_j(a_j, \bar{s}_{-j}(t_j); t_j) \\
&= (p^0_j + v^u - c^0_j)\sum_i P_{ij}(a_j, \bar{s}_{-j}(t_j); t_j).
\end{aligned}
$$

Define $\Pi_j(a_j, \bar{s}_{-j}(t_j); t_j) \equiv \tau_j\left(\Pi^1_j(a_j, \bar{s}_{-j}(t_j); t_j) - \kappa_j\right) + (1-\tau_j)\Pi^0_j(a_j, \bar{s}_{-j}(t_j); t_j)$, i.e. the expected profits for fully cursed school j of type t_j.

Definition 4.1 *In the static game of incomplete information described above, a pure strategy profile $\bar{s}^* = (\bar{s}^*_1 \ldots, \bar{s}^*_J)$ is a **fully cursed equilibirum** if for each j and for each t_j,*

$$a^*_j \in \arg\max_{a_j} \Pi_j(a_j, \bar{s}^*_{-j}(t_j); t_j).$$

Note that, in a fully cursed equilibrium, each school correctly predicts the probability distribution over

[17] In general, 2^{J-1} equilibrium prices need to be computed.

[18] See related discussion in Jehiel (2005) about the impossibility of a chess player to know what the opponent might do at every board position.

[19] See, e.g., Kagel and Levin (1986, 2002), Thaler (1988), Holt and Sherman (1994), Converse (2000), Charness and Levin (2009), Esponda and Vespa (2014).

[20] See appendix C for a revision of the theoretical and empirical motivations for fully cursed equilibrium.

its opponents' actions, but ignores the correlation between other schools' actions and their types. As a consequence, fully cursed equilibrium does not suffer from the curse of dimensionality problem present in BNE, since only one set of equilibrium prices (and program participation decisions) need to be computed, regardless of the number of opponents.

When schools' types are independent—meaning that for each t_j, t'_j, t_{-j}, $F(t_{-j}|t_j) = F(t_{-j}|t'_j)$—then each type of player j as well as any type of player k share common beliefs about the strategy of any player $l \neq j, k$; namely, $\bar{s}_l(t_j) = \bar{s}_l(t'_j) = \bar{s}_l(t_k) = \bar{s}_l(t'_k)$, for any t_j, t'_j, t_k, t'_k.

School j's best-response functions satisfy the following set of (in)equations,

$$\begin{aligned}
p^1_j(a_j, \bar{s}_{-j}(t_j); t_j) &\geq c^{1,H}_j - v^u - \frac{\sum_i (1 - D_i) P_{ij}(a_j, \bar{s}_{-j}(t_j); t_j)}{\sum_i (1 - D_i) \frac{\partial P_{ij}(a_j, \bar{s}_{-j}(t_j); t_j)}{\partial p^1_j}}, && (2)\\
0 &= p^1_j(a_j, \bar{s}_{-j}(t_j); t_j) \frac{\partial \Pi^1_j(a_j, \bar{s}_{-j}(t_j); t_j)}{\partial p^1_j}, && (3)\\
p^1_j(a_j, \bar{s}_{-j}(t_j); t_j) &\geq 0, && (4)\\
p^0_j(a_j, \bar{s}_{-j}(t_j); t_j) &\geq c^0_j - v^u - \frac{\sum_i P_{ij}(a_j, \bar{s}_{-j}(t_j); t_j)}{\sum_i \frac{\partial P_{ij}(a_j, \bar{s}_{-j}(t_j); t_j)}{\partial p^0_j}}, && (5)\\
0 &= p^0_j(a_j, \bar{s}_{-j}(t_j); t_j) \frac{\partial \Pi^0_j(a_j, \bar{s}_{-j}(t_j); t_j)}{\partial p^0_j}, && (6)\\
p^0_j(a_j, \bar{s}_{-j}(t_j); t_j) &\geq 0, && (7)\\
\tau_j(a_j, \bar{s}_{-j}(t_j); t_j) &= \mathbb{1}\left\{ \left(\Pi^1_j(a_j, \bar{s}_{-j}(t_j); t_j) - \kappa_j \right) - \Pi^0_j(a_j, \bar{s}_{-j}(t_j); t_j) > 0 \right\}, && (8)
\end{aligned}$$

where equations (2) and (5) are the first order conditions for p^1_j and p^0_j, respectively, equations (3) and (6) are the corresponding complementary slackness conditions, and equations (4) and (7) are the corresponding non-negativity constraints. Note that p^1_j is a function of the marginal cost of educating a high-income student in the in-the-program regime, $c^{1,H}_j$, the universal voucher, v^u, and the markup the school charges over the price under perfect competition with subsidy, which is the last term on the right-hand side of equation (2). This markup term depends on the price-elasticity of the demand of high-income students only, and not on that of low-income students, since it is only high-income students that face this price. Also, the markup is lower the more price-elastic is the demand, as is usual in imperfect competitive markets. Note, too, that the universal voucher enters equation (2) linearly, and therefore acts as a marginal cost reducer. Similarly, p^0_j depends on the marginal cost of educating a student in the not-in-the-program regime, the universal voucher, and a markup term. Notice that the marginal cost c^0_j does not vary with the socioeconomic status of the student, and the markup term depends on the price-elasticity of the demand of all students, since all students face this price. Equation (8) is the optimality condition for τ_j, and states that school j joins the targeted program if and only if the profits of joining the program net of program participation costs are greater than the profits of not joining the program.

As a final note on schools' best-response functions, notice that prices depend on the universal voucher but not on the targeted voucher. In contrast, the program participation decision depends on both the universal and the targeted vouchers.

5 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.

5.1 Demand

5.1.1 Schools' Quality

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 Neilson (2017), and use test scores data to recover a proxy measure of schools' quality (or schools' test scores productivity).[21] Specifically, I estimate the following regression model:

$$y_{ij} \quad = \quad \alpha_1' x_i + \alpha_2' X_j^{\alpha} + q_j + \upsilon_{ij}, \tag{9}$$

where y_{ij} is the test score of student i in school j, x_i is a vector of student's observed characteristics, Z_j is a vector of the school's observed characteristics, and q_j groups all school j's unobserved characteristics that matter for tests scores, which I call *unobserved quality*. Finally, υ_{ij} is an idiosyncratic error term.

For estimation, I proceed in two steps. In the first step, I run OLS on,

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

and recover $\hat{\alpha}_1$ and $\hat{\rho}_j$. In the second step, I use the estimated $\hat{\rho}_j$ to recover estimates of α_2 and q_j, by running OLS on

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

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

The identification of schools' fixed effects, ρ, rests on the assumptions of selection on observables and of nonexistence of peer effects. This assumption is restrictive, but does not differ much from standard value-added models (Chetty et al., 2014a,b, 2016). Similar assumptions have been made in Neilson (2017), Allende (2019), and Allende et al. (2019). In practice, I include a large set vector of students' demographics in x_i, to minimize the potential bias from selection on unobservables.

5.1.2 Preferences

I estimate demand parameters following Goolsbee and Petrin (2004) and Hackmann (2019). The estimation is done in two steps. First, I use Maximum Likelihood to estimate distance and preference parameters

[21] See also Allende (2019) and Allende et al. (2019).

capturing taste heterogeneity. 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, and mean utilities, δ_j^{ζ}. Heterogeneity in preferences is captured by a set of students' observable demographic characteristics. Mean utilities vary at the school-student's socioeconomic status, and absorb the remaining preference components from the indirect utility function,

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

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:

$$\hat{\delta}_j^{\zeta} = \beta_1^{\zeta} p_j^{\zeta} + \beta_3^{\zeta\prime} X_j^{\beta} + \beta_4^{\zeta\prime} q_j + \xi_j^{\zeta}. \tag{10}$$

As is usual in demand models, I assume that X_j^{β} is uncorrelated with ξ_j^{ζ}. However, $p_j^{\zeta} = \tau_j(1-D_i)p_j^1 + (1-\tau_j)p_j^0$ is endogenous, since both τ_j and p_j are chosen by taking into account the realization of ξ_j^{ζ}. I overcome this endogeneity issue by estimating equation (10) by 2SLS, using BLP-type of instruments (Berry et al., 1995).

Identification is ensured as long as the variables used to instrument for tuition are valid instruments, in the sense that they 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 schools make their program participation and tuition decisions by taking into account their competitors' characteristics, but 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.[22]

[22] 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.

5.2 Supply

I parameterize schools' costs structure as follows,

$$\begin{aligned} c_j^{1,H} &\sim N\left(X_j^{\omega}\omega_{c^{1,H}}, \sigma^2_{c^{1,H}}\right) \\ c_j^{1,L} &\sim \omega_{c^{1,L}} c_j^{1,H} \\ c_j^{0} &\sim N\left(X_j^{\omega}\omega_{c^{0}}, \sigma^2_{c^{0}}\right) \\ \kappa_j &\sim N\left(X_j^{\omega}\omega_{\kappa}, \sigma^2_{\kappa}\right), \end{aligned}$$

where X_j^{ω} is a vector of observable (to the econometrician) variables affecting marginal and fixed costs, respectively. $\omega_{c^{1,H}}$, $\omega_{c^{1,L}}$, $\omega_{c^{0}}$, and ω_{κ} are parameters to be estimated. In particular, $\omega_{c^{1,L}}$ is a scalar denoting the relative weight between $c_j^{1,L}$ and $c_j^{1,H}$.

I combine demand estimates and schools' optimality conditions (2)–(8) to recover the parameters governing schools' costs structure. Let $\bar{s}_j(\bar{s}_{-j}) \equiv \int_{T_j} s_j(\bar{s}_{-j}; t_j) dF(t_j)$ be school j's fully cursed strategy, where T_j is the space of school j's types. Thus,

$$\begin{aligned} \bar{p}_j^1(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j} \mid X_j^{\omega}) &= \left[1 - \Phi\left(\frac{-\left(X_j^{\omega}\omega_{c^{1,H}} - v^u - \frac{\sum_i (1-D_i) P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\sum_i (1-D_i) \frac{\partial P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\partial p_j}}\right)}{\sigma_{c^{1,H}}}\right)\right] \\ &\quad \left[X_j^{\omega}\omega_{c^{1,H}} - v^u - \frac{\sum_i (1-D_i) P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\sum_i (1-D_i) \frac{\partial P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\partial p_j}}\right. \\ &\quad \left. + \sigma_{c^{1,H}} \lambda\left(\frac{-\left(X_j^{\omega}\omega_{c^{1,H}} - v^u - \frac{\sum_i (1-D_i) P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\sum_i (1-D_i) \frac{\partial P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\partial p_j}}\right)}{\sigma_{c^{1,H}}}\right)\right], \end{aligned} \tag{11}$$

where $\lambda(\nu) = \frac{\phi(\nu)}{1-\Phi(\nu)}$ is the inverse Mill's ratio, and $\phi(\cdot)$ and $\Phi(\cdot)$ are the standard normal density and probability distribution, respectively. Note that,

$$P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}) = \frac{e^{V_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}}{\sum_k e^{V_{ik}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}},$$

where, $V_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}) = \beta_{1i}\left(\bar{\tau}_j(1-D_i)\bar{p}_j^1 + (1-\bar{\tau}_j)\bar{p}_j^0\right) + \beta_2^{\zeta} d_{ij} + \beta_3^{\zeta\prime} X_j + \beta_4^{\zeta} q_j + \xi_j^{\zeta}$. Also,

$$\frac{\partial P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\partial p_j} = \beta_{1i} P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}) \left(1 - P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})\right).$$

Similarly,

$$\bar{p}_j^0(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j} \mid X_j^\omega) = \left[1 - \Phi\left(\frac{-\left(X_j^\omega \omega_{c^0} - v^u - \frac{\sum_i P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\sum_i \frac{\partial P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\partial p_j}}\right)}{\sigma_{c^0}}\right)\right]$$

$$\left[X_j^\omega \omega_{c^0} - v^u - \frac{\sum_i P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\sum_i \frac{\partial P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\partial p_j}}\right.$$

$$\left. + \sigma_{c^0} \lambda \left(\frac{-\left(X_j^\omega \omega_{c^0} - v^u - \frac{\sum_i P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\sum_i \frac{\partial P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\partial p_j}}\right)}{\sigma_{c^0}}\right)\right]. \tag{12}$$

Finally,

$$\bar{\tau}_j(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j} \mid X_j^\omega) = \Phi\left(\frac{\Pi_j^1(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}) - \Pi_j^0(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}) - X_j^\omega \omega_\kappa}{\sigma_\kappa}\right), \tag{13}$$

where,

$$\begin{aligned}
\Pi_j^1(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}) &= \left(\bar{p}_j^1(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j} \mid X_j^\omega) + v^u - X_j^\omega \omega_{c^{1,H}}\right) \sum_i (1 - D_i) P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}) \\
&\quad + \left(v^u + v^t - \omega_{c^{1,L}} X_j^\omega \omega_{c^{1,H}}\right) \sum_i D_i P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}), \\
\Pi_j^0(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}) &= \left(\bar{p}_j^0(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j} \mid X_j^\omega) + v^u - X_j^\omega \omega_{c^0}\right) \sum_i P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j}).
\end{aligned}$$

Implicit is the assumption of conditional independence of the costs elements, both within and across schools, i.e. $c_j^{1,H} \perp\!\!\!\perp c_{j'}^{1,L} \perp\!\!\!\perp c_{j''}^0 \perp\!\!\!\perp \kappa_{j'''} \mid X^\omega$ for any j, j', j'', j''', where $\perp\!\!\!\perp$ denotes statistical independence, and X^ω is the vector collecting all X_j^ω.

Identification proceeds as follows. $\bar{p}_j^1(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j} \mid X_j^\omega)$ is the conditional mean of a normal censored (from below at zero) variable. Normality ensures the identification of $\omega_{c^{1,H}}$ and $\sigma_{c^{1,H}}$. Moreover, the model is overidentified, because theory imposes the coefficient accompanying $\frac{\sum_i (1-D_i) P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\sum_i (1-D_i) \frac{\partial P_{ij}(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})}{\partial p_j}}$ to be equal to one. A similar argument identifies ω_{c^0} and σ_{c^0}. From the probit model for $\bar{\tau}_j(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j} \mid X_j^\omega)$, variation in X_j^ω identifies $\frac{\omega_\kappa}{\sigma_\kappa}$. The coefficients accompanying $\Pi_j^1(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})$ and $\Pi_j^0(\bar{s}_j(\bar{s}_{-j}), \bar{s}_{-j})$ are constrained to be one by the theory, which allows the identification of two additional parameters, σ_κ and $\omega_{c^{1,L}}$.

I utilize a Generalized Method of Moments (GMM) routine to estimate the parameters in the supply. I combine GMM with a Mathematical Program with Equilibrium Constraints (MPEC; Dube et al., 2012; Su and Judd, 2012) approach, that minimizes the objective function (i.e. moment conditions) subject to constraints that endogenous variables are consistent with the model's equilibrium conditions.

The sample moments I choose to construct the GMM objective function are the following,

$$g_{p^1} = \frac{1}{\sum_{m=1}^{M} J_m} \sum_{m=1}^{M} \sum_{j=1}^{J_m} \tau_{j,m} X_j^{\omega\prime} \left(p_{j,m} - \bar{p}^1_{j,m}(\bar{s}_{j,m}(\bar{s}_{-j,m}), \bar{s}_{-j,m} \mid X_j^{\omega}) \right), \tag{14}$$

$$g_{p^0} = \frac{1}{\sum_{m=1}^{M} J_m} \sum_{m=1}^{M} \sum_{j=1}^{J_m} (1-\tau_{j,m}) X_j^{\omega\prime} \left(p_{j,m} - \bar{p}^0_{j,m}(\bar{s}_{j,m}(\bar{s}_{-j,m}), \bar{s}_{-j,m} \mid X_j^{\omega}) \right), \tag{15}$$

$$g_{\tau} = \frac{1}{\sum_{m=1}^{M} J_m} \sum_{m=1}^{M} \sum_{j=1}^{J_m} X_j^{\omega\prime} \left(\tau_{j,m} - \bar{\tau}_{j,m}(\bar{s}_{j,m}(\bar{s}_{-j,m}), \bar{s}_{-j,m} \mid X_j^{\omega}) \right), \tag{16}$$

$$g_{p^1_m} = \frac{1}{M} \sum_{m=1}^{M} \left(\frac{1}{J_m} \sum_{j=1}^{J_m} \tau_{j,m} \left(p_{j,m} - \bar{p}^1_{j,m}(\bar{s}_{j,m}(\bar{s}_{-j,m}), \bar{s}_{-j,m} \mid X_j^{\omega}) \right) \right), \tag{17}$$

$$g_{p^0_m} = \frac{1}{M} \sum_{m=1}^{M} \left(\frac{1}{J_m} \sum_{j=1}^{J_m} (1-\tau_{j,m}) \left(p_{j,m} - \bar{p}^0_{j,m}(\bar{s}_{j,m}(\bar{s}_{-j,m}), \bar{s}_{-j,m} \mid X_j^{\omega}) \right) \right), \tag{18}$$

$$g_{\tau_m} = \frac{1}{M} \sum_{m=1}^{M} \left(\frac{1}{J_m} \sum_{j=1}^{J_m} \left(\tau_{j,m} - \bar{\tau}_{j,m}(\bar{s}_{j,m}(\bar{s}_{-j,m}), \bar{s}_{-j,m} \mid X_j^{\omega}) \right) \right), \tag{19}$$

$$g_{q^u_m} = \frac{1}{M} \sum_{m=1}^{M} \left(\frac{1}{J_m} \sum_{j=1}^{J_m} \left(\tau_{j,m} q^u_{j,m} - \bar{\tau}_{j,m}(\bar{s}_{j,m}(\bar{s}_{-j,m}), \bar{s}_{-j,m} \mid X_j^{\omega}) q^u_{j,m} \right) \right), \tag{20}$$

$$g_{q^t_m} = \frac{1}{M} \sum_{m=1}^{M} \left(\frac{1}{J_m} \sum_{j=1}^{J_m} \left(\tau_{j,m} q^t_{j,m} - \bar{\tau}_{j,m}(\bar{s}_{j,m}(\bar{s}_{-j,m}), \bar{s}_{-j,m} \mid X_j^{\omega}) q^t_{j,m} \right) \right), \tag{21}$$

where $p_{j,m}$ and $\tau_{j,m}$ are the actual prices and participation decisions observed in the data, and J_m is the total number of private-voucher schools in market m. Sample moments (14)–(16) are implied by the orthogonality conditions between the error terms and the instruments X^{ω}, in the models for $p^1_{j,m}$, $p^0_{j,m}$, and $\tau_{j,m}$. These moments are sufficient to consistently estimate all supply parameters. Nonetheless, I add market-level moments (17)–(21) to improve the fit of the model in each market. Sample moments (17)–(19) minimize the difference between actual market-averages and market-averages implied by the model for $p^1_{j,m}$, $p^0_{j,m}$, and $\tau_{j,m}$. Sample moments (20) and (21) minimize the difference between actual market-averages and market-averages implied by the model for two measures of school quality for schools participating in the targeted program.

Vertically stack sample moments in $g(\omega, \bar{s}) = (g_{p^1}, g_{p^0}, g_{\tau}, g_{p^1_m}, g_{p^0_m}, g_{\tau_m}, g_{q^u_m}, g_{q^t_m})$. Also. let

$$W = diag\left(\left(\frac{1}{\sum_{m=1}^{M} J_m} X^{\omega\prime} X^{\omega} \right)^{-1}, \left(\frac{1}{\sum_{m=1}^{M} J_m} X^{\omega\prime} X^{\omega} \right)^{-1}, \left(\frac{1}{\sum_{m=1}^{M} J_m} X^{\omega\prime} X^{\omega} \right)^{-1}, I_5 \right),$$

where $diag(v)$ denotes a matrix with v in its diagonal and zeros elsewhere, and I_5 is the identity matrix of dimension 5. Finally, let $h(\omega, \bar{s})$ be the $3\sum_{m=1}^{J_m} \times 1$ vector of equilibrium conditions (11)–(13).

The GMM-MPEC problem is,

$$\min_{\omega, \bar{s}} \quad g(\omega, \bar{s})' W g(\omega, \bar{s}),$$

subject to,

$$h(\omega, \bar{s}).$$

The MPEC algorithm simultaneously searches over parameters ω and endogenous variables $\bar{s}$, to minimize the objective function subject to equilibrium conditions to be satisfied. As in many industrial organization applications, this problem is sparse, as the equilibrium conditions need to hold for each market separately. The sparsity of the problem allows to find a solution relatively quickly compared to other approaches such as Nested Fixed Point algorithms, that require solving for equilibria for each guess of the parameters (Dube et al., 2012; Su and Judd, 2012). In practice, I implement the GMM-MPEC routine in MATLAB/TOMLAB using the professional solver KNITRO. I provide the automatic differentiated Jacobian and (approximated) Hessian using TOMLAB's TomSym package.

6 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).[23]

Tables 5 and 6 present summary statistics for the variables used in estimation. Table 5 describes variables at the student level. On average, a student travels 3.05 km. to her school of choice. 53% of students are economically 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 income of $1,902.91 or higher.

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

Table 5: Summary Statistics - Student Level

	mean	std. dev.	median
distance to school of choice (km.)	3.05	9.49	1.39
low-income	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 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 about half 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 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$/US$).

6.1 Demand Estimates

Tables 7 and 8 present the results of estimating the test scores equation (9). Table 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.[24] 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.[25] Low-income students score lower than higher-income students. 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.

[24] 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.

[25] 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 7: Test Scores Regressions - Step 1

variable	coef.	std. err.
male	-0.057***	0.005
low-income	-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 8 shows the results for the second step of the estimation procedure of the test scores equation (9), 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 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	

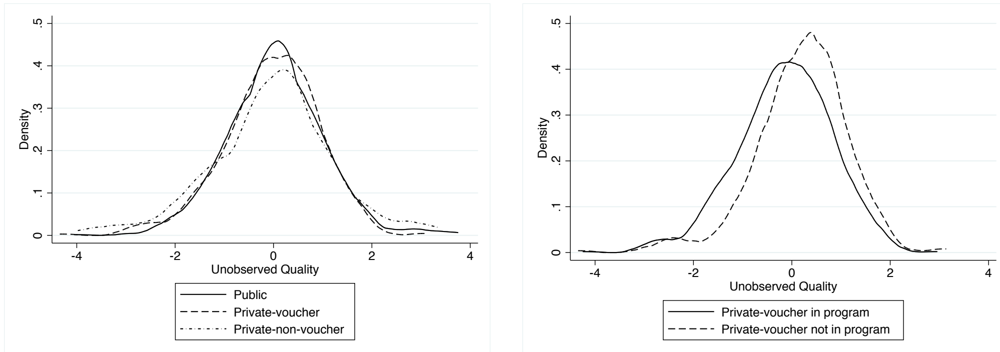
Notes: Estimated coefficients from second step of test scores regressions (at the school level). Market fixed-effects are included. * denotes significance at the 90% level, ** denotes significance at the 95% level, *** denotes significance at the 99% level.

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 2 and 3 display the distributions of the estimated schools' unobserved and teacher quality, respectively. Panel A in Figure 2 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 2: Schools' Unobserved Quality Distribution

A. All Schools B. Private-voucher Schools

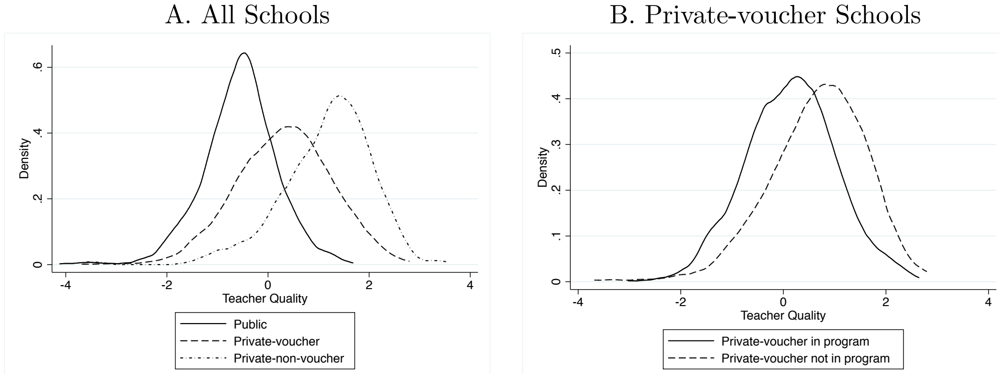


Notes: This figure plots kernel density estimates for the distribution of schools' estimated unobserved quality.

Figure 3 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 2, 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: 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 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 fees, 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 fees.[26] Also, low-income students have in general more negative coefficients for fees, suggesting a greater dislike for higher prices for this group of students. 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 high-income students may have stronger preferences for quality than low-income students.

Table 9: Estimates for Demand Model

	high-income		low-income	
	coef.	std. err.	coef.	std. err.
annual fees/100	-0.177	0.004	-0.055	0.007
annual fees/100 × mother's education: primary	-0.095	0.011	-0.196	0.008
annual fees/100 × mother's education: secondary	0.083	0.010	-0.037	0.002
annual fees/100 × mother's education: college	0.138	0.010	0.003	0.002
annual fees/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". The variables for fees is instrumented with non-price attributes of other schools in the market in the 2SLS estimation. Fee 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$/US$).

6.2 Supply Estimates

Table 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

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

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. Lastly, schools that participate in the targeted program have on average \$315.8 lower marginal costs. In other words, the marginal cost of educating high-income students is about three hundred dollars lower than the marginal cost of educating both low-income and high-income 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.

Table 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: All marginal and fixed cost parameters were estimated using a GMM-MPEC 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\$).

Table 11 presents the predicted mean and median marginal and program participation costs for schools, which were constructed using the estimates presented in Table 10. The average (median) marginal cost of educating a high-income student is \$237 (\$279), about half as much as the average (median) marginal cost of educating both low- and high-income 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

[27]Recall from section 4.2 that the marginal cost of educating high-income students is identified from schools participating in the targeted program, whereas the marginal cost of educating both low- and high-income students is identified from schools that do not participate in the program.

the participation in the program (e.g. preference for attracting economically disadvantaged students), or to efficiency gains associated to participation.

Table 11: Predicted Costs

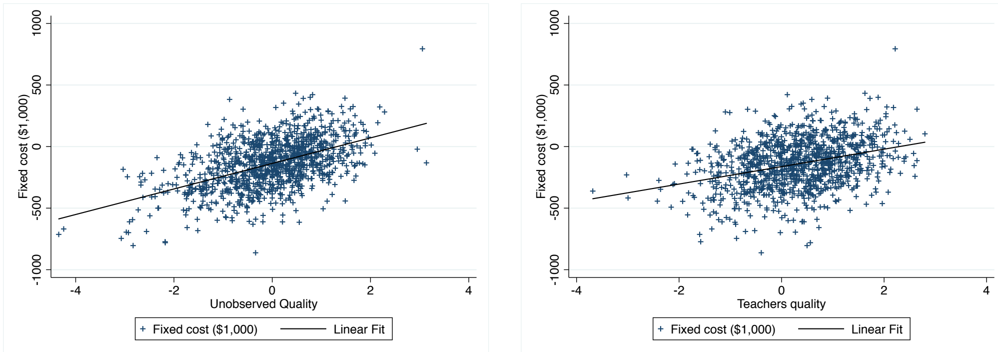
	mean	median
marginal cost ($):		
c_j^H	237	279
$c_j^{L\&H}$	553	595
participation cost ($1,000):		
κ_j	-158	-156

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-MPEC 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 4 complements the results for the program participation cost from Table 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. This is an important empirical result, which has not yet 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 show evidence suggesting that such finding may be due to only low-quality private schools joining the program.

Figure 4: 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-MPEC 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$/US$).

7 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 top-up fee responses to policies. I also investigate whether and how such responses affect students' school choices.

I perform two series of counterfactual exercises. First, I analyze markets' equilibria in scenarios where either only universal or only targeted vouchers are allowed. Results from this counterfactual exercise are relevant for policymakers considering introducing voucher programs. They provide a somewhat detailed picture of the mechanisms through which a universal and a targeted voucher program operate on markets' equilibria and outcomes. Thus, counterfactual results may help governments choose the type of program that produces the outcomes most closely aligned to the officials' goals.

Second, I combine different amounts of the universal and targeted vouchers in a context where both types of program are simultaneously implemented. This counterfactual exercise allows policymakers to fine tune the subsidies' amounts to achieve any particular desired outcome. The simulated context is particularly applicable to the Chilean case; however, it also informs governments in other countries that are open to simultaneously implement different policies to achieve their policy goals.

7.1 Only Universal/Only Targeted Voucher Program

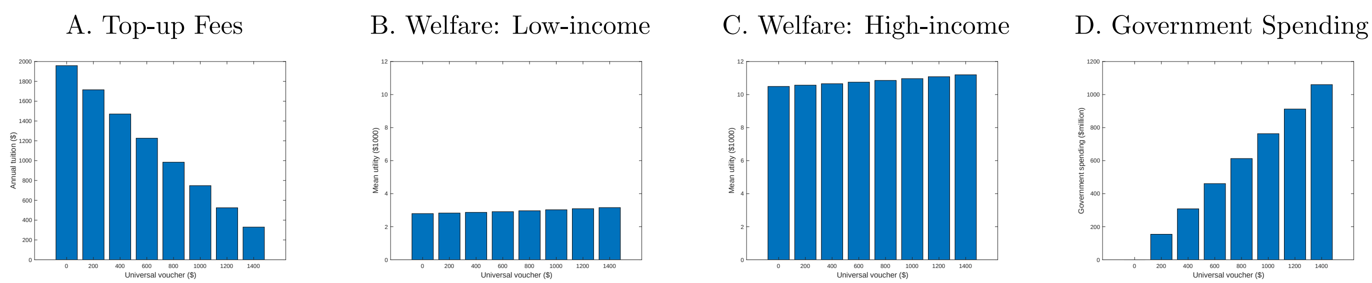
In analyze markets' equilibria in scenarios where only one of universal or targeted voucher programs are allowed. For each scenario, I simulate the estimated model varying the subsidy amount to either $0, $200, $400, $600, $800, $1,000, $1,200, or $1,400.

7.1.1 Only Universal Voucher Program

I study private-voucher schools' participation in the targeted voucher program, top-up fees, as well as students' welfare and government's spending under counterfactual scenarios where only the universal voucher program is in place and the per-student subsidy varies between \$0 and \$1,400.

Figure 5 presents the results of the counterfactual exercises. Panel A shows private-voucher schools' responses on the fees they charge to students as a function of the per-student universal subsidy amount. As suggested by equation (5), fees charged by schools linearly decrease as the subsidy increases. High average fees of almost \$2,000 are found when no subsidy is provided to schools. On the contrary, fees of about \$300 are set on average by schools when the scenario with the highest subsidy (\$1,400) is simulated. Panels B and C display the average welfare effects on students of each counterfactual scenario, for low-income and high-income students, respectively. Welfare units are in \$1,000.[28] Consistent with utility being decreasing in top-up fees, both low-income and high-income students' welfare increases as the universal subsidy increases, which induces schools to lower their fees (panel A). Finally, Panel D shows government's total spending on vouchers as a function of the subsidy amount. Not surprisingly, government's spending linearly increases as the universal voucher increases.

Figure 5: Counterfactual Exercise: Only Universal Voucher Program



Notes:

7.1.2 Only Targeted Voucher Program

I study private-voucher schools' participation in the targeted voucher program, top-up fees, as well as students' welfare and government's spending under counterfactual scenarios where only the targeted voucher program is in place and the per-student subsidy varies between \$0 and \$1,400.

Figure 6 presents the results of the counterfactual exercises. Panel A shows private-voucher schools' program participation responses. As predicted by the model, a higher targeted voucher increases the profit in the in-the-program regime, with the corresponding consequence of increasing the likelihood that a private-voucher school joins the targeted voucher program. A relatively low per student subsidy of \$200 induces about a third of all private-voucher schools to join the program. Participation increases as the subsidy becomes more generous, with the highest participation found at the subsidy level of \$1,400, where about

[28] 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 $w_i = \ln\left(\sum_j e^{V_{ij}}\right)$, which is my measure of student welfare.

two thirds of private-voucher schools opt into the program.

Panel B shows the average quality of participating schools corresponding to each subsidy amount. More specifically, at each subsidy amount I take the set of schools that decide to join the program, and compute the average teachers' quality among those schools. Interestingly, The average quality of schools that participate in the targeted voucher program increases as the voucher amount goes up. This result, together with the result from panel A, imply that as the subsidy gets higher, not only more schools join the program, but also higher quality schools decide to participate.

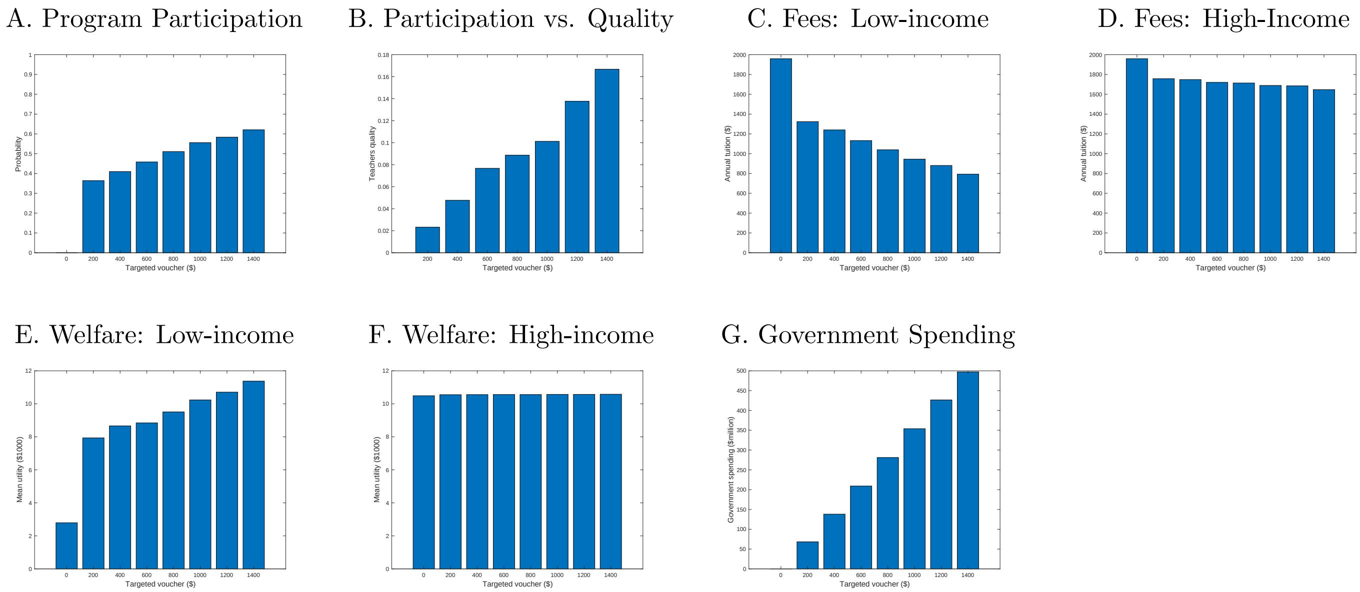
Panel C shows the effect of different targeted voucher amounts on the top-up fees faced by low-income students in the market. Recall that as a school joins the program, it is immediately mandated to set the fees it charges to low-income students to zero. Our simulation results are consistent with this feature of the program. When the targeted voucher goes from \$0 to \$200, a third of private-voucher schools join the program and are forced to charge no fees to low-income students. Thus, the average top-up fees faced by eligible students drops considerably, from almost \$2,000 to about \$1,300. As the subsidy gets higher, the fees charged to low-income students steadily decreases. The lowest average fee, about \$800, is found when the subsidy is set at \$1,400.

Panel D shows the relationship between the fees charged to higher-income students and the targeted subsidy amount. The highest effect is found when the subsidy increases from \$0 to \$200. This is explained by schools setting their optimal fees based on the marginal cost of educating all students when the targeted voucher is not in place (equation (5)), and by schools choosing the fees they charge to higher-income students based on the marginal cost of educating high-income students (equation (2)). Higher subsidy amounts only slightly decrease the fees schools charge to high-income students.

Panel E displays the relationship between lo-income students' welfare and the targeted voucher amounts. Welfare considerably increases as the subsidy gets more generous. This is especially so when the market goes from a scenario of no targeted voucher program (i.e. targeted subsidy equal to \$0) to a scenario where the targeted program is in place and the subsidy is \$200. Panel F does similarly, but for higher-income students' welfare. Since this type of students do not get directly benefited from the targeted program, their welfare does not vary much changes in the targeted voucher amount.

Finally, panel G. shows that, quite naturally, the government spending on vouchers increases as the per-student targeted subsidy increases.

Figure 6: Counterfactual Exercise: Only Targeted Voucher Program



Notes:

7.2 Simultaneous Universal and Targeted Vouchers

I next examine markets' equilibria in scenarios that combine the simultaneous implementation of a universal voucher and a targeted voucher. Counterfactual scenarios include all combinations of universal and targeted voucher amounts in $\{\$200, \$400, \$600, \$800, \$1000, \$1200, \$1400\}$. I focus on private-voucher schools' response on participation in the program, top-fees, as well as on students' welfare and on government spending.

Figure 7 displays the results of the counterfactual exercises. Panel A presents the program participation responses of schools to different combinations of universal and targeted voucher amounts. The gradient of schools' participation decision is positive along both the universal and the targeted vouchers dimensions, although the corresponding slope is steeper along the targeted subsidy. Notice that the targeted voucher has a direct effect on schools' decision to join the program through the increase of schools' profit in the in-the-program regime (equation (8)). The universal voucher, on the other hand, only indirectly affects schools' program participation via lowering the fees schools charge to high-income students (Figure 5), which, for a given targeted voucher amount, makes relatively more attractive joining the targeted program. Consequently, the highest participation rate is found when both universal and targeted vouchers are highest. In this case, about three quarters of schools decide to join the program.

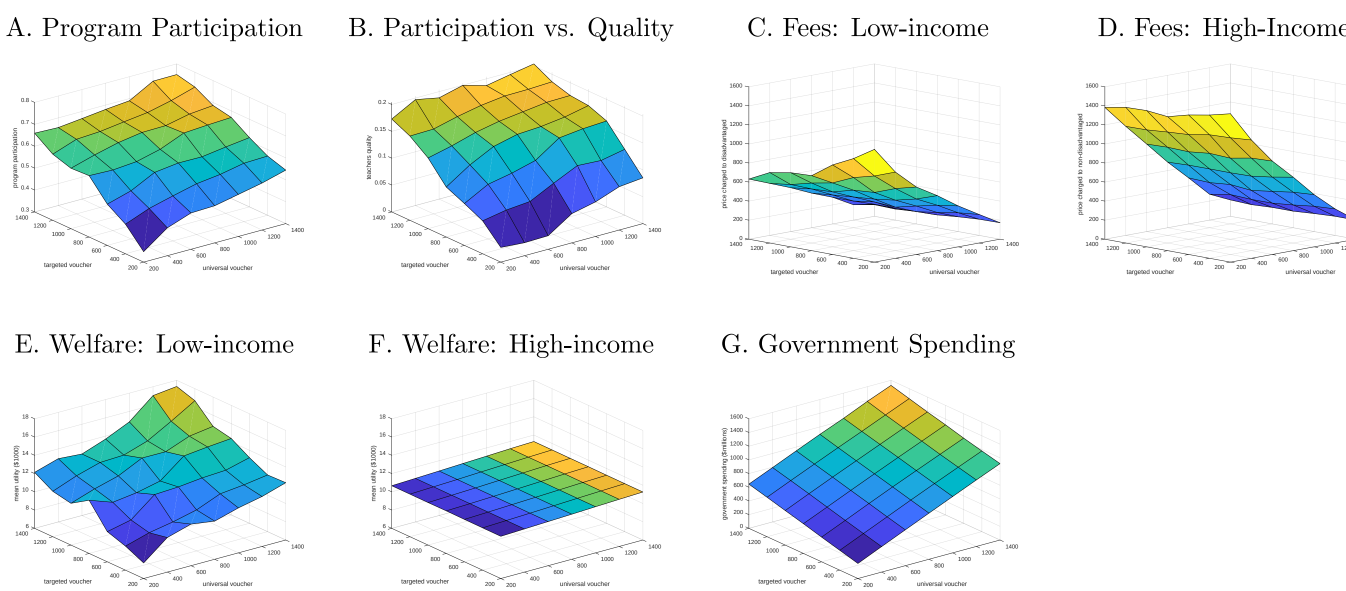
Consistent with our findings for scenarios where only the targeted voucher program is in place (Figure 6), panel B shows that the quality of schools that are part of the program increases as the voucher amounts get higher. The corresponding implication is, again, that it is the low-quality schools that first join the program, and that high-quality schools join the program only if the subsidies are high enough.

Panels C and D show schools' fee responses to different combinations of the universal and targeted vouchers, for low- and high-income students, respectively. Fees faced by low-income students decrease when either the targeted voucher, the universal voucher or both become more generous. The lowest fees charged to low-income students is found when both types of vouchers are at their highest. In contrast, fees charged to higher-income students are only responsive to changes in the universal voucher. This effect is mostly driven by the direct effect of the universal subsidy on schools' pricing best-responses (equations (2) and (5)).

Panels E and F present low-income and high-income students' welfare under various combinations of the universal and the targeted vouchers. Consistent with our findings from counterfactuals where only one of the subsidies is in place, low-income students' welfare considerably increases as the voucher amounts get higher. The corresponding mechanism is mostly the increase in private-voucher schools participation in the targeted program. On the other hand, higher-income students' welfare is almost invariable to changes in the subsidy amounts. The corresponding mechanisms for explaining this result are the relatively low price sensitivity of these students, and the fact that the targeted voucher does not directly affect the prices faced by high-income students.

Lastly, panel G shows the spending the government incurs to fund the vouchers. Such spending increases linearly with both universal and targeted vouchers. More importantly, the spending has a steeper slope along the universal voucher dimension, because any increase in this subsidy implies a higher spending to every student, whereas an equivalent increase in the targeted subsidy only involves a higher payment to every low-income student.

Figure 7: Counterfactual Exercise: Simultaneous Universal and Targeted Voucher Programs



Notes:

As a final exercise, I compute the average welfare for students per every dollar spent in the subsidies, for each of the universal and targeted vouchers combinations I have already presented. Table 12 shows the corresponding results. A first observation is that in general welfare per dollar decreases as the subsidies increase. This is so for both the universal and the targeted vouchers. Second, the highest welfare per dollar are found for low levels of the subsidies, implying that marginal welfare gains are decreasing on the subsidies. The highest welfare per dollar spent is $0.37, and is found for a case where only the targeted voucher is in place, with a subsidy amount of $200.

Table 12: Welfare per Government Dollar Spent

targeted	universal voucher							
voucher	0	200	400	600	800	1000	1200	1400
0	–	0.12	0.06	0.04	0.03	0.02	0.02	0.02
200	0.37	0.12	0.08	0.06	0.04	0.04	0.03	0.03
400	0.19	0.09	0.06	0.05	0.04	0.04	0.03	0.03
600	0.13	0.08	0.06	0.05	0.04	0.03	0.03	0.03
800	0.10	0.07	0.05	0.04	0.04	0.03	0.03	0.03
1000	0.08	0.06	0.05	0.04	0.04	0.03	0.03	0.03
1200	0.07	0.05	0.04	0.04	0.03	0.03	0.03	0.03
1400	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03

Notes: Government spending is in $million. Students' welfare is in $thousand.

8 Conclusions

This paper empirically studies the program participation and fee setting behavior of Chilean elementary private-voucher schools in a context where they are eligible to receive a universal voucher and a targeted voucher. I develop 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.

References

Abdulkadiroglu, A., P. A. Pathak, and C. R. Walters (2018): "Free to choose: Can school choice reduce student achievement?" *American Economic Journal: Applied Economics*, 10, 175–206.

Allende, C. (2019): "Competition Under Social Interactions and the Design of Education Policies," .

Allende, C., F. Gallego, and C. Neilson (2019): "Approximating the Equilibrium Effects of Informed School Choice," .

Amemiya, T. (1985): *Advanced Econometrics*, Cambridge, Massachusetts: Harvard University Press.

Angrist, J., E. Bettinger, E. Bloom, E. King, and M. Kremer (2002): "Vouchers for private schooling in Colombia: Evidence from a randomized natural experiment," *American Economic Review*, 92, 1535–1558.

Angrist, J., E. Bettinger, and M. Kremer (2006): "Long-Term Educational Consequences of Secondary School Vouchers: Evidence from Administrative Records in Colombia," *American Economic Review*, 96, 847–862.

Arcidiacono, P., K. Muralidharan, E.-Y. Shim, and J. D. Singleton (2016): "Valuing School Choice: Using a Randomized Experiment to Validate Welfare Evaluation of Private School Vouchers," *Manuscript*.

Barrera-Osorio, F., D. S. Blakeslee, L. L. Linden, and S. P. Ryan (2017): "Delivering Education to the Underserved through a Public-Private Partnership Program in Pakistan," *World Bank Policy Research Working Paper 8177*.

Battigalli, P., S. Cerreia-Vioglio, F. Maccheroni, and M. Marinacci (2015): "Self-confirming equilibrium and model uncertainty," *American Economic Review*, 105, 646–677.

Bau, N. (2017): "School Competition and Product Differentiation," .

Berry, S., J. Levinsohn, and A. Pakes (1995): "Automobile Prices in Market Equilibrium," *Econometrica*, 63, 841–890.

Berry, S. and P. Reiss (2007): "Chapter 29 Empirical Models of Entry and Market Structure," *Handbook of Industrial Organization*, 3, 1845–1886.

Berry, S. T. (1992): "Estimation of a Model of Entry in the Airline Industry," *Econometrica*, 60, 889–917.

Bravo, D., S. Mukhopadhyay, and P. E. Todd (2010): "Effects of school reformon education and labor market performance: Evidence from Chile's universal voucher system." *Quantitative Economics*, 1, 47–95.

Bresnahan, T. F. and P. C. Reiss (1991): "Entry and competition in concentrated markets," *Journal of Political Economy*, 99, 977–1009.

Bryan, G., S. Chowdhury, and A. M. Mobarak (2014): "Underinvestment in a Profitable Technology: The Case of Seasonal Migration in Bangladesh," *Econometrica*, 82, 1671–1748.

Card, D., M. Dooley, and A. Payne (2010): "School Competition and Efficiency with Publicly Funded Catholic Schools," *American Economic Journal: Applied Economics*, 2, 150–176.

Chakrabarti, R. (2008): "Can increasing private school participation and monetary loss in a voucher program affect public school performance? Evidence from Milwaukee," *Journal of Public Economics*, 92, 1371–1393.

——— (2013a): "Impact of Voucher Design on Public School Performance: Evidence from Florida and Milwaukee Voucher Programs," *The B.E. Journal of Economic Analysis & Policy*, 13, 349–394.

——— (2013b): "Vouchers, public school response, and the role of incentives: Evidence from florida," *Economic Inquiry*, 51, 500–526.

Chan, P. C. W. and R. McMillan (2009): "School Choice and Public School Performance: Evidence from Ontario's Tuition Tax Credit," .

Charness, G. and D. Levin (2009): "The origin of the winner's curse: A laboratory study," *American Economic Journal: Microeconomics*, 1, 207–236.

Chetty, R., J. N. Friedman, and J. E. Rockoff (2014a): "Measuring the Impacts of Teachers I: Evaluating Bias in Teacher Value-Added Estimates," *American Economic Review*, 104, 2633–2679.

——— (2014b): "Measuring the Impacts of Teachers II: Teacher Value-Added and Student Outcomes in Adulthood," *American Economic Review*, 104, 2633–2679.

Chetty, R., J. Rockoff, and J. N. Friedman (2016): "Using Lagged Outcomes To Evaluate Bias in Value-Added Models," *American Economic Review P&P*, 106, 393–399.

Ciliberto, F. and E. Tamer (2009): "Market Structure and Multiple Equilibria in Airline Markets," *Econometrica*, 77, 1791–1828.

Converse, P. E. (2000): "Assessing the Capacity of Mass Electorates," *Annual Review of Political Science*, 3, 331–353.

Correa, J. A., F. Parro, and L. Reyes (2014): "The Effects of Vouchers on School Results: Evidence from Chile's Targeted Voucher Program," *Journal of Human Capital*, 8.

Cuesta, J. I., F. González, and C. Larroulet (2017): "Distorted Quality Signals in School Markets," *Manuscript*.

Dekel, E., D. Fudenberg, and D. K. Levine (2004): "Learning to play Bayesian games," *Games and Economic Behavior*, 46, 282–303.

Dinerstein, M. and T. D. Smith (2014): "Quantifying the Supply Response of Private Schools to Public Policies," .

Draganska, M., M. Mazzeo, and K. Seim (2009): "Beyond plain vanilla: Modeling joint product assortment and pricing decisions," *Quantitative Marketing and Economics*, 7, 105–146.

Draganska, M., S. Misra, V. Aguirregabiria, P. Bajari, L. Einav, P. Ellickson, D. Horsky, S. Narayanan, Y. Orhun, P. Reiss, K. Seim, V. Singh, R. Thomadsen, and T. Zhu (2008): "Discrete choice models of firms' strategic decisions," *Marketing Letters*, 19, 399–416.

Dube, J.-P., J. T. Fox, and C.-L. Su (2012): "Improving the Numerical Performance of Static and Dynamic Aggregate Discrete Choice Random Coefficients Demand Estimation," *Econometrica*, 80, 2231–2267.

Epple, D. and R. E. Romano (1998): "Competition Between Private and Public Schools , Vouchers , and Peer-Group Effects," *The American Economic Review*, 88, 33–62.

——— (2008): "Educational Vouchers and Cream Skimming," *International Economic Review*, 49, 1395–1435.

Epple, D., R. E. Romano, and M. Urquiola (2017): "School Vouchers: A Survey of the Economics Literature," *Journal of Economic Literature*, 55, 441–492.

Esponda, I. (2008): "Behavioral equilibrium in economies with adverse selection," *American Economic Review*, 98, 1269–1291.

Esponda, I. and D. Pouzo (2016): "Berk-Nash Equilibrium: A Framework for Modeling Agents With Misspecified Models," *Econometrica*, 84, 1093–1130.

Esponda, I. and E. Vespa (2014): "Hypothetical Thinking and Information Extraction in the Laboratory," *American Economic Journal: Microeconomics*, 6, 180–202.

Eyster, E. and M. Rabin (2005): "Cursed equilibrium," *Econometrica*, 73, 1623–1672.

Feigenberg, B., S. G. Rivkin, and R. Yan (2017): "Illusory Gains from Chile's Targeted School Voucher Experiment," .

Ferreyra, M. M. (2007): "Estimating the Effects of Private School Vouchers in Multidistrict Economies," *American Economic Review*, 97, 789–817.

Ferreyra, M. M. and G. Kosenok (2017): "Charter School Entry and School Choice: The Case of Washington, D.C." *Manuscript*.

Figlio, D. N. and C. M. D. Hart (2014): "Competitive effects of means-tested school vouchers," *American Economic Journal: Applied Economics*, 6, 133–156.

Figlio, D. N. and C. E. Rouse (2006): "Do accountability and voucher threats improve low-performing schools?" *Journal of Public Economics*, 90, 239–255.

Fontaine, A. and S. Urzúa (2018): *Educación con Patines*, Santiago: Ediciones El Mercurio.

Friedman, M. (1962): *Capitalism and Freedom*, Chicago: University of Chicago Press.

Fudenberg, D. (2006): "Advancing beyond Advances in Behavioral Economics," *Journal of Economic Literature*, 44, 694–711.

Fudenberg, D. and D. K. Levine (1993): "Self-Confirming Equilibrium," *Econometrica*, 61, 523–545.

Gallego, F. A. and A. E. Hernando (2009): "School Choice in Chile: Looking at the Demand Side," .

Gazmuri, A. M. (2015): "School Segregation in the Presence of Student Sorting and Cream-Skimming: Evidence from a School Voucher Reform," .

Goolsbee, A. and A. Petrin (2004): "The consumer gains from direct broadcast satellites and the competition with cable TV," *Econometrica*, 72, 351–381.

Hackmann, M. B. (2019): "Incentivizing Better Quality of Care: The Role of Medicaid and Competition in the Nursing Home Industry," *American Economic Review*, 109, 1684–1716.

Holt, C. A. and R. Sherman (1994): "The Loser's Curse," *American Economic Review*, 84, 642–652.

Hoxby, C. (2003): "School choice and school productivity: Could school choice be a tide that lifts all boats?" in *The Economics of School Choice*, January, chap. 8, 289–342.

Hsieh, C.-T. and M. Urquiola (2006): "The Effects of Generalized School Choice on Achievement and Stratification: Evidence from Chile's Voucher Program," *Journal of Public Economics*, 90, 1477–1503.

Jehiel, P. (2005): "Analogy-based expectation equilibrium," *Journal of Economic Theory*, 123, 81–104.

Jehiel, P. and F. Koessler (2008): "Revisiting games of incomplete information with analogy-based expectations," *Games and Economic Behavior*, 62, 533–557.

Jehiel, P. and D. Samet (2007): "Valuation equilibrium," *Theoretical Economics*, 2, 163–185.

Kagel, J. H. and D. Levin (1986): "The Winner's Curse and Public Information in Common Value Auctions," *American Economic Review*, 76, 894–920.

——— (2002): *Common Value Auctions and The Winner's Curse*, Princeton: Princeton University Press.

Lara, B., A. Mizala, and A. Repetto (2011): "The Effectiveness of Private Voucher Education: Evidence from Structural School Switches," *Educational Evaluation and Policy Analysis*.

Manski, C. F. (1992): "Educational choice (vouchers) and social mobility," *Economics of Education Review*, 11, 351–369.

McEwan, P. J. and M. Carnoy (2000): "The Effectiveness and Efficiency of Private Schools in Chile's Voucher System," *Educational Evaluation and Policy Analysis*, 22, 213–239.

Murnane, R. J., M. R. Waldman, J. Willett, M. S. Bos, and E. Vegas (2017): "The Consequences fo Educational Voucher Reform in Chile," *NBER Working Paper 23550*.

Nechyba, T. J. (1999): "School finance induced migration and strafication patters: The impact of private school vouchers," *Journal of Public Economic Theory*, 1, 5–50.

——— (2000): "Mobility, Targeting, and Private-School Vouchers," *The American Economic Review*, 90, 130–146.

——— (2003a): "Centralization, Fiscal Federalism and Private School Attendance," *International Economic Review*, 44, 179–204.

——— (2003b): "Introducing School Choice into Multidistrict Public School System," in *The Economics of School Choice*, January, 145–194.

Neilson, C. (2013): "Targeted Vouchers, Competition Among Schools, and the Academic Achievement of Poor Students," .

——— (2017): "Targeted Vouchers, Competition Among Schools, and the Academic Achievement of Poor Students," .

Rau, T., C. Sánchez, and S. Urzúa (2018): "The Short- and Longer-Term Effects of Vouchers: Evidence from Chile," *Manuscript*.

Rouse, C. E. (1998): "Private School Vouchers and Student Achievement: An Evaluation of the Milwaukee Parental Choice Program," *The Quarterly Journal of Economics*, 113, 553–602.

Rouse, C. E. and L. Barrow (2009): "School Vouchers and Student Achievement: Recent Evidence and Remaining Questions," *Annual Review of Economics*, 1, 17–42.

Sánchez, C. (2018): "Skipping your Exam? The Unexpected Response to a Targeted Voucher Policy," .

Sandström, F. M. and F. Bergström (2005): "School vouchers in practice: Competition will not hurt you," *Journal of Public Economics*, 89, 351–380.

Seim, K. (2006): "An empirical model of firm entry with endogenous product-type choices," *RAND Journal of Economics*, 37, 619–640.

Singleton, J. D. (2017): "Incentives and the Supply of Effective Charter Schools," *Manuscript*.

Su, C.-L. and K. L. Judd (2012): "Constrained Optimization Approaches to Estimation of Structural Models," *Econometrica*, 80, 2213–2230.

Sullivan, C. J. (2017): "The Ice Cream Split: Empirically Distinguishing Price and Product Space Collusion," *Manuscript*.

Sweeting, A. (2009): "The strategic timing incentives of commercial radio stations: An empirical analysis using multiple equilibria," *RAND Journal of Economics*, 40, 710–742.

Thaler, R. H. (1988): "Anomalies: The Winner's Curse," *The Journal of Economic Perspectives*, 2, 191–202.

Tobin, J. (1958): "Estimation of Relationships for Limited Dependent Variables," *Econometrica*, 26, 24–36.

Urquiola, M. and E. Verhoogen (2009): "Class-Size Caps, Sorting, and the Regression-Discontinuity Design," *American Economic Review*, 99, 179–215.

Walters, C. R. (2017): "The demand for effective charter schools," .

Weintraub, G. Y., C. L. Benkard, and B. Van Roy (2008): "Markov Perfect Industry Dynamics With Many Firms," *Econometrica*, 76, 1375–1411.

Wollmann, T. (2017): "Trucks without bailouts: Equilibrium product characteristics for commercial vehicles," *Manuscript*.

A Data

Below, I present a detailed description of the data sets used in this paper:[29]

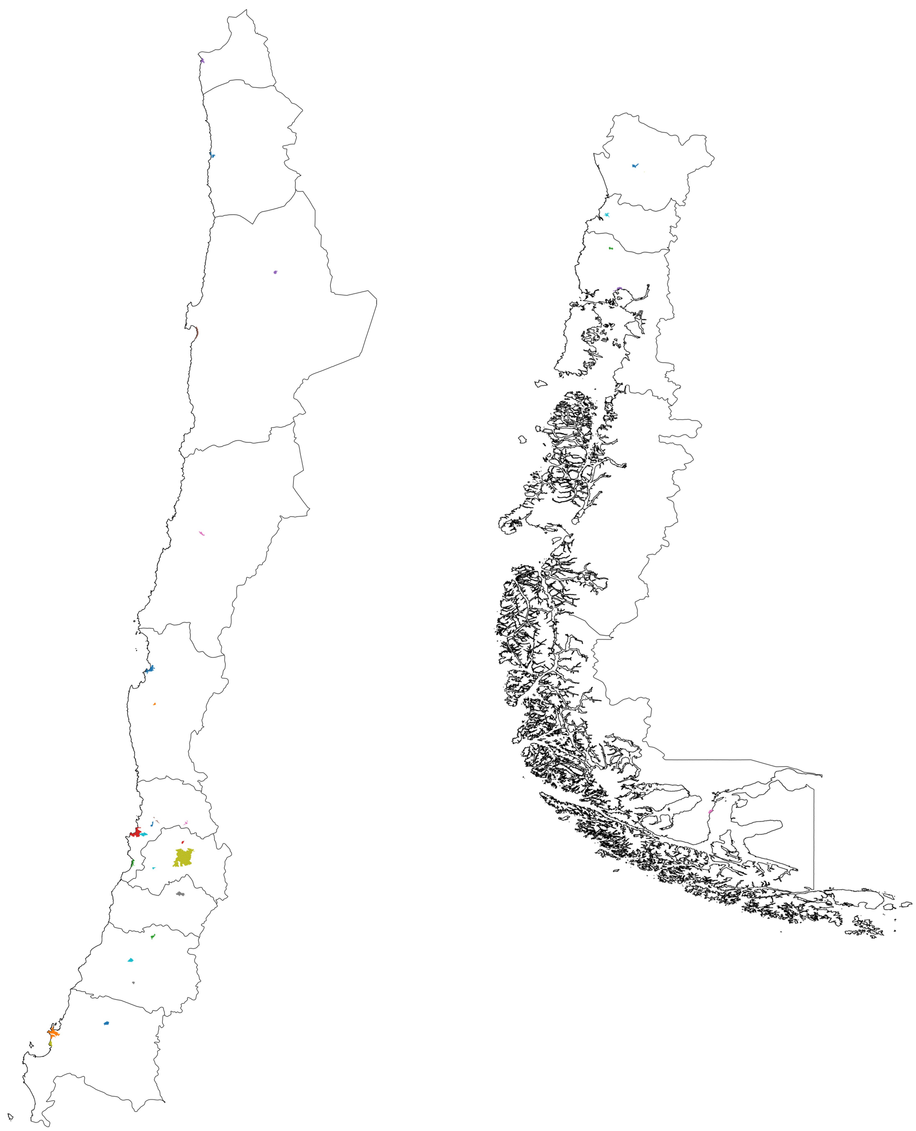
- *Registry of students, 2013.*
  These data provide information on students' gender, date of birth, age, residential address, type and level of education, grade, class, grade repetition status, special education status, and various characteristics of the school of attendance, such as municipality, type of management (public, private-voucher, private-non-voucher), single/double shift schedule, and urban status.
- *Registry of schools, 2013.*
  These data provide information on schools' municipality, type of management, urban status, address, tuition, religious orientation and type and level of education offered.
- *Registry of students that are eligible to participate in the targeted voucher program, 2013.*
  These data provide information on the characteristics of students that are eligible to participate in the targeted voucher program. They provide 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, 2013.*
  These data provide 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.
- *National standardized exams (SIMCE) for 4th graders, student-level, 2013*
  These data provide information on students' test scores for three different subjects: verbal, mathematics, and natural sciences.
- *4th grade SIMCE's questionnaire to parents and tutors, 2013.*
  These data consist 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 more than 90% of parents respond it every year. It provides information on students' household size, house amenities, and time use, total number of books available in the house, 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.

[29]These data sets were kindly provided by the Chilean Ministry of Education and Agencia de Calidad de la Educación.

B Markets

Figure 8 displays the map of all educational markets used in the empirical analysis. Each market is colored within the territory.

Figure 8: Map of Educational Markets



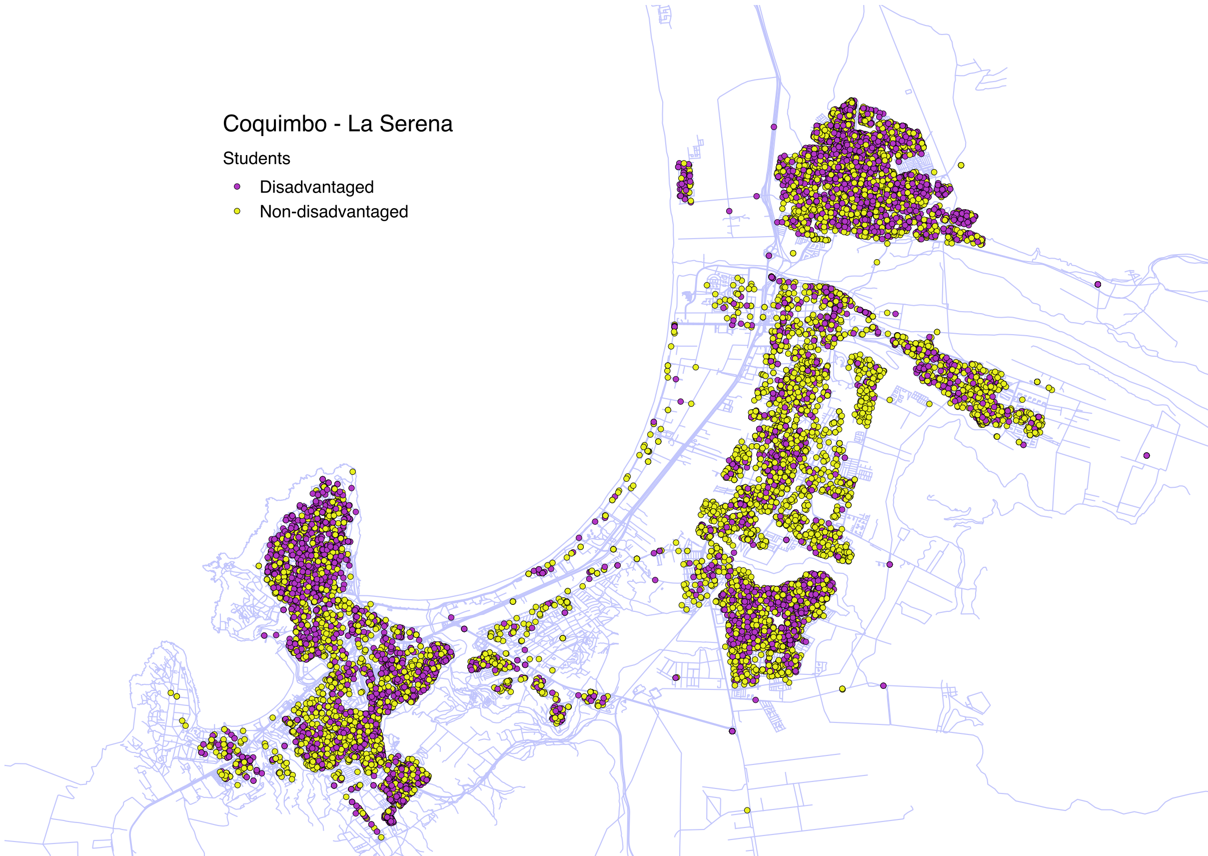
Notes: This figure shows the map of all educational markets used in the empirical analysis.

Figures 9-12 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 9 displays the streets and roads layout for the market. Figure 10 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 11 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 12 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 10) 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 9: Educational Market: Coquimbo-La Serena

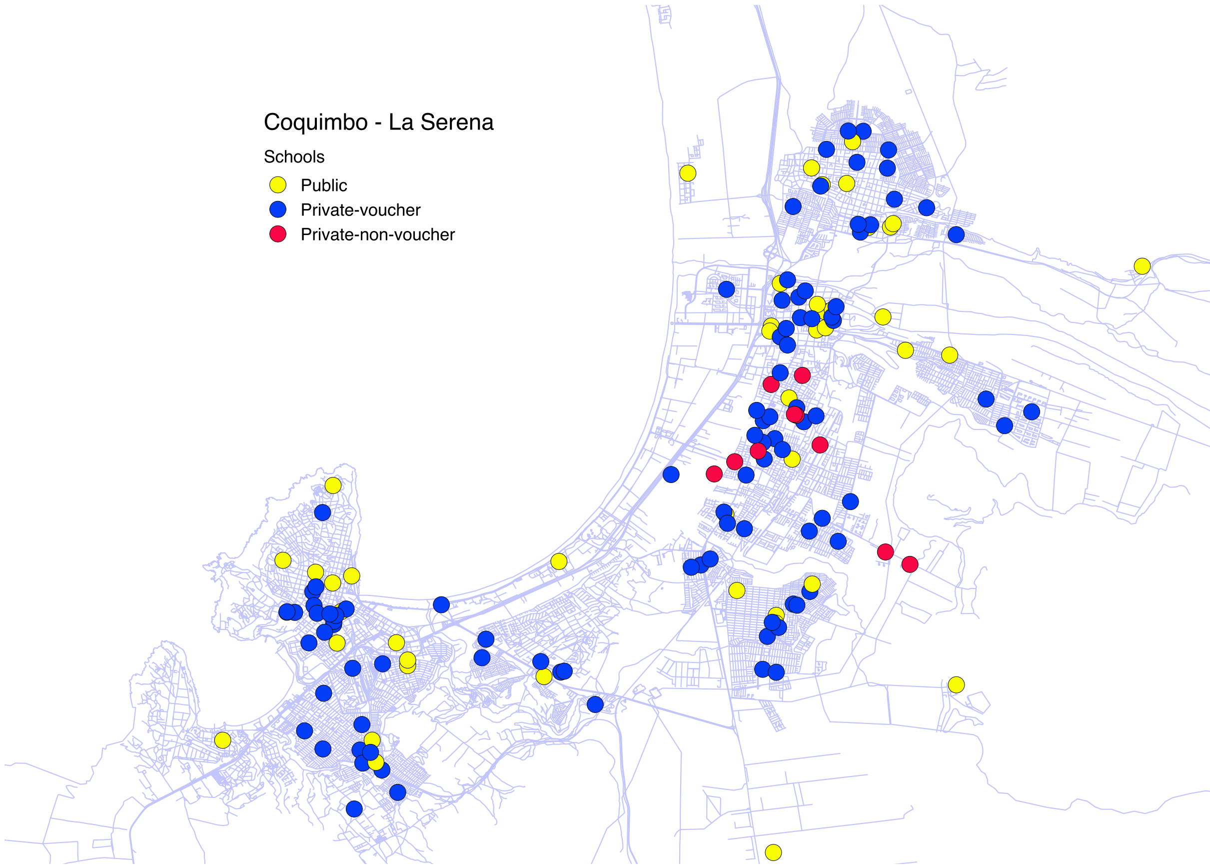
Notes: This figure shows the streets and roads layout for the educational market formed by the municipalities of Coquimbo and La Serena, in Northern Chile.

Figure 10: Educational Market: Coquimbo-La Serena - Students



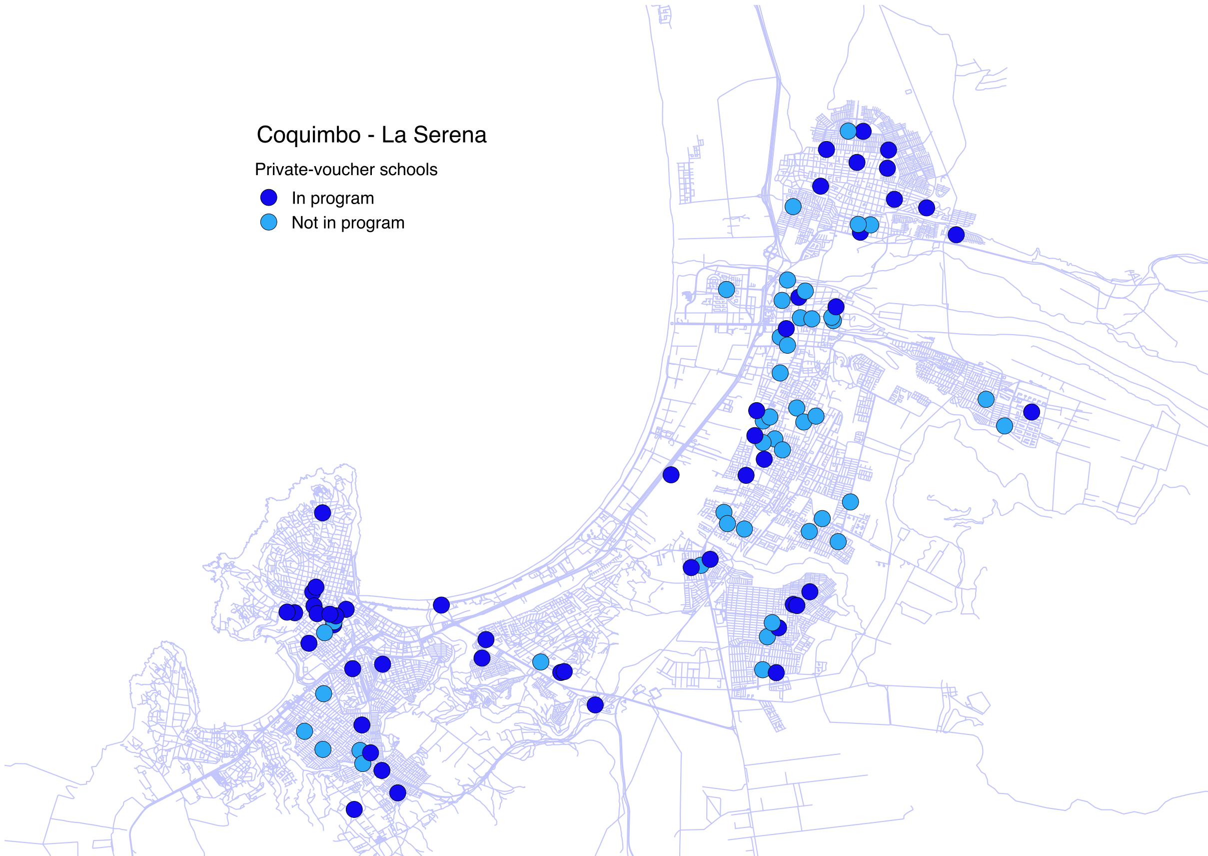
Notes: This figure shows the spatial distribution of students in the educational market formed by the municipalities of Coquimbo and La Serena, in Northern Chile. It distinguishes between disadvantaged (in purple) and non-disadvantaged (in yellow) students.

Figure 11: 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 12: 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.

C Theoretical and Empirical Motivations for Fully Cursed Equilibrium

I adopt Eyster and Rabin (2005)'s concept of fully cursed equilibrium.[30] Fully cursed agents have correct beliefs about the distribution of others' types, but fail to account for the correlation between other players' types and actions. Fully cursed agents, therefore, best respond to their opponents' average distribution of actions. Fully cursed equilibrium is a limit case of Eyster and Rabin (2005)'s more general concept of (partial) cursed equilibrium, that assumes that each player plays a best response to a convex combination of others' actual strategies and the aggregate distribution. A disadvantage of this intermediate case of cursed equilibrium is that it is hard to imagine a learning process that leads to such concept (Eyster and Rabin, 2005; Fudenberg, 2006). On the contrary, fully cursed equilibrium is founded on a well defined learning process, in which agents observe others' actions but neither their types nor their own payoffs.

Fully cursedness is related to other equilibrium concepts of games with agents that fail to account for the informational content of others' play. Self-confirming equilibrium (Fudenberg and Levine, 1993; Dekel et al., 2004; Battigalli et al., 2015) does not assume that players have correct beliefs about the distribution of opponents' play, but only that the beliefs are consistent with what players observe when the game is played (i.e. beliefs are correct only along the equilibrium path). Fully cursed equilibrium corresponds to a self-confirming equilibrium where players only observe the aggregate distribution of others' actions but not their types. Relatedly, Esponda (2008) combines self-confirming-equilibrium with some monotonicity restrictions to study the impact of naive agents on equilibrium play in adverse selection models. Jehiel and Koessler (2008)'s analogy-based expectation equilibrium (ABEE) assumes that players bundle states into analogy classes and best respond to opponents' average strategy in those analogy classes.[31] Analogy classes simply are a coarse partition of the distribution of states and types. Fully cursed equilibrium is a special case of ABEE, in which all states are bundled into a common analogy class. Moreover, ABEE can be viewed as a natural selection of self-confirming equilibrium, in which the signals received by players after each round of play correspond to the average play in each analogy class. Finally, Esponda and Pouzo (2016)'s Berk-Nash equilibrium presents a unifying framework of equilibrium models of games with agents with misspecified views of their environment, that includes Bayesian Nash equilibrium, self-confirming equilibrium, ABEE, and fully cursed equilibrium as special cases.

All of the above-mentioned theories constitute a response to a body of evidence on bounded rationality that is both economically significant and regular enough to be modeled (Fudenberg, 2006). The winner's curse is early documented in experimental and non-experimental studies of auctions and trade with adverse selection (Kagel and Levin, 1986, 2002; Thaler, 1988; Holt and Sherman, 1994; Charness and Levin, 2009).[32] Individuals' failure to account for the informational content of other people's actions is also empirically present in contexts of voting in elections and juries (Converse, 2000; Esponda and Vespa, 2014). More importantly, Kagel and Levin (1986), and Eyster and Rabin (2005) find that these phenomena are more likely to arise in large games, highlighting the limits of human cognition and the difficulty of evaluating counterfactual situations as the number of players/types/states grows (similar to the storage and memory

[30]For early developments of the concept of fully cursed equilibrium, see Kagel and Levin (1986), and Holt and Sherman (1994).

[31]See also Jehiel (2005).

[32]The winner's curse is generally defined as the winner's disappointment after the auction or trade takes place (Thaler, 1988).

limits of a personal computer).[33]

In sum, fully cursed equilibrium is a well accepted equilibrium model of games with agents that fail to account for the informational context of other players' actions. It is a special case of several other related models, and is founded on a realistic learning process. It is parsimonious, and therefore computationally tractable.

[33]See related discussions in Jehiel (2005), Jehiel and Samet (2007), Jehiel and Koessler (2008), and Esponda and Vespa (2014).

D Discussion on the Supply side Modeling Assumptions

Profit maximization. I assume all private-voucher schools are profit-seekers. This assumption is convenient as it simplifies the choice of the objective function of schools. An alternative is to model schools as being not-for-profit. However, it is not clear what is the objective function of not-for-profit schools. Moreover, the for-profit assumption for Chile's schools is standard and accepted in the literature (Urquiola and Verhoogen, 2009; Neilson, 2017; Allende et al., 2019).

Incomplete information. I assume that schools' costs are private information, and therefore the static game that schools play is one of incomplete information. This is a reasonable assumption as long as costs include both public information components such as teachers' salaries and utilities' bills, and private information components such as schools' intrinsic efficiency and level of bureaucracy. I argue this is the case for the context I study. As supporting evidence, Allende et al. (2019) find that, in Chile, schools' costs are partly determined by the level of skills of the school's principal, which is usually unobserved to the other schools.

Marginal costs. I allow marginal costs of education to vary by school's program participation regime (τ_j), and by student's disadvantaged status (ζ), i.e. $c_j^{\tau_j,\zeta}$. Different costs across regimes allow for the targeted program to have an efficiency effect on schools' production of education. Also, different costs across student's disadvantaged status captures the fact that educating a disadvantaged student, who is likely to come from a vulnerable and at-risk family, may involve more educational efforts than educating a non-disadvantaged student, who is likely to experience a richer and more stimulating environment at home. Fontaine and Urzúa (2018) discuss this latter phenomenon for the Chilean context. In such respect, I improve on previous studies, both in education markets and in other industries, that restrict costs to be invariant to firms' decisions (and, for the case of education, to students' characteristics).