Targeted Vouchers, Competition Among Schools, and the Academic Achievement of Poor Students

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Abstract

In this paper I use detailed administrative data to study the effects of targeted school vouchers on the outcomes of poor children in Chile. A difference-in-differences analysis reveals that this reform raised the test scores of poor children significantly and closed the gap between these students and the rest of the population by one third. I estimate an empirical model of school choice to construct counter-factual simulations that allow me to isolate the different mechanisms through which this policy affected outcomes. In addition, the explicit modeling of schools' choice of price and quality allows for the analysis of how the policy changed the nature of competition among schools. The model estimates imply that the observed policy effect is due mostly to the increase in the quality of schools in poor neighborhoods and not to a resorting of students to better schools or the entry of new higher-quality schools. The introduction of targeted vouchers is shown to have effectively raised competition in poor neighborhoods, pushing schools to improve their academic quality.

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1 Introduction

Introducing competitive market incentives in education has been a frequent topic in the policy debate. Advocates have long argued that privatization will improve aggregate academic achievement and provide poor families with better educational opportunities. However, theoretical and empirical research has suggested that the privatization of education markets can in some cases increase inequality and potentially lower outcomes of poor students (Bettinger 2011, Epple and Romano 2012). In particular, the regulation of prices and the type of voucher structure used can have a significant effect on academic achievement and the distribution of educational quality across socioeconomic groups. One strategy that may help poor students benefit more from a market-oriented school choice system is to implement vouchers that provide larger subsidies to poor students.[1]

In this paper I use detailed administrative data to study the effects of targeted school vouchers on the outcomes of poor children in Chile. Introduced in 2008, this policy effectively eliminated tuition fees for approximately 40% of students at most voucher schools. A difference-in-differences analysis reveals that this reform raised test scores for poor children by 0.2 standard deviations and closed the gap between these students and the rest of the population by a third. This represents a significant break in the evolution of average test scores and inequality in educational achievement in Chile.

There are two possible explanations for this result in the context of Chile's market-oriented school choice system. First, conditional on the quality of available schools, the increased vouchers may allow families to choose better schools that were previously considered too expensive. Second, the increased incentive to compete for the enrollment of poor students may lead schools to improve their quality, especially if these students are now worth more to the schools. To disentangle these effects, I estimate an empirical model of school choice that allows me to isolate the different mechanisms through which this policy affected outcomes. I explicitly model the schools' choice of price and quality and show how the policy changed the nature of competition among schools.

[1]Several authors have suggested deviating from a flat voucher environment to one that conditions the voucher amount on student characteristics such as income (Nechyba 2000, Neal 2002, Epple and Romano 2008) and in the case of Chile in particular, Gonzlez et al. (2002) and Gallego and Sapelli (2007) argue in favor of targeted voucher system similar to the implementation that was carried out in 2008.

To implement this empirical strategy I collected new survey data on school prices and assembled several administrative data sets with the help of various Chilean government agencies including the Ministry of Health, Ministry of Education and the Chilean College Admissions Test Agency, DEMRE. The final data set includes over 1.5 million students and their choices linked to a large set of demographic characteristics. Using this data I estimate a model of demand for elementary schools in an environment where spatially differentiated schools compete for students by choosing their quality and prices. The model accommodates school unobservable characteristics as well as observable and unobservable consumer heterogeneity at the census block level, providing a rich description of how families and schools interact. This level of geographic detail is important to describe schools' local market power as most students travel less than two kilometers to get to school.

I use the estimated empirical model to construct counterfactual simulations that allow me to isolate the demand- and supply-side effects generated by the policy. The first counterfactual simulation is to allow students to sort according to the prices that would be effective after the policy has been implemented, but assuming schools have the same characteristics as in the baseline year. The increase in test scores in this situation is induced only by the reallocation of students to schools that have higher quality and are now more desirable to poor students given that their prices have been eliminated. The total policy effect can be calculated by simulating the choices that would be made by the same students with the prices and characteristics of schools available after the policy has been implemented.

I find that score gains for poor students are largely driven by the supply-side response to the increased voucher amount for poor students. The model estimates imply that approximately one third of the observed improvement is due to families ability to choose better schools with the larger voucher, while two thirds of the effect is due to the rise in quality of existing schools in response to the policy. Moreover, schools in the poorest neighborhoods improved their quality significantly more in response to the policy than schools in less poor areas. Applying a difference in differences analysis of school quality across time and across poor and non-poor neighborhoods reveals that schools in the poorest neighborhoods increased their quality by 0.14 standard deviations.

To better understand why schools in poor neighborhoods raised their quality, I develop a model of school profit maximization which highlights the tradeoffs schools make when choosing quality and price. Schools' first order conditions can be arranged to show how much quality will be marked down as a function of local market power, which in turn depends in the sensitivity of demand to changes in school quality. Demand estimates indicate that preferences for prices, distance and quality are heterogeneous, and that poor households are particularly sensitive to price and distance to the school. Given the distribution of households, schools in poor neighborhoods have more local market power and thus mark down their quality more than schools in more affluent areas given the same voucher amount.

Targeted voucher policies diminish schools' local market power in poor neighborhoods by making better but more expensive schools attractive to poor students. The model estimates indicate that the introduction of targeted vouchers effectively raised competition in these neighborhoods by reducing the role of prices in limiting the choices of these families and pushing schools to endogenously improve their quality.

These findings are important as they suggest avenues for the improvement of current or future voucher systems, and emphasize the important role of the supply-side response to targeted subsides in a market-oriented school system. The explicit modeling of price and quality highlights empirically that the details of the regulatory environment matter substantially for the incentives schools face and the resulting equilibrium outcomes. Targeted vouchers for the poorest students improve outcomes by increasing competition in neighborhoods where incentives are weakest.

2 Literature Review

Milton Friedman argued that a market for elementary schools would improve academic outcomes by providing choice to families which would in turn provide incentives to both public and private schools to work harder to satisfy their students (Friedman 1962). A profit motive would promote innovation and the proliferation of alternatives for families to choose from and this would force all institutions to exert more effort as families could now vote with their feet. Friedman also argued that choice would be a significant improvement for poor families, who cannot afford to move to a better school zone or pay tuition at the unsubsidized private schools.

The debate that followed both for and against Friedman's original view includes theoretical and empirical arguments that paint a mixed picture. The lack of consensus is due both to the scarcity of large scale empirical implementations of Friedman's original ideas and also to the inherent difficulty of evaluating extensive market level policy interventions. One strand of the literature has advanced by deriving theoretical models and uses simulation exercises to describe the potential outcomes that could arise in a market for schools. Important contributions by Manski (1992), Epple and Romano (1998), Nechyba (1999) and McMillan (2004) highlight the idea that introducing market incentives and choice would not necessarily level the playing field and could potentially harm some participants and increase educational inequality.[2] Epple and Romano (2012) review the current literature on models of voucher school markets and conclude that whether choice and competition improve outcomes for all will depend a great deal on the voucher policy design. The implementation of targeted vouchers that provide larger subsidies to poor families is one strategy that may help poor students benefit more from a market-oriented school choice system (Neal 2002, Gallego and Sapelli 2007, Epple and Romano 2008).

A second strand of literature focuses on the empirical evidence. First is a line of empirical research that examine whether alternatives to public schools are more productive and raise the achievement of students. Examples in this literature include evaluations that compare public schools to private schools, and Catholic schools, and more recently charter schools.[3] In the context of Chile, several authors have compared the test score gains or quality of voucher schools to public schools and generally find positive but relatively small average effects.[4] Empirical studies in both Chile and in the US have found that there are some alternative schools that do provide higher quality education but that there is considerable heterogeneity across individual schools within broad school categories (Betts and Tang 2011, Mizala and Torche 2012).

[2]Ferreyra (2007) and Altonji et al. (2010) have pushed this literature to the first empirical equilibrium models to evaluate the effects of different educational reforms.

[3]A sample of papers document that students at alternative schools have higher academic achievement (Coleman et al. 1966, Neal 1997, Grogger et al. 2000, Altonji et al. 2005). Most of the empirical difficulty is accounting for students characteristics to disentangle the contribution of the school to the observed achievement. These papers generally find that private Catholic schools in the US improve academic achievement. More recent studies have used lotteries to provide evidence on the added academic achievement that can be attributed to charter schools (Hoxby and Murarka 2009, Dobbie and Fryer 2011, Abdulkadiroğlu et al. 2011, Hastings et al. 2012).

[4]A list of relevant papers includes (Mizala and Romaguera 2000, Carnoy and McEwan 2003, Anand et al. 2009, Lara et al. 2011). A recent review of this literature is Drago and Paredes (2011).

A group of related empirical papers test whether individual students benefit from general school choice. Some of these papers use lotteries to evaluate whether public school choice is beneficial for lottery winners by comparing the academic achievement of winners and losers. Cullen et al. (2006) show that students in Chicago gained little from participating in public choice. Deming et al. (2011) show that in North Carolina students obtained both short and long run benefits from attending the public school of their choice. Rouse and Barrow (2009) survey the evidence on the implementation of choice through small scale voucher programs in the US and find that in general, results have been positive but relatively small.[5] Bettinger (2011) reviews the international experience from Colombia, Chile and Sweden and concludes that the evidence is mixed, partly because of the very different institutional settings and contexts.[6] A recent large scale experiment in India provided school vouchers through a lottery. It was found that after several years, academic achievement of lottery winners increased when averaging over all subjects, and private schools were significantly more efficient than public schools (Muralidharan and Sundararaman 2013).

A final group of empirical papers study the role of competition on aggregate outcomes. These papers combine the demand-side effect of sorting and any supply-side effects of increased competition on the quality of schools. The empirical strategy is to compare different geographic areas or markets that potentially have more competitive pressure than others and relate that to outcomes. The evidence suggests that when public schools are faced with more competition, they are more productive, although the magnitudes are modest. Hoxby (2000) looks at cities that have more or less Tiebout sorting possibilities due to the configuration of districts caused by rivers and streams. Cities with more districts to choose from had better outcomes, suggesting that competitive pressures were at work as families could to some extent move within the city to more options. In a similar vein Card et al. (2010) provide evidence from Ontario, Canada where students of Catholic background can switch across public and private non profit Catholic schools.

[5] One example is Rouse (1998), which studies the implementation of vouchers in Milwaukee in the early 1990s and finds that students that use vouchers to attend private schools improve their academic results in math. Closely related to this literature is the evaluation of tax rebates in Florida that act as school vouchers, which were found to raise outcomes (Figlio and Hart 2010).

[6] Two well known papers study the voucher program PACES in Colombia (Angrist et al. 2002, Angrist et al. 2006). Vouchers were provided through a lottery only to poor students to help pay for private secondary schooling. The study results found that vouchers raised test scores and educational attainment. This program affected a small portion of students (approximately 10% of matriculation) as it was targeted to only the poorest of the student population and it was later discontinued.

The authors show that areas with more Catholic families, and thus where public schools face more competitive pressure from the Catholic private sector, have higher test scores, again suggesting that competition improves the outcomes of public schools. Another group of papers takes advantage of policy changes that allow students to choose among different types of schools starting from a system with very little choice. Lavy (2010) finds that allowing public school choice generated important gains in achievement in Israel. Gibbons et al. (2008) studies the introduction of choice in England and uses the timing of the policy together with the local concentration of available schools to determine the effect of increased competition. They find that when choice was allowed, only schools that had significant freedom in adjusting inputs reacted to competition while the majority of public schools did not.

In the case of Chile, studies have been limited in their ability to evaluate the overall effect of the 1980 reform that introduced a flat voucher. This is partly due to a lack of data and also partly due to the comprehensive nature of the policy that limits the application of traditional identification schemes. Some authors have found creative ways to get around this limitation using different strategies. In an influential paper, Hsieh and Urquiola (2006) use an IV strategy to compare the change in test scores of across communities with varying degrees of private sector entry over 20 years of school competition in Chile. They find little evidence that voucher schools matter for educational outcomes but they argue that the policies implemented in Chile significantly lead to more socioeconomic stratification. On the other hand, Gallego (2012) uses the number of priests in a municipality as an instrument that varies the number of voucher schools and competition and finds positive effects. Bravo et al. (2010) use a different strategy based on the labor market outcomes of adults. They use later life outcomes to compare cohorts that were exposed to the reforms in the 1980s to those who were not and find that there are significant benefits in terms of earnings and welfare. Patrinos and Sakellariou (2011) also use the idea of comparing cohorts that were exposed more or less by the reform and find that the educational system became more efficient although potentially at a cost of higher segregation.

Overall the evidence on the role of private market incentives is mixed and the interpretation of the results from empirical studies depends very much on the context. One important consideration that has been emphasized, is that families may choose schools based on other characteristics besides school quality, potentially due to a lack of information or other restrictions. Furthermore, this can be exacerbated by heterogeneity in preferences. In this case choice can lead to sorting that does not necessarily raise academic achievement in the aggregate and increase inequality (Hastings et al. 2009, Bayer et al. 2007, Gallego and Hernando 2010, Carneiro et al. 2013). To the extent that families care about quality, policies that generate competition for enrollment can be expected to improve academic outcomes. This competition effect can also be expected to be smaller if families value other characteristics such as price, distance or other non-academic feature of the school. This point is relevant for determining supply-side incentives as well, although the existing literature has not explicitly studied this empirically.

3 Institutional Context and Stylized Facts

3.1 Voucher Market in Chile

The voucher market in Chile was first created through reforms to the organization and financing of the education system in 1980.[7] The main features of this reform consisted of 1) the decentralization of public schools, 2) the introduction of a flat voucher and 3) teachers' contracts were made more flexible (Espínola et al. 1999). The first feature was the transfer of the administration of public schools from the central government to local municipalities, and aimed to stream line the operations of the ministry of education away from school administration. The second feature of the reform was to transfer public school teacher contracts from rigid public sector contracts to more flexible private sector labor contracts.[8] The third, was to modify the financing of schools through the establishment of a flat voucher which would be paid per student (on the basis of attendance) to any school, public or private. It would vary according to level of education and geographic location and would be measured in units of the *Unidad Subvencion Escolar (USE)*.

In 1993, schools were allowed to charge fees in addition to the voucher with the establishment of the *Financiamiento compartido, Ley 19.247*. Over the next two decades the

[7] Gauri (1999), Beyer et al. (2000) and Espínola et al. (1999) provide excellent reviews of the education reform in Chile. Prieto Bafalluy (1983) is authored by the minister of education that implemented the reforms, and provides a clear description of the context and arguments that motivated the reforms.

[8] Public school teacher benefits were partially restored in 1991 through the *Estatuto Docente (Ley 19.070)*, but the growing private sector continued to hire teachers with much more flexibility.

government steadily raised the real value of the voucher and made efforts to help the most vulnerable schools through programs like the *P-900* and *Programa MECE*. Nevertheless, basic features of the voucher program did not change dramatically over the 28 years.

Today over 60% of students entering first grade are matriculated in the private sector. This number is closer to 70% when looking only at urban areas. Figure A1 shows how a significant proportion of students shifted from the public sector towards private sector over time.

3.2 Introducing a Targeted Voucher

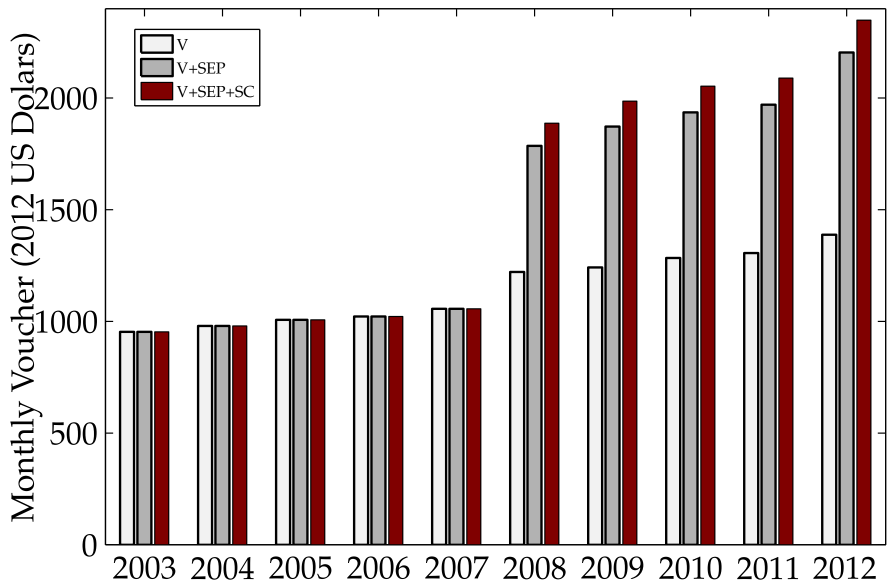
In 2008 the *Ley de Subvenciòn Escolar Preferencial (SEP), Ley 20.248*, was put into place and established a new targeted voucher that would transfer significantly more resources to schools for each eligible student matriculated. Eligibility to the program was reserved for approximately the poorest 40% of the population. Eligibility is determined in several ways but the two most common ways are for the student to be accredited as belonging to the lowest 33% of the income distribution according to the government ranking of socioeconomic status called *Ficha de Proteccion Social* or to belong to the social program for poor families called *Chile Solidario*. These two criteria accounted for over 86% of all participants in the SEP program in 2010.[9] The same law that introduced the SEP targeted voucher also introduced an additional voucher subsidy for schools that had a high percentage of poor students. This additional subsidy is called the *Subvención por Concentración* (SC) and was much smaller in size than the SEP voucher. The additional targeted vouchers would be available to all public schools, as well as for voucher schools that signed up for the policy. It also required schools to not charge eligible students any tuition fees and they could not select students on the basis of their previous academic performance. Schools also needed to provide a plan (*Plan de Mejoramiento Educativo*) regarding how the additional resources were going to be used. Schools joined the policy in large numbers and in 2011, 75% of schools receiving vouchers had been accredited, including virtually all public schools and two thirds of private voucher schools.[10] In 2011

[9] Additional avenues to be considered eligible are that the students' parents show that they are poor, of very low education or part of the lowest socioeconomic group in the public health system.

[10] Additional regulation was implemented with the *Ley General de Educación (LGE), Ley 20.370*, including the creation of an agency in charge of regulating and informing on the quality of schools. These policies

the SEP subsidy amount was further increased by 21%.

Figure 1: Voucher Size



Note: This figure shows how the voucher evolved over time differentiating the baseline voucher (V), SEP eligible students (V+SEP), and SEP eligible students at schools with the highest (SC) voucher. These amounts are in 2012 US dollars and represent a year of transfers. The voucher presented is for students in first grade at schools with full school shifts (*Jornada Completa (JEC)*) in Santiago.
Source: Ministry of Education MINEDUC.

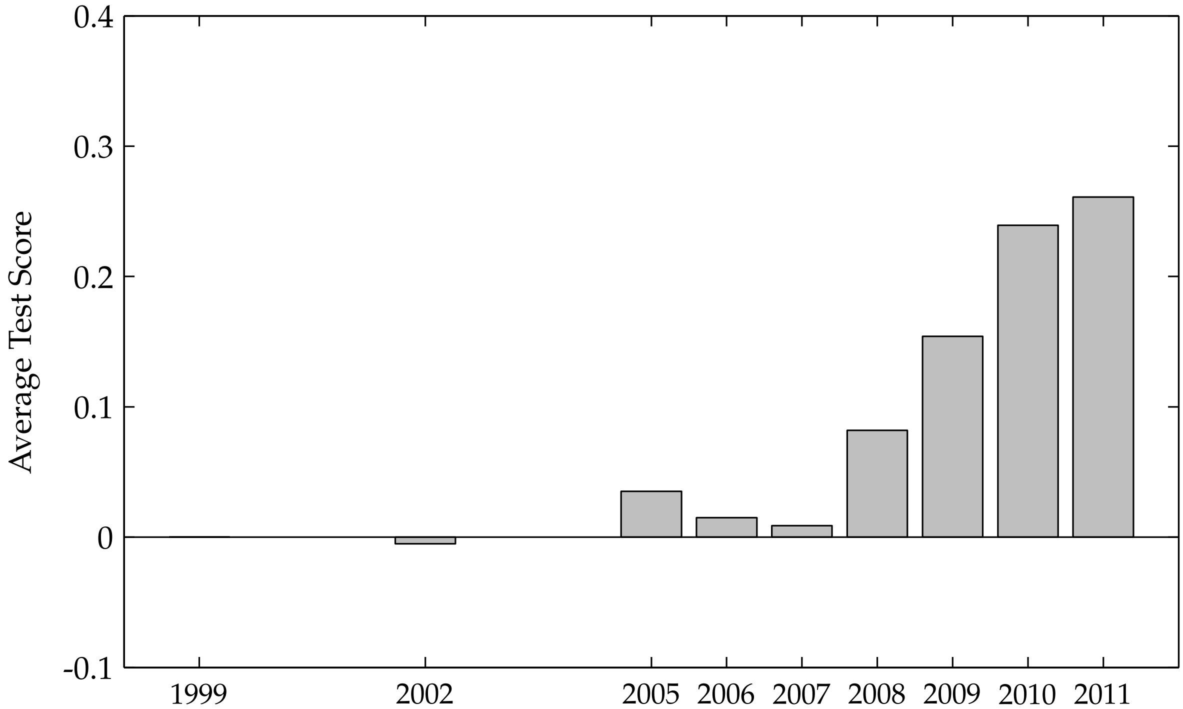
3.3 Stylized Facts and Policy Outcomes

In this section I document a series of stylized facts about the Chilean education system and how they have changed over time. The first stylized fact is that over the last four years, test scores have improved in the aggregate, breaking with eight years of stagnation. Test scores are standardized relative to a baseline test in 1999 so that scores are comparable across time. Figure 2 shows the evolution of the average test score for students in 4th grade (averaged over both math and language). From 1999 to 2007, the growth in the average test score was almost negligible, while the next six years saw growth of almost 0.3σ. Figure 3 shows this growth pattern was also seen among the poorest students in the

were not directly related to the SEP policy.

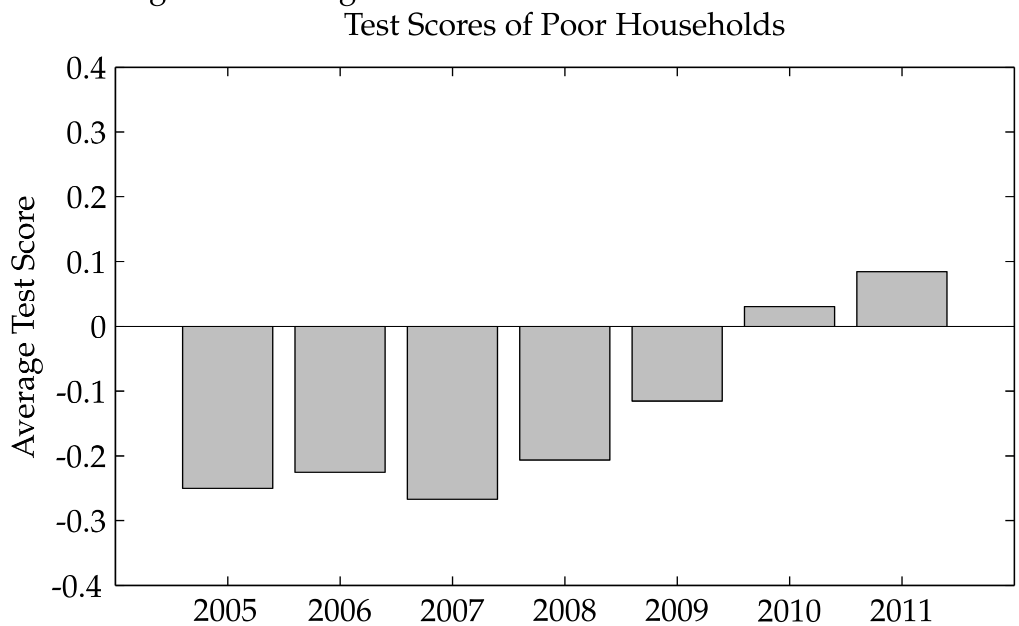
country.

Figure 2: Average Test Scores



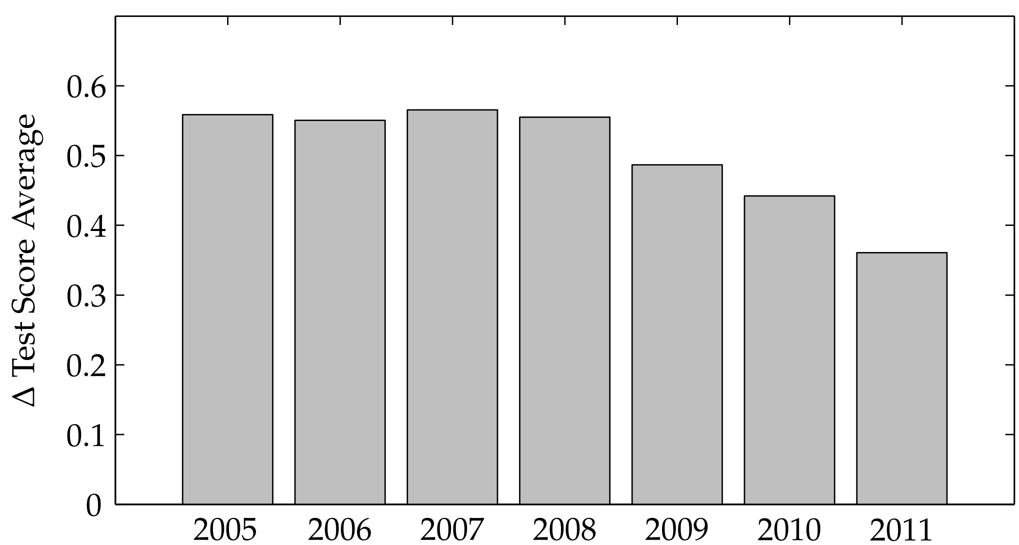
Note: This figure shows how average test scores evolved over time since 1999. The test was administered in 1999, 2002 and 2005 onward. Test scores are comparable across years and are standardized relative to the baseline test in 1999, so that the mean in 1999 is forced to be zero by construction. The average test score indicates the average across math and reading test scores of all students in a given year.
Source: Ministry of Education MINEDUC.

Figure 3: Average Test Scores of Poorest 40% of Students



Note: This figure shows how average test scores for students in the 40% poorest households in 4th grade evolved over time. Test scores are comparable across years and are standardized relative to a baseline test in 1999. See Data Appendix for details on sample construction.
Source: Ministry of Education MINEDUC.

Figure 4: Test Score Gap



Note: This figure shows how the gap in average test scores between the 40% poorest students and the rest evolved over time. See Data Appendix for details on sample construction.
Source: Ministry of Education MINEDUC.

The second relevant feature is that the large gap between the academic achievement of students with different socioeconomic backgrounds has closed over the last six years. In 2005, the average test score of students from the 40% poorest households was -0.25σ. However the average student in the richest 60% had an average of 0.31σ. The difference is larger when comparing children with mothers of different educational backgrounds. Children of mothers with a technical or college education had an average of 0.61σ while students with mothers with less than a high school degree had an average of -0.32σ. Since 2005, these differences have diminished as can be seen in Figure 4. In 2011, students of the 40% poorest families obtained an average of 0.08σ while the average of the rest of the students was 0.44σ which represents a closing of the gap by 0.2σ from 0.56σ to 0.36σ. When looking at children with mothers with different education levels, this gap falls 0.21σ, from 0.93σ to 0.72σ. These aggregate results have not gone unnoticed; the improvements in test scores and the reduction of the gap between socioeconomic groups has been mentioned in the press and in the policy debate. News pieces in the popular press and as well as in other parallel academic work done in Chile have identified the targeted voucher policy as being an important contributor to the observed results.[11] International evaluations such as the PISA and TIMSS evaluations also show that students in Chile have made important progress in recent years. For example, when comparing 8th grade TIMSS results for science and math in 2011 to the previous evaluation in 2003, students from Chile had the 2nd and 4th highest growth respectively out of over fifty countries evaluated.[12]

The policy of targeted vouchers implemented in 2008 was intended to help students from poor backgrounds. We have seen that these students have been catching up with their peers from higher income families over time. To further study the impact of the policy, I run a difference in differences regression comparing students from the 40% poorest part of the distribution to the rest of the population and how these differences changed once the policy was implemented.

Specifically I run the following regression :

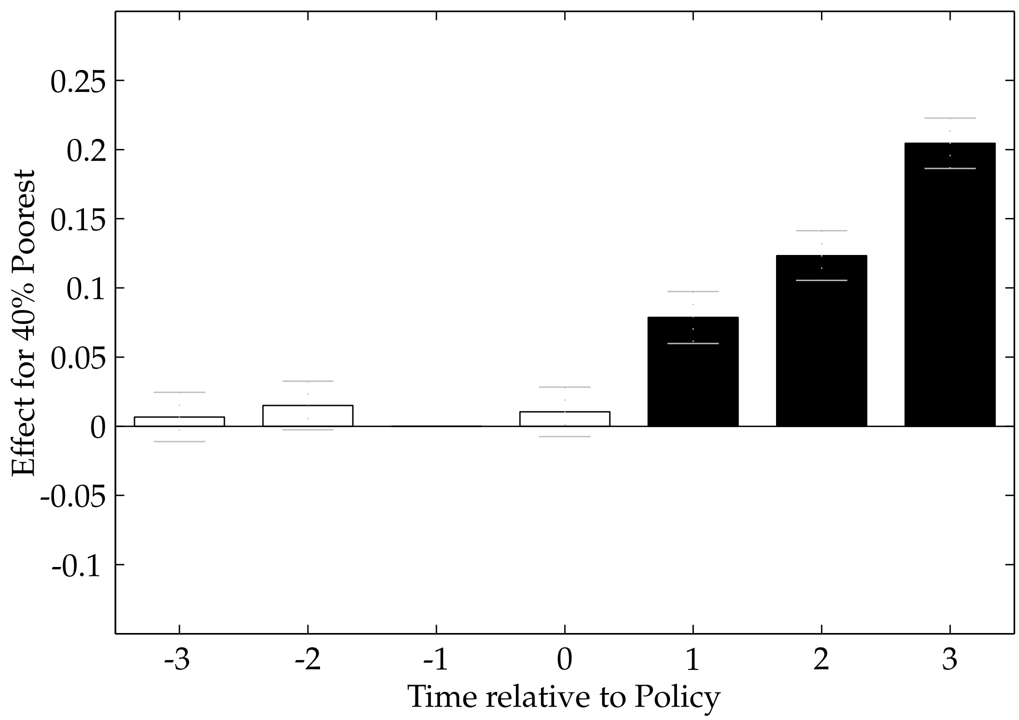
[11] Examples from the popular press include *La Nacion, 04/11/2012* and *La Tercera, 04/14/2012*. The official policy brief of the results can be found *Resultados Nacionales SIMCE 2011, MINEDUC*. Some recent academic work documenting the important gains in test scores attributable to the SEP policy are Raczynski et al. (2013), Correa et al. (2013).

[12] See official policy brief from MINEDUC, *Presentacion Resultados TIMSS, 2011*.

$$\text{test score}_{it} = \alpha_0 + \alpha_1 \text{Poor}_i + \sum_t \beta_t \mathbf{D}_t + \sum_t \gamma_t \left(\mathbf{D}_t \times \text{Poor}_i \right) + \epsilon_{it} \tag{1}$$

where test scores are standardized averages over math and language tests in fourth grade. Poor_i is an indicator equal to 1 if the student is among the poorest 40% of students. $\mathbf{D}_t$ is an indicator for the year where 2007 is omitted and thus the baseline year and $\mathbf{D}_t \times \text{Poor}_i$ represents an interaction term between time and status. The parameters of interest are the γ's as they indicate the difference between poor and non poor students over time. Table A1 shows the results of this regression and Figure 5 presents the estimated γ coefficients with a 1% confidence interval. Dark bars indicate significance at the 1% confidence level. The previous results are corroborated in this regression as we see positive time trend in Table A1, but the difference between the poorest 40% and the rest only become significant once the policy is in place, as can be seen in Figure 5.

Figure 5: Difference in Differences Regression Coefficients



Note: This figure shows how average test scores for students in the 40% poorest households in 4th grade evolved over time. Test scores are comparable across years and are standardized relative to a baseline test in 1999. See Data Appendix for details on sample construction.
Source: Ministry of Education MINEDUC.

We have established two main stylized facts. The first is that average test scores have increased over time. The second is that the poorest students have seen their test scores rise faster than their richer counterparts and as a result the test score gap between them has been reduced significantly. These results happen after the introduction of the targeted voucher policy. In the absence of other simultaneous changes to policy of relevance, the important gains in test scores that have just been documented can be credibly attributed to the targeted voucher program. To summarize, the policy impact of the targeted voucher program (SEP) was to increase test scores of the poorest 40% of students by 0.20σ after the fourth year of its implementation.

4 Empirical Model of School Choice

I develop an empirical model of school choice that allows for the construction of different counterfactual situations which will isolate and quantify both the demand- and supply-side mechanism. The objective of this empirical model is to quantify the behavior of families regarding their choice of school based on the underlying characteristics such as price, quality and distance, so as to be able to replicate credible counterfactual scenarios. To this end, I develop a model of demand for elementary schools in an environment where spatially differentiated schools choose quality and prices to maximize profits. The model accommodates school unobservable characteristics as well as observable and unobservable family heterogeneity at the census block level, providing a rich description of how families and schools interact.

The specific context is a static choice model where families must choose exactly one provider of educational services from their market. Families are assumed to be able to attend any school in the market as long as they are willing to pay the price and travel to get there. Public and private schools are differentiated spatially and compete for students. Private schools can choose to charge a price above a subsidy given by the government for each student while public schools cannot. Both public and private schools can choose their quality, presumably through the hiring of more qualified teachers, materials and also by exerting more effort. In what follows I make these ideas more precise and derive some empirical implications from the model.

4.1 Model of School Choice

Families are indexed by i and are members of one observable family type k and have unobservable characteristic v_i. They derive utility from a school indexed by j at time t as a function of the schools observable and discrete characteristics x_{jt}, its price p_{jt}, quality q_{jt} and the proximity to the families home d_{ij}. Preferences over these characteristics are heterogenous across family observable discrete type k. Preferences for quality are also heterogeneous along an unobserved family characteristic v_i. Families share a common preference for unobservable characteristics of the school ξ_{jt}. Finally family i has a random iid preference shock for school j at time t that is ϵ_{ijt}. A family i's utility derived from a school indexed by j at time t is the following:

$$U_{ijt} = \eta_k x_{jt} + \beta_k q_{jt} + \xi_{jt} - \alpha_k p_{jt} + \lambda_k d_{ij} + \beta^u v_i q_{tj} + \epsilon_{ijt} \tag{2}$$

The distribution of unobservable characteristics is assumed to be normal with a zero mean and a variance of σ^2 so that $v_i \sim N(0, \sigma)$. The distribution of the random preference shock ϵ_{ijt} is assumed to have a standard extreme-value distribution. Families live at a specific geographic location within the market which defines the distance to each school. The geographic location will be defined as a node on a grid of N_m nodes across the market, discussed further below.

Furthermore, families must choose one school out of the F_t^m schools in the market m at time t. Note there is no outside option in this case. One particular school is chosen to be the reference in each market and we can normalize $\xi_{1t} = 0$ without loss. Given the assumptions described above we can calculate the share of families of type k who live at node n at time t who will select school j as follows:

$$s_{jt}^{nk}(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi}) = \frac{1}{N_{vi}} \sum_{i=1}^{N_{v_i}} \left(\frac{\exp\left(\beta_k q_{jt} + \xi_{jt} - \alpha_k p_{jt} + \lambda_k d_{nj} + q_{jt} v_i\right)}{\sum_f^{F_t^m} \exp\left(\beta_k q_{ft} + \xi_{ft} - \alpha_k p_{ft} + \lambda_k d_{nf} + q_{ft} v_i\right)} \right) \tag{3}$$

In Equation 3, the bold symbols $(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi})$ represent vectors of quality, price and unobservable characteristics of all schools in the market. The market is comprised of a total of N students who live on the discrete set of N_m nodes. The distribution of students of type k across nodes is given by the vector w_k^m with

$$\sum_n^{N_m} w_{nk}^m = 1 \qquad \forall \quad k \tag{4}$$

The proportion of the students in the market who are of type k is given by Π_k^m where

$$\sum_{k=1}^{K} \Pi_k^m = 1 \tag{5}$$

.

The total market share of a given school j will be :

$$s_{jt}(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi}) = \sum_{k}^{K} \sum_{n}^{N_m} s_{jt}^{nk}(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi}) \cdot w_{nk}^{m} \Pi_k^m \tag{6}$$

Several important assumptions have been made to derive this parsimonious model of school choice. One assumption is that parents do not bargain with schools over the price. Another important assumption is that students can attend any school that they are willing to travel to and pay for. This assumption avoids the explicit modeling of capacity constraints and allows for straightforward counterfactual exercises. To the extent prices are correlated with selectivity, ignoring supply-side selection will make poor students seem to behave as though they are more price elastic. In practice, strict capacity constraints seems to not be that relevant as no more than 4% of schools have enrollments that are binding to the legal class size limit in first grade. It is of course possible that schools have a desired class size that is lower than the legal limit which may still serve as a constraint. However Table A2 shows survey evidence from 4th grade parents, who almost never say they have been rejected from the school they actually wanted to send their child to. Finally, selection of any kind is prohibited by law at elementary schools that take vouchers, *Ley General de Educación (LGE), Ley N20.370*.[13] These points suggest that at least in elementary schools, selection on the part of schools is not the main driver of the distribution of students we see in the data.

Another important assumption is that families are aware of the location, quality and price of all options. There is some empirical evidence that suggests this is not always the case (Hastings and Weinstein 2008, Cooper et al. 2013). In this application I also assume residential location is not a relevant dimension in the school choice problem. In the US neighborhood-based public school system, modeling residential location is very important (Nechyba 1999, Nechyba 2000, Nechyba 2003, Bayer et al. 2007). However in the case of Chile and in many other voucher applications in the world, the link between residential location and school choice is less important as it does not determine the school or choice set (Bettinger 2011). Future empirical applications should extend this analysis

[13]In the literature comparing voucher and public schools, some authors have emphasized that voucher schools screen their students and argue this is a reason that voucher schools preform better on average than public schools (Rounds 1996, Contreras et al. 2010). These studies are based on survey evidence that application processes at some voucher schools request parents to provide documents such as marriage certificates, current employment and in some cases an academic evaluation.

to incorporate some of these additional features and see how they interact with voucher policy.

4.2 Market Definition and Data

4.2.1 Urban Markets in Chile

Defining the market is a difficult task in many settings when physical distance is a relevant characteristic. It is generally not easy to find a boundary where one market ends and one begins in broad urban areas. Papers that study retail markets typically have used political or administrative boundaries to define markets such as cities or counties (Davis 2006). In some cases, such as small isolated communities, this works well but in large urban areas consumers close to the border of a county might also be close to firms in the next county. Therefore, it is possible for consumers to choose to cross market lines to buy from firms in neighboring "markets" in these cases. In this application I take advantage of the relatively sparse distribution of the population in Chile where communities tend to be far from each other. This creates a natural definition of a market based on the idea that consumers in one city will not not travel very far across rural areas to go to school in another city.

In practice I use the Chilean census maps of all urban areas in the country to define markets. I join all urban areas that are five kilometers apart or less at their closest point. The union of all connected urban areas is defined as one market under the assumption that students could feasibly travel within this set of urban areas due to their proximity. Using this method across the entire country defines $M = 205$ urban markets. Many of these markets are very small with the median market size being just under 4.5 square kilometers.

The Chilean census also provides detailed block level data on every urban area and thus on every market I have just defined. Block level census data is used to describe the distribution of student characteristics in the market across a grid of N_m nodes. I group census blocks into squares approximately 5 blocks wide to define a node and aggregate the block level information to this level. I use the most recent available census data from 2002[14] to

[14]Data from the 2012 Census was expected to be available in 2013 but will not be available in the foresee-

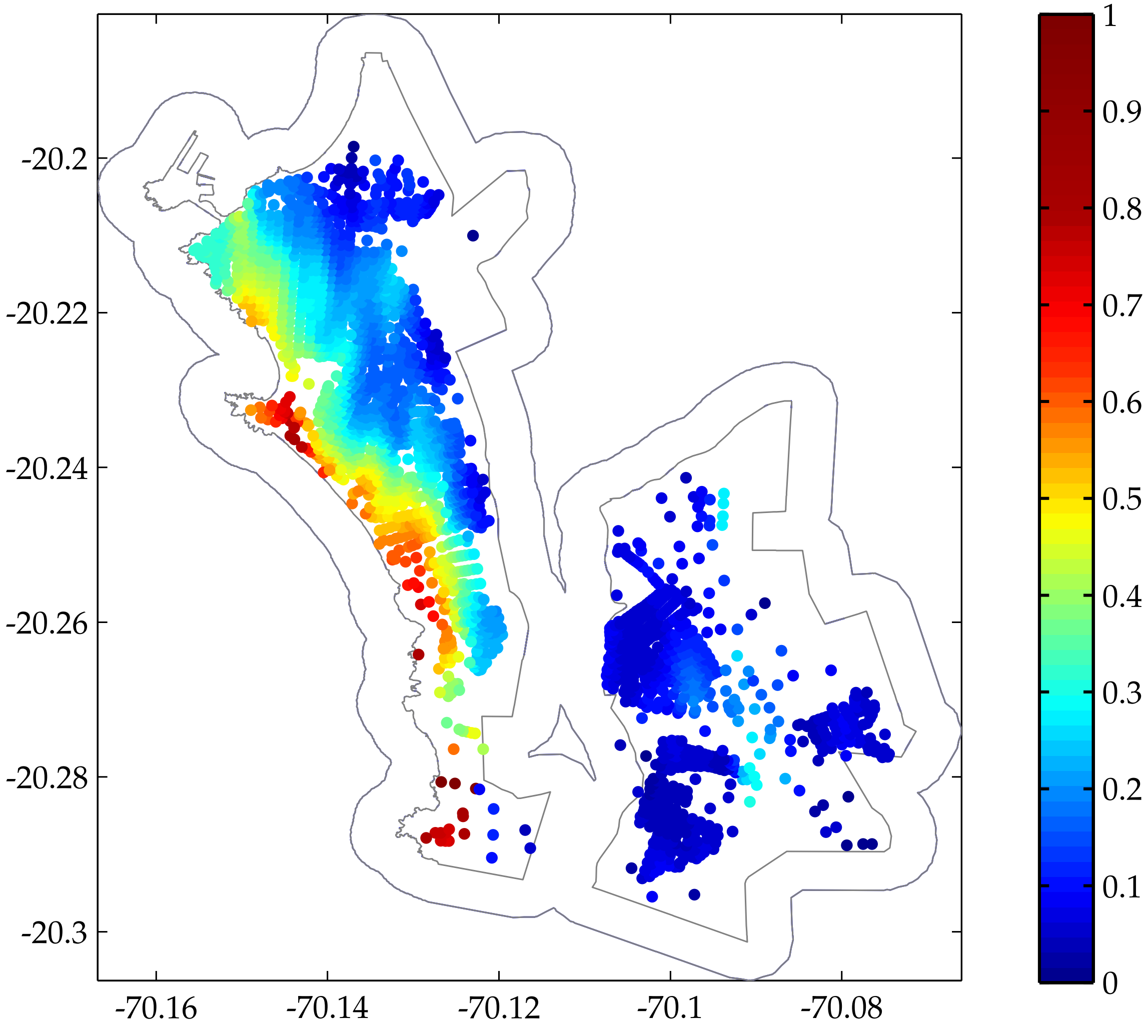
estimate w^m_{nk}, the distribution of families across each node within the market. I use current microdata on all students in the market to determine the aggregate participation of each type of family Π^m_k in the market. In the empirical application Π^m_k varies with time from 2005 to 2011 but w^m_{nk} does not[15].

Figure 6 displays the distribution of students who have mothers with more than a high school degree in market 2. This market includes the cities of Iquique and Alto Hospicio and is located in the northern region of Tarapacà. It can be seen that students with educated mothers are more highly concentrated on the left of the market which is along the coast. On the bottom right hand side of the market is Alto Hospicio which has lower overall education levels. This market also illustrates how two urban areas that are close by are joined into one market following the algorithm described above.

able future according to INE.

[15]Ideally when the 2012 census is made available, the transitions from $w^{m,2002}_{nk}$ to $w^{m,2012}_{nk}$ can be incorporated.

Figure 6: Percentage of students at each block with a mother with more than HS education



Note: This figure shows the map of market 2 that includes the comunas of Iquique and Alto Hospicio which together had a population of approximately 250,000 in the last census in 2002. The relative fraction of mothers with more than a high school education is shown at the census block level. In terms of the model, if $k = \ell$ is the type defined by mothers education above high school, then the figure shows $p_{\ell,n} = \frac{\Pi^m_\ell \cdot w^m_{n\ell}}{\sum_k \Pi^m_k \cdot w^m_{nk}}$ at each $n \in N^m$.

4.2.2 Schools

Administrative records on all schools in the country are available from the Ministry of Education of the Chilean government (MINEDUC). This lists the type of school, the aggregate matriculation by grade level and address of the school among other school characteristics. I concentrate on regular elementary schools and exclude schools that focus only on special needs children or only on high school students between the years 2005 and 2011. Using the address information on each school I associate schools with the markets defined above if the school is within the boundaries of the market, with a small buffer zone to avoid excluding schools on the edge of the cities. This gives a total of 4,809 schools across 205 markets. Market shares are constructed using the aggregate information on matriculation for all schools in the market for each year by grade. Most markets are characterized by a small number of schools. There are only a few large urban areas that have over 100 schools while the capital of Santiago has over 1,400 schools.

Table 1: Descriptive Statistics on the Distribution of School Characteristics

	Public			Voucher			Non-Voucher		
	p25	p50	p75	p25	p50	p75	p25	p50	p75
School Characteristics									
Average Score (in 2011)	-0.65	-0.07	0.53	-0.04	0.57	1.13	1.22	1.85	2.28
Price (2012 US dollars)	0	0	0	123	300	427	3452	4572	5254
Number of Students	22	34	54	25	39	69	16	31	57
School Composition									
% Mothers with $> HS$	0.19	0.25	0.32	0.26	0.34	0.48	0.78	0.89	0.95
% Mothers with HS	0.29	0.38	0.46	0.36	0.46	0.53	0.04	0.10	0.22
% Mothers with $< HS$	0.25	0.36	0.47	0.05	0.14	0.26	0.00	0.00	0.00
Total Number of Schools			2242			1523			393

Note: This table shows some descriptive statistics on the distribution of school characteristics given the type of school. The columns show the 25th, 50th and 75th percentil school ranked according to the variable indicated on that row on the left.

4.2.3 Students

Detailed individual level data is useful to describe the choices that families make and to estimate school quality. I use administrative panel data from 2005 to 2011 on all students in the country from the Ministry of Education of the government of Chile. These data record the school attended for every year as well as information on grades and some basic demographic information. It also includes individual level eligibility for the *Subvencion Escolar Preferencial* (SEP) targeted voucher which started after 2008. I use these data to document choices given the type of student. This dataset also contains address information for a subset of students for the years 2010 and 2011 which I use to estimate the joint distribution of program eligibility and mothers education across census blocks. A second source of data is from birth records from the Ministry of Health of the government of Chile. This database covers all births in the country after 1992 and contains information on the health conditions of a child at birth such as birth weight, length and gestation. It also contains information regarding the mother and father, such as education level and marriage status. The original source data also contained the mother's id number with allowed the identification of siblings and the possibility to link other administrative educational information from the mother at the Ministry of Education. A third source of data on students are test scores from the SIMCE test and an accompanying survey for the population of 4th and 8h grade students. The survey contains detailed information about the household composition, demographics and income. A fourth source of data comes from college entrance exams which covers all applicants to college from 1980 forward and are linked to students mothers[16]. Since the sample of students entering 1st grade in 2005 would have been born in 1998 or 1999, virtually all mothers who took the test would be included in the data.

These datasets are linked at MINEDUC using individual level identifiers which are masked and the resulting database is stripped of any individual level identification. Geographic location is associated with a census block and address information is also eliminated. From this sample I exclude students who attend special education schools and link students to markets through the school they attend. The resulting sample dataset of elementary school students in markets I am studying contains almost 12 million student-year observations which accounts for 86% of the system during that period. Census block level geographic information is available for approximately 5 million (or 45%) of this sample. The Data Appendix explains the data processing in detail.

[16]Data on college entrance exams prior to 2000 was originally collected from archival records as part of the *Proyecto 3E*, Hastings et al. (2013), a joint research effort with DEMRE, the institution that administers the college entrance exam in Chile.

4.3 Empirical Model of School Choice

4.3.1 Estimating Measures of Quality

In Chile, test scores are available only in 4th grade at the elementary school level.[17] This precludes empirical strategies that use student fixed effects or other similar identification strategies reviewed in Meghir and Rivkin (2011).

Previous work estimating discrete models of school choice have used average school test scores as a measure of quality (Hastings et al. 2009, Bayer et al. 2007, Gallego and Hernando 2010, Chumacero et al. 2011). This empirical strategy has the benefit of being straightforward, but it also confounds the schools' contribution to learning with the students' own characteristics. It also makes constructing counterfactual test score distributions very difficult. I will argue that while average test scores are a good proxy for school quality in some applications, a school's contribution to learning (i.e. value added) is what families should consider when comparing schools on quality. The estimation of the empirical model of school choice will then determine whether families' choices take into account school quality or other characteristics as some research has indicated in the past (Rothstein 2006, Mizala and Urquiola 2013).

In this application I assume quality is not directly observable to the econometrician in the data. However, families recognize the school's ability to improve students scores. The assumed relationship between observable test scores y_{ijt} and quality q_{jt} is defined in Equation 7, where X_{it} is a large vector of observable individual student characteristics the and v_{ijt} is an random iid shock to observable test scores. The vector of characteristics used in the empirical estimation is unusually large relative to the literature and includes detailed information on the student's family background.

$$y_{ijt} = q_{jt} + X_{it}\gamma + v_{ijt} \tag{7}$$

The estimated value of q_{jt} is the school fixed effect and is the component of the average test score in the school that is not explained by the individual characteristics of the students. This will capture the school inputs such as teacher quality, infrastructure and any

[17] Tests are also available in 8th and 10th grade on alternating years between 2005 and 2011.

other school specific characteristic that raises the average test score. To the extent that the demographic composition of the schools students' matter for test scores, these effects will also be included in the school fixed effect quality measure.[18]

Important assumptions are made in the estimation of school quality. I do not model peer effects directly and I assume that v_{ijt} is orthogonal to q_{jt} which precludes selection on unobservable characteristics. These assumptions are restrictive but provide a parsimonious model that can produce counterfactual test score distributions in a tractable way. In practice, estimation will be carried out with a large vector of family observable characteristics to limit the extent of selection driving the estimates.[19] Moreover, the growth in aggregate test scores documented in Figure 2 and Figure 4 is not likely to be driven by selection effects or peer effects. This suggests that these assumptions will not be critical for the results in the paper and are discussed further in section 5.

4.3.2 Estimating Demand for Schools

I estimate parameters from Equation 2, $\theta = \{\alpha, \beta, \lambda, \sigma, \xi\}$ by using a method of moments estimator. I combine both aggregate, IV and micro moments following Berry (1994), Berry et al. (1995), Petrin (2002) and Berry et al. (2004). Aggregate moments discipline the model estimates making it fit the market participation of schools observed in the data. The estimation of a year and firm specific term ξ allows the model to match school level shares perfectly. The rich micro data define a set of type specific moments so that the estimation routine chooses θ so as to approximate the heterogeneity in behavior across different types of families. Noting that ξ is correlated with both q_j and p_j, I solve the endogeneity problem using an IV strategy following Berry (1994). I define instruments taking advantage of the variation of costs across markets and changes to policy over time. I develop each set of moments below.

For each school and time period we ask the estimation routine to choose θ such that the model replicates the share of the market that the school has in the administrative data. I refer to this set of moments as aggregate moments. This defines one moment for each

[18] Altonji et al. (2010) considers a wide array of assumptions regarding the role of peer composition in determining test scores.

[19] In ongoing work I model selection on unobservable characteristics.

firm and time period. $\mathbb{N}^{f\times t} = \sum_t^T N_{m,t}^f$

$$G^1(\theta) = s_{jk} - s_{jt}(\theta) \tag{8}$$

I then define the micro moments of interest to be the expected quality, price and distance each type of family chooses in each market in each period.

$$E(d\big|k,t,m); \quad E(p\big|k,t,m); \quad E(q\big|k,t,m) \qquad \forall\, t,m \quad \text{and } k$$

The model parameters are chosen so as to match the empirical counterpart of these expressions. From the microdata we have N_{kt}^m observations in market m of students identified as type k at time t. Each of these observations has chosen an option with a q, p and d associated to it, thus we can generate empirical averages to approximate the expectations of interest. Given a set of parameters and the distribution of students across the market (census blocks) we can construct moments implied by the model to compare with the empirical ones given by the microdata. This defines $\mathbb{N} = \sum_{m\in M} N^m xKxT$ moments for price, quality, and distance.

$$G_d^2(\theta) = \sum_{i\in N_{kt}^m} d_{ik} - \sum_n^{N_m} \sum_j^{N_{m,t}^f} s_{jt}^{nk}(\theta)\cdot w_{nk}^m \cdot d_{jn} \tag{9}$$

$$G_q^2(\theta) = \sum_{i\in N_{kt}^m} q_{ik} - \sum_n^{N_m} \sum_j^{N_{m,t}^f} s_{jt}^{nk}(\theta)\cdot w_{nk}^m \cdot q_{jt} \tag{10}$$

$$G_p^2(\theta) = \sum_{i\in N_{kt}^m} p_{ik} - \sum_n^{N_m} \sum_j^{N_{m,t}^f} s_{jt}^{nk}(\theta)\cdot w_{nk}^m \cdot p_{jt} \tag{11}$$

where $N_{m,t}^f$ schools in each year t and market m.

Finally I define a last set of moments as a set of orthogonality conditions. Specifically, to identify the school demand parameters, I need instruments that are related to price and quality but not related to the unobserved quality of the school ξ. I define moments that are of the following type

$$G^3(\theta) = \xi \cdot IV' \tag{12}$$

The instruments include cross market cost shifters such as teacher wages in each market. I use the baseline voucher which varies across time. I also use the variation in prices that is induced by the SEP policy. This policy effectively eliminated prices at a significant number of schools for almost half of all students. The change in prices induced by this policy affect equilibrium prices and quality for all students through schools first order conditions. This equilibrium effect occurs differentially across neighborhoods that have more or less concentration of eligible students.

4.3.3 Implementing Estimation

The estimation of θ done using the MPEC approach following Dubé et al. (2012) and Su and Judd (2012). The main idea of this methodology is to transform the unconstrained minimization problem posed in the GMM estimator into a constrained optimization problem. I augment the application in Dubé et al. (2012) to the case with additional micro moments and no outside option, which requires an additional normalization of ξ in each market and time period. The optimization problem can be written as follows

$$\min_{\{\theta,\xi,g_2,g_3\}} \begin{bmatrix} g_2 \\ g_3 \end{bmatrix}' \begin{bmatrix} W_{MM} & 0 \\ 0 & W_{IV} \end{bmatrix} \begin{bmatrix} g_2 \\ g_3 \end{bmatrix} \tag{13}$$

$$\underline{\text{subject to:}}$$

$$\overline{S} - s(\theta,\xi) = 0 \qquad \text{Share equations} \tag{14}$$

$$\left(M(\theta,\xi) - \overline{M}\right) - g_2 = 0 \qquad \text{Micro moments} \tag{15}$$

$$IV'\xi - g_3 = 0 \qquad \text{IV moments} \tag{16}$$

$$\xi^{\text{norm}} = 0 \qquad \text{Normalization restrictions} \tag{17}$$

Notice that in this formulation, aggregate moments are written directly as a constraint. Both micro moments and IV moments have been reformulated as constraints to provide a computationally favorable sparsity structure in the Jacobian and Hessian of the corresponding Lagrangian. Further details are discussed in the Estimation Appendix.

5 Model Estimates

5.1 Quality Estimates

School quality is estimated by OLS according to Equation 7. The school quality is the school and year fixed effect in a regression of students test scores that controls for a large vector of student characteristics including household income, detailed parental educational levels, mothers' math and language college entrance exam scores, demographic composition of the family, and early childhood health indicators.

Table 2 presents results from estimating Equation 7, which includes school and year fixed effects. The top panel shows the role of parents education and the mothers college entrance exam results in math and language. Both parents' education have significant and relatively large coefficients. Students whose mother took the college entrance exam also did significantly better, adding almost 0.3σ to the students' test scores. Mothers who did better on the college entrance exam also had children who did better on 4th grade evaluations. A mother who scored one standard deviation above the mean test score in language had children who scored 0.3σ better. Interestingly, mothers' performance on math tests are much less important in magnitude than language test scores by a factor of four or five.

Health at birth has been shown to be a important predictor of later life outcomes[20]. Bharadwaj et al. (2010) show that health outcomes are systematically correlated with academic outcomes in the case of Chile. Table 2 shows that birth weight, birth length and weeks of gestation are all significantly related to test scores, even after controlling for school and year fixed effects as well as many other demographic characteristics.

[20]See Behrman and Rosenzweig (2004),Currie and Almond (2011), and Almond and Currie (2011) for examples.

Household income per capita percentile rank and a indicator for being below the 40th percentile are also significant predictors of test scores as is having an internet connection and a computer at home.

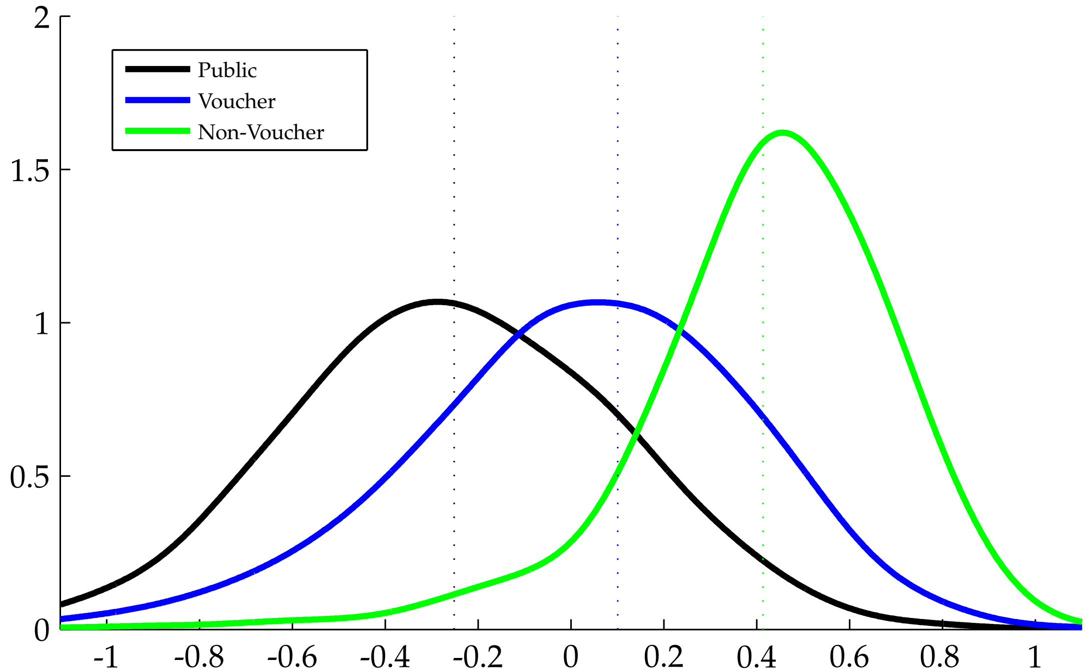
Table 2: School Quality Estimation Regression

	Coeff	Std Err	P-values
Mother Ed High School	0.1864 ***	0.003	0.00
Mother Ed More than High School	0.1660 ***	0.002	0.00
Father Ed More than High School	0.1936 ***	0.003	0.00
Father Ed High School	0.0823 ***	0.002	0.00
Mother Took College Entrance Exam	0.2814 ***	0.007	0.00
Mother Math Test $\mu - \sigma > Score > \mu - 2\sigma$	-0.0308 ***	0.009	0.00
Mother Math Test $\mu > Score > \mu - \sigma$	0.0406 ***	0.010	0.00
Mother Math Test $\mu + \sigma > Score > \mu$	0.0619 ***	0.010	0.00
Mother Math Test $\mu + 2\sigma > Score > \mu + \sigma$	0.0747 ***	0.011	0.00
Mother Math Test $Score > \mu + 2\sigma$	0.0694 ***	0.012	0.00
Mother Lang Test $\mu - \sigma > Score > \mu - 2\sigma$	0.0456 ***	0.010	0.00
Mother Lang Test $\mu > Score > \mu - \sigma$	0.1807 ***	0.010	0.00
Mother Lang Test $\mu + \sigma > Score > \mu$	0.2698 ***	0.011	0.00
Mother Lang Test $\mu + 2\sigma > Score > \mu + \sigma$	0.3597 ***	0.012	0.00
Mother Lang Test $Score > \mu + 2\sigma$	0.2787 ***	0.013	0.00
Parents Married at Birth	0.0145 ***	0.002	0.00
Birth Weight	0.0110 ***	0.000	0.00
Birth Weight^2	0.0000 ***	0.000	0.00
Gestation	0.0153 ***	0.001	0.00
Gestation^2	-0.0004 ***	0.000	0.00
Birth Length	0.0287 ***	0.002	0.00
Birth Length 2	-0.0002 ***	0.000	0.00
Single Birth	0.0387 ***	0.006	0.00
Number of Older Siblings	-0.0347 ***	0.001	0.00
Male	-0.0484 ***	0.002	0.00
Income	0.0071 ***	0.000	0.00
Income^2	-0.0001 ***	0.000	0.00
Income^3	0.0000 ***	0.000	0.00
Family has a PC	0.0675 ***	0.002	0.00
Family has internet	0.045 **	0.002	0.06
Poor	0.0190 ***	0.004	0.00
Constant	-1.80 ***	0.0552	0.00
N=1,155,114			
R^2=0.31			
School x Year FE Included			

Note: This table presents regression results for estimates of test scores on a large vector of individual student level characteristics. School quality is estimated as the school and year fixed effect and have not been presented in this table.

The resulting school and time fixed effect estimates for school quality are too numerous to present in a table. I summarize two main results that stem from this analysis. The first is that, consistent with the results from the literature on school quality in Chile summarized in Drago and Paredes (2011), voucher schools have higher quality than public schools on average and private non-voucher schools have much higher quality than either. In addition, school quality is very heterogeneous within groups and there are many voucher schools that are worse than public schools.

Figure 7: Distribution of Estimated School Quality by School Type in 2007



Note: This figure shows the student weighted distribution of quality estimated from 7 and Table 2 for schools before 2008. The dotted lines indicate the average for each distribution.

The second result is that school quality rose both in the aggregate and within public and voucher schools. Table 3 summarizes the growth in school quality by type of school. Public schools improved their student weighted average quality by 0.21σ while private non-voucher schools did not improve at all. Voucher schools that were eligible for SEP targeted vouchers increased their quality by 0.16σ and non-SEP eligible voucher schools increased by 0.08σ.

Table 3: Distribution of Estimated School Quality by School Type in 2007

	Score 2005-2007	Score 2011	Δ Score	q 2005-2007	q 2011	Δq
Public	-0.22	0.02	0.24	-0.25	-0.04	0.21
Voucher SEP	0.10	0.27	0.17	-0.04	0.11	0.16
Voucher (no SEP)	0.38	0.48	0.10	0.10	0.17	0.08
Private Non Voucher	0.97	0.98	0.01	0.41	0.40	-0.02

Note: This figure shows the distribution of quality estimated from 7 and Table 2. The black line represents the distribution of quality within public schools. The red line represents the distribution of quality in voucher schools. The blue line represents the distribution of quality in private non-voucher schools.

One natural check is to look at the relationship between estimated school quality and the schools inputs which from theory and other empirical evidence we think affect the quality of the school. Figure A3 plots the nonparametric relationship between a school's estimated quality and the average college entrance exam math test scores of the teachers at the school. This measure has been shown in other work to be related to teacher quality measured in several ways (Alvarado and Neilson 2013). Here we see a positive relationship. This suggests that one of the reasons schools may have higher quality and raise test scores more is that they have better teachers. We might also think that if a school is indeed better at raising test scores, it would be expected to raise its prices. In Figure A4 we see a positive relationship between school quality and prices charged by voucher schools.

5.2 Demand Parameter Estimates

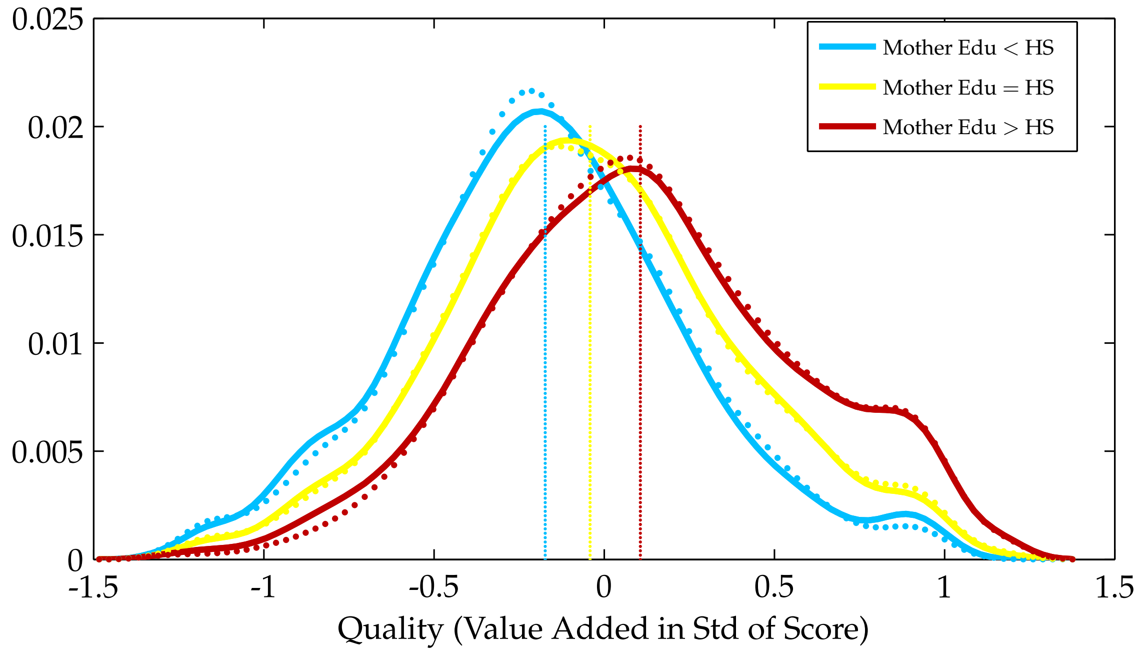
Using the estimated school quality together with the microdata moments and instruments described above, I estimate the model and present the results in Table 4. The first result is that preferences are very heterogeneous across socioeconomic groups and follows findings by several authors (Hastings et al. 2009, Gallego and Hernando 2010). Families of lower income and less educated mothers tend to put more weight on price and distance. Differences are less pronounced regarding school quality. Using the estimated model parameters we can show how well it fits the empirical features we are interested in replicating. The distribution of school quality in aggregate fits perfectly given the model must replicate the aggregate share of each school perfectly. Figure 8 shows the fit of the model by the mothers' educational group.

Table 4: Demand Model Estimates

	Coefficients	Standard Error
Voucher School	2.799***	0.0317
Public School	3.711***	0.0364
For Profit School	-0.030***	0.0137
Religious School	-0.980***	0.0150
Quality	0.099***	0.0371
Quality x HS Mom	0.011***	0.0001
Quality x College Mom	0.012***	0.0001
Quality x Poor	-0.011***	0.0001
Price x NHS Mom	-4.768***	0.0328
Price x HS Mom	-1.758***	0.0196
Price x College Mom	-0.001	0.0244
Price x Poor	-2.926***	0.0209
Distance x NHS Mom	-2.264***	0.0052
Distance x HS Mom	-1.856***	0.0034
Distance x College Mom	-1.380***	0.0030
Distance x Poor	-0.125***	0.0031
Sigma Preference - Quality	0.001	0.7607

Note: Estimation uses 500 draws of v_i^q.

Figure 8: Demand Model Fit by Mother's Education



Note: This figure shows the distribution of school quality by the mothers educational group. The solid lines show the distribution estimated from the microdata and the dotted line are from the fitted model.

6 How did the targeted voucher policy raise test scores?

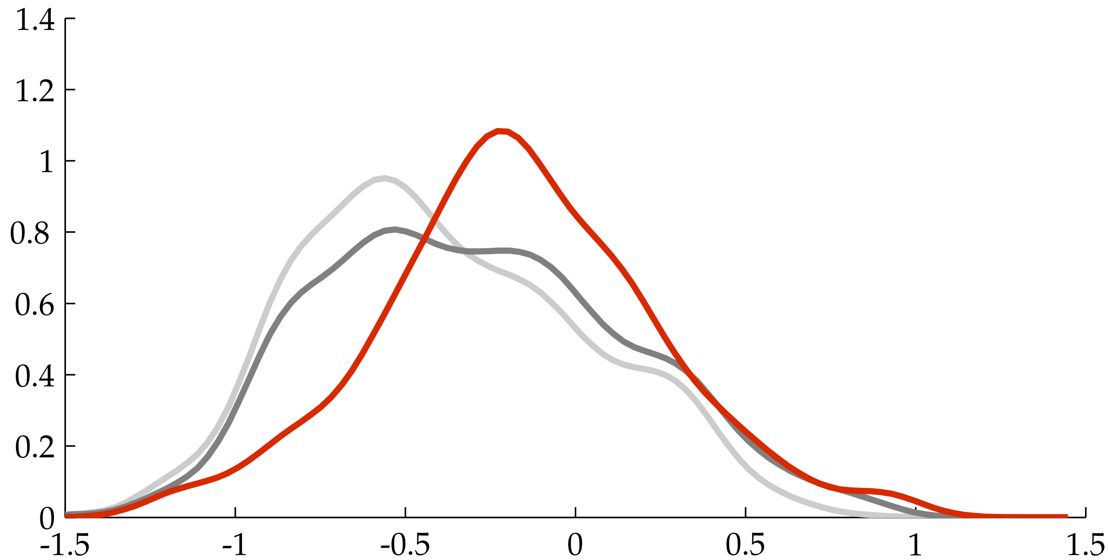
Using the estimated demand model I disentangle the different channels through which the targeted voucher policy raised test scores. The first exercise is to hold school quality fixed and apply the targeted voucher policy in the baseline year. This will isolate the increase in aggregate test scores that is attributable to only demand side sorting when the policy is in place. The second is hold fixed the available schools prior the policy but allowing them to change their quality. The final counterfactual is to let the families in the model sort to schools and use the schools available in 2011 with their characteristics. This last situation measures the full policy impact within a consistent framework in the model.

6.1 Demand and Supply Policy Mechanisms

To isolate the demand side contribution I fix the schools available to be the ones available in 2007 but the prices are now adjusted assuming the targeted voucher policy is in place as in 2011. The model then assigns students to schools and the distribution of test scores, school quality, and changes in these quantities can be calculated relative to the baseline year of 2007. This produced an increase in average test scores of 0.08σ for students in the poorest 40% of the distribution.

The next counterfactual is to fix the schools that were available in 2007 and exclude new entrants. I reassign students according to estimated preferences using 2011 school characteristics. This generates an aggregate increase of 0.13σ. The remainder of the effect to reach 0.23σ is attributable to the entry of new schools. Entry is not found to be a significant driver of the improvement in aggregate test scores of the poor induced by the policy. The growth in school quality at existing schools explains almost two thirds of the total effect. Figure 9 shows the distribution of school quality for poor students under each scenario.

Figure 9: Decomposition of Policy Effects



Note: This figure shows the distribution of school quality under different counterfactual situations. The light gray distribution is the baseline situation for the 40% poorest families in the model. The second intermediate gray line shows the new distribution when only prices are modified by the policy. The final dark line to the right is the outcome when schools quality changes as well as prices. The average effect is 0.23σ and the second movement that represents the supply side reaction accounts for almost two thirds of the total policy impact.

Given the large effects that are attributable to the supply side reaction, the next step is to further analyze the incentives schools had to invest more in producing quality once the targeted voucher policy was in place. To do this I develop a model of school profit maximization and use the demand estimates to quantify the schools local market power and how this changes with the implementation of the policy.

6.2 Model of Voucher School Profit Maximization

I model private voucher schools behavior as profit maximizing schools. The profit function for a school in a particular market with N students is the following :

$$\pi_{jt}(\mathbf{q}_t, \mathbf{p}_t, \boldsymbol{\xi}_t) = N s_{jt}(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi}) \left(v + p_j - MC(q_j)\right) - F_j \tag{18}$$

We can replace Equation 6 in Equation 18 so that we can write profits as a function of the students of each type who attend the school from each node in the market:

$$\pi_{jt}(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi}) = N \underbrace{\left(\sum_{k}^{K} \sum_{n}^{N_m} s_{jt}^{nk}(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi}) w_{nk}^{m} \Pi_k \right)}_{s_j} \left(v + p_j - MC(q_j) \right) - F_j \tag{19}$$

Schools choose price and quality. In choosing price, they compare the marginal gain from raising the price to the marginal cost of attracting fewer students. In practice, at high levels of p the voucher diminishes so that $v(p_j) + p_j$ is a concave function of p. For simplicity I ignore this feature of the voucher payout scheme and I also assume that capacity constraints are not relevant to get at a simple expression for price and quality.

The first order condition with regard to price is the following:

$$\frac{\partial \pi_j(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi})}{\partial p_j} = N \frac{\partial s_j(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi})}{\partial p_j} \left(v + p_j - MC(q_j) \right) + N s_j(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi}) \quad = 0 \tag{20}$$

$$p_j^* = \underbrace{\left[MC(q_j) - v \right]}_{\text{MC after subsidy}} + \underbrace{s_j(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi}) \left[- \frac{\partial s_j(\mathbf{q}, \mathbf{p}, \boldsymbol{\xi})}{\partial p_j} \right]^{-1}}_{\text{Price Mark up}} \tag{21}$$

By reordering we can get to an expression for the price, assuming no corner solution at zero. The first expression on the right represents the pricing in perfect competition. The price should be equal to marginal costs minus the subsidy per student. The second term represents the “markup” relative to marginal costs that schools can charge because of their local market power. The price markup is smaller the more sensitive the schools share is when its own price changes. Note also that the markup depends in the prices and qualities of all other schools in the market.

Similar arguments also can be made for the choice of quality. Schools choose quality comparing the marginal benefit of attracting more students relative to the marginal increase in the costs.

$$\frac{\partial \pi_j(\mathbf{q},\mathbf{p},\boldsymbol{\xi})}{\partial q_j} = N\frac{\partial s_j(\mathbf{q},\mathbf{p},\boldsymbol{\xi})}{\partial q_j}\left(v + p_j - MC(q_j)\right) - Ns_j(\mathbf{q},\mathbf{p},\boldsymbol{\xi}) \cdot \frac{\partial MC(q_j)}{\partial q_j} = 0 \tag{22}$$

I further assume that $MC(q_j) = c_0 + c_1 \cdot q_j$. Rearranging we get to the following expression for quality:

$$q_j^* = \underbrace{\left[\frac{v + p_j - c_0}{c_1}\right]}_{\text{Competitive Quality}} \underbrace{- s_j(\mathbf{q},\mathbf{p},\boldsymbol{\xi})\left[\frac{\partial s_j(\mathbf{q},\mathbf{p},\boldsymbol{\xi})}{\partial q_j}\right]^{-1}}_{\text{Quality Mark Down}} \tag{23}$$

The school will provide quality that is lower than they would in perfect competition. Market power will allow schools to provide quality with a "mark down" relative to marginal costs. The market power again stems from the term $\frac{\partial s_{jt}(\mathbf{q},\mathbf{p},\boldsymbol{\xi})}{\partial q_{jt}}$ which shows how sensitive demand of this school is with respect to quality.

In both cases, the incentives of the firm depend on their local market power. This stems from the fact that schools are differentiated not only by price and quality, but by their location.

The market power that a school has will depend on its competitors and their characteristics including their prices and how close they are. It will also depend crucially on the types of students that live near the school and what characteristics they most value.

$$\frac{\partial s_{jt}(\mathbf{q},\mathbf{p},\boldsymbol{\xi})}{\partial q_{jt}} = \sum_k^K \sum_n^{N_m} \frac{\partial s_{jt}^{nk}(\mathbf{q},\mathbf{p},\boldsymbol{\xi})}{\partial q_{jt}} \cdot w_{nk}^m \Pi_k^m \tag{24}$$

with

$$\frac{\partial s_{jt}^{nk}(\mathbf{q},\mathbf{p},\boldsymbol{\xi})}{\partial q_{jt}} = \beta_k \frac{1}{N_{vi}} \sum_{i=1}^{N_{v_i}} \left[s_{jti}^{nk}(\mathbf{q},\mathbf{p},\boldsymbol{\xi})(1 - \sum_f^{F_t^m} s_{fti}^{nk}(\mathbf{q},\mathbf{p},\boldsymbol{\xi})) \right] \tag{25}$$

so that one can write the derivative of the schools' share with respect to quality as a weighted average of the preferences of the families that live nearby:

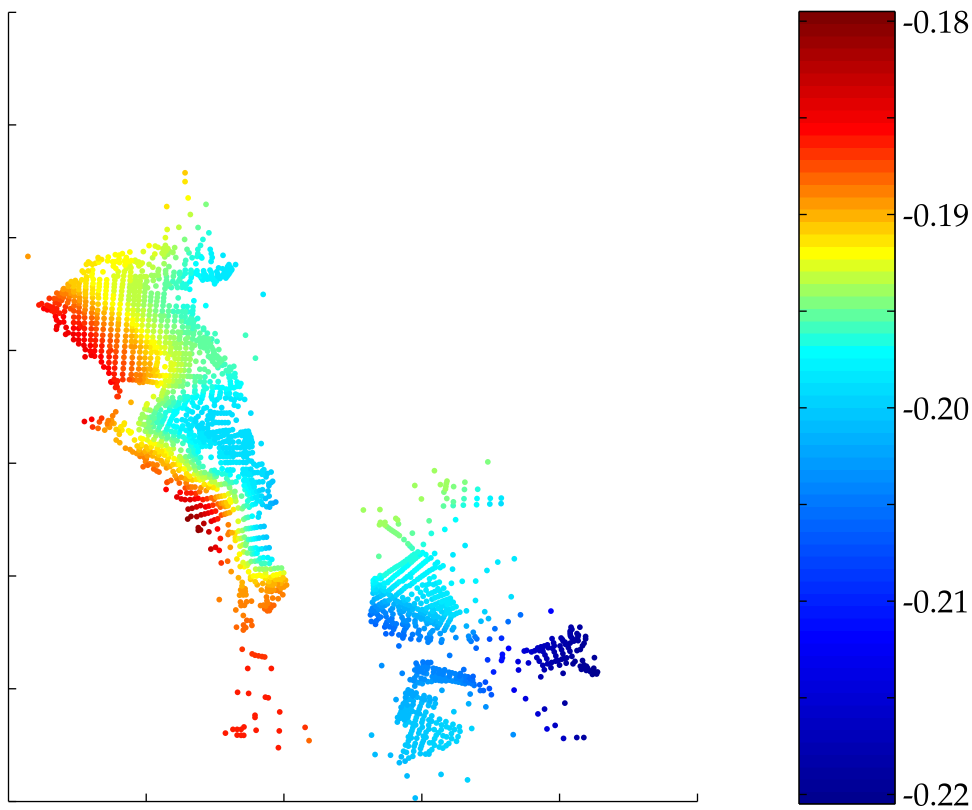
$$\frac{\partial s_{jt}(\mathbf{q},\mathbf{p},\boldsymbol{\xi})}{\partial q_{jt}} = \sum_{k}^{K}\sum_{n}^{N_m}\left(\beta_k \cdot w_{nk}^{m}\Pi_k^m\right) \cdot \left(\frac{1}{N_{vi}}\sum_{i=1}^{N_{v_i}} \cdot \left[s_{jt}^{nk}(\mathbf{q},\mathbf{p},\boldsymbol{\xi})(1-\sum_{f}^{F_t^m} s_{ft}^{nk}(\mathbf{q},\mathbf{p},\boldsymbol{\xi}))\right]\right) \quad (26)$$

In conjunction with the previous findings that indicated significant differences in preferences, we expect schools to have very different incentives if they are located in poor or rich neighborhoods. In addition, it is intuitive to think the policy of targeted vouchers would modify the competition in poor neighborhoods. The first reason is that the poor are more price sensitive and thus the targeted voucher is likely to affect their choices more. In Equation 26 this can be seen in the first term in brackets on the left. There are additional incentives to compete as students are also worth more to schools with this higher voucher, but this effect is not directly captured by the mark down expression. In what follows I quantify the quality markdown described above and then show how this changed systematically with the introduction of the policy.

6.3 Firm Incentives and Targeted Vouchers

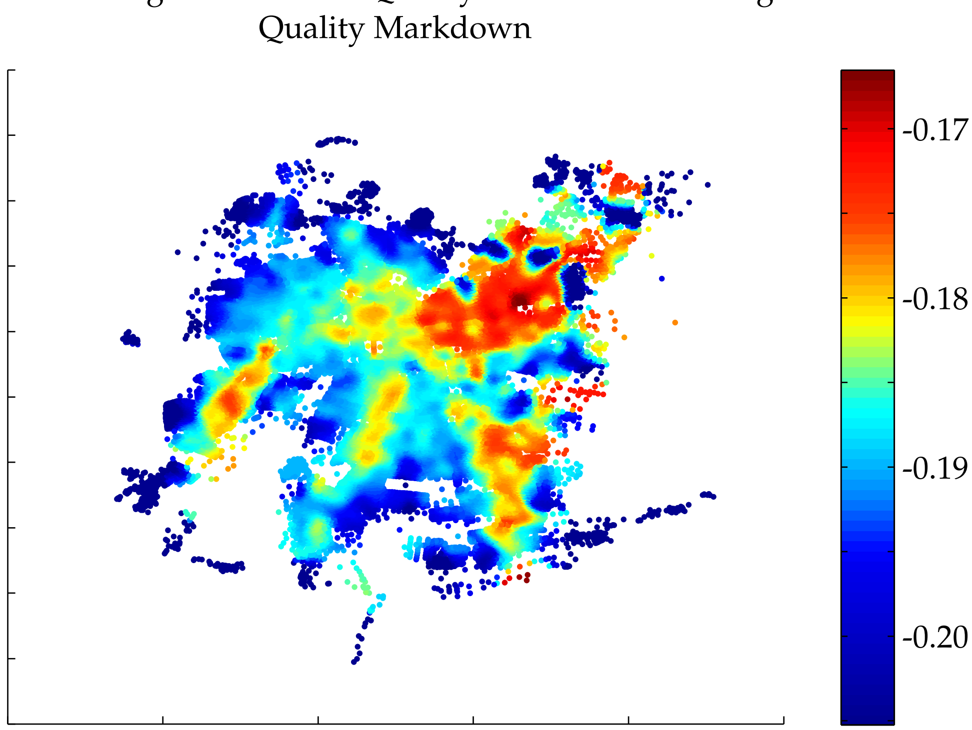
Figures 10 and Figure 11 show the mark down defined in Equation 26 for 2007. Specifically what is shown is a distance weighted average mark down from Equation 26 evaluated at each census block centroid. This heterogeneity in the quality response across schools is produced by the heterogeneity in preferences and the residential distribution of different types of families. It is also a function of the schools nearby and how desirable they are to local residents. From the demand estimates we know poor, less educated families are more price sensitive and are less inclined to travel very far from their homes. This leads to high markdowns in poor neighborhoods as better, more expensive schools are not close substitutes given the families' high price elasticities. The fact that schools in poor neighborhoods have more local market power to markdown their quality partially helps understand the inequality in outcomes.

Figure 10: School Quality Markdown - Iquique and Alto Hospicio



Note: This figure shows the distance weighted average mark down from Equation 26 evaluated at each census block centroid in market 2 which corresponds to the cities of Iquique and Alto Hospicio.

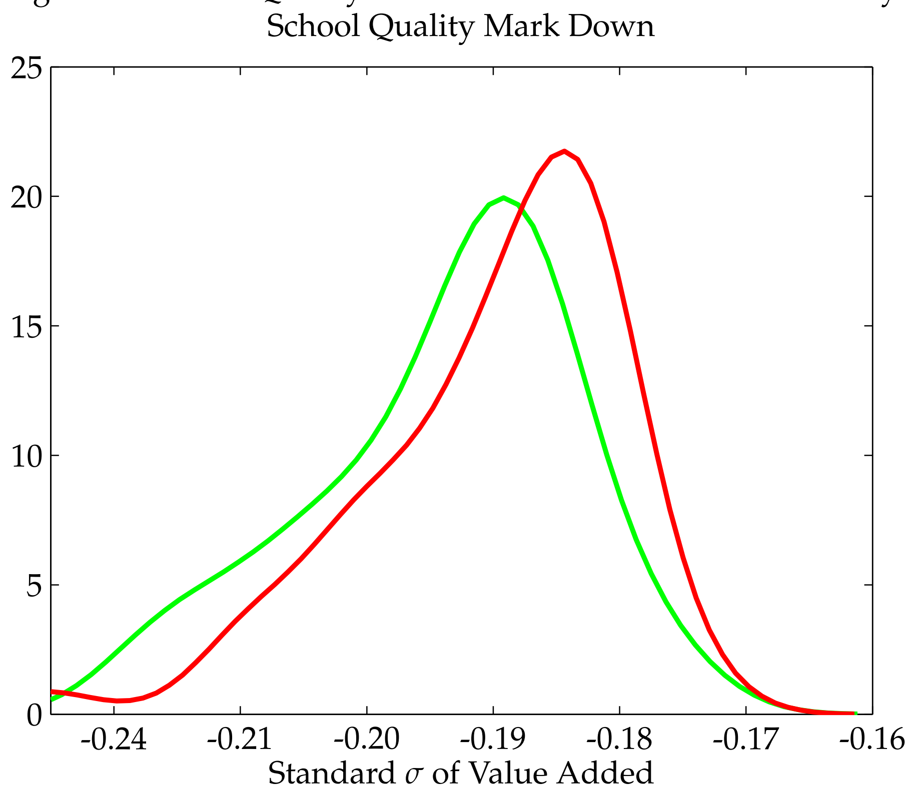
Figure 11: School Quality Markdown - Santiago



Note: This figure shows the distance weighted average markdown from Equation 26 evaluated at each census block centroid in market 58 which corresponds to the city of Santiago which is the largest market.

The SEP policy that targets more resources to poor students and lowers their out of pocket expenses intuitively can be expected to diminish schools' local market power. More expensive schools of good quality will become more attractive to poor families and increase the effective competitive pressure schools in poor neighborhoods face. In Figure 12 we see that this is indeed the case and the entire distribution of school mark down shifts to the right, in particular the lower tail of the distribution.

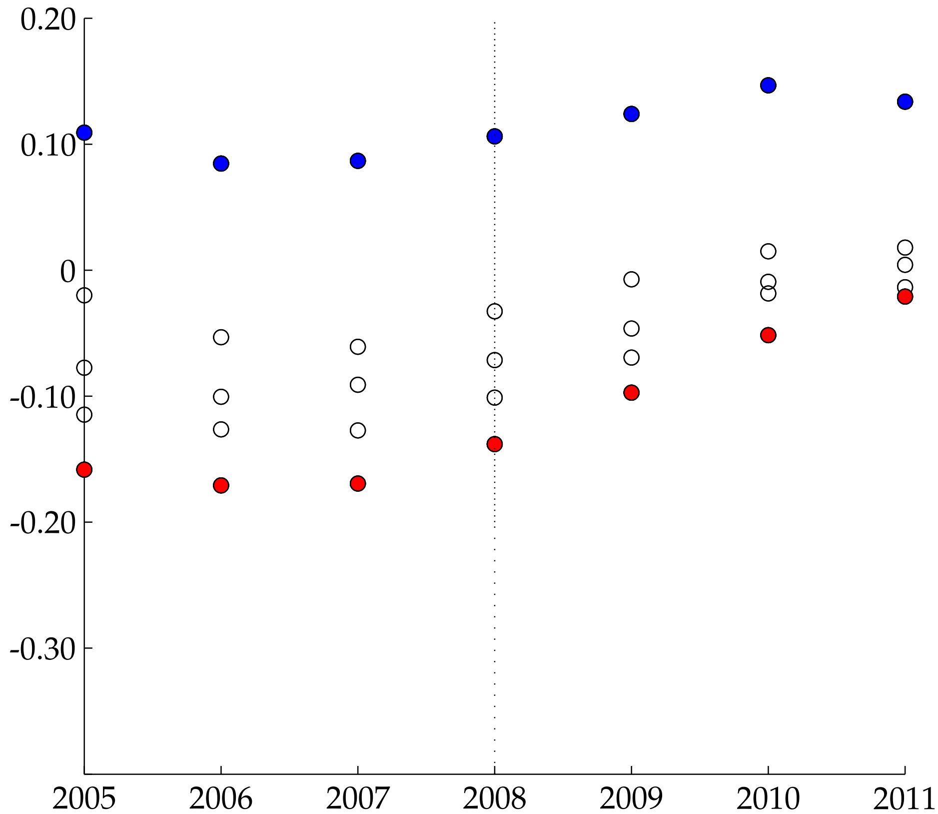
Figure 12: School Quality Mark Down - Before and After Policy



Note: This figure shows the distribution of school level mark downs calculated in 2007 and 2011 using Equation 26.

The impact of the targeted voucher policy will also affect some neighborhoods more than others. We expect schools in poor neighborhoods to have increased incentives to improve their quality. To explore how school quality improved across schools in different neighborhoods I divide schools into five groups according to the percentage of students who live within 1 km of the school that are eligible. Figure 13 shows how the average quality of schools in poor neighborhoods changed over time relative to that of other groups of schools in neighborhoods with less poverty.

Figure 13: Average School Quality by Poverty Group



Note: This figure shows the average estimated quality of schools with different levels of poor students living within one kilometer of the school. The red dots represent the schools with the most concentration of poor students, with over 60% of students being eligible once the policy is in place.

To complement the results above I run the following regression

$$q_{jt} = \alpha_0 + \alpha_1(\text{Poorest Neighborhood})_j + \sum_t \beta_t \mathbf{D}_t + \sum_t \gamma_t \mathbf{D}_t \times (\text{Poorest Neighborhood})_j + \epsilon_{jt} \quad (27)$$

where q_{jt} represents the quality of school j at time t. Poorest Neighborhood$_j$ is an indicator variable that takes the value of one if the school is located in the poorest neighborhoods defined as the 20% of schools with the highest concentration of policy eligible students within one kilometer. Equation 27 presents the interaction coefficients γ_t that indicate the gain in quality at schools in the poorest neighborhoods relative to schools in other areas. I estimate this regression for all schools and for voucher, public and non voucher private schools separately. There are two main results in this table. The first is that schools in the poorest neighborhoods improve their quality significantly more than those in other less poor areas. In 2011 schools with the highest concentration of poor students had raised their quality by 0.14σ relative to schools in other areas. The second result is that these gains are mostly occurring for voucher schools. Public schools in poor neighborhoods have significantly higher gains than other public schools, but only in the last year. Private non-voucher schools do not significantly react to the policy more in poor neighborhoods.

Table 5: Regression of School Quality and Neighborhood Poverty x Policy

	All	Voucher	Public	Private
Poorest Neighborhood $\times T_{05}$	-0.01	-0.03	0.00	-0.12
Poorest Neighborhood $\times T_{06}$	0.01	0.01	0.00	-0.13
Poorest Neighborhood $\times T_{08}$	0.04 **	0.06 **	0.01	-0.06
Poorest Neighborhood $\times T_{09}$	0.07 **	0.08 **	0.05	-0.08
Poorest Neighborhood $\times T_{10}$	0.09 **	0.11 **	0.04	0.05
Poorest Neighborhood $\times T_{11}$	0.14 **	0.13 **	0.09 **	-0.05
Poorest Neighborhood	-0.17 **	-0.13 **	-0.06 **	0.12
T_{05}	0.05 **	0.04 **	0.08 **	0.04
T_{06}	0.01	-0.02	0.03 **	0.00
T_{08}	0.05 **	0.03 **	0.07 **	0.08 **
T_{09}	0.11 **	0.09 **	0.13 **	0.06
T_{10}	0.17 **	0.15 **	0.22 **	0.08 **
T_{11}	0.16 **	0.12 **	0.26 **	0.03
constant	-0.12 **	-0.06 **	-0.32 **	0.26 **
N	25882	9891	13651	2340
R^2	0.08	0.07	0.04	0.002

Note: This table presents regression results from Equation 27.

7 Conclusion

This paper uses detailed administrative data to study the effects of targeted school vouchers in Chile. I present evidence that this policy significantly improved academic outcomes for the poorest students in the country. Specifically, I show this policy raised test scores of the poorest 40% of students by 0.2 standard deviations and closed the gap between those students and the rest of the distribution by one third. These aggregate policy effects are large relative to the previous trend. Understanding the channels through which the policy affected outcomes is important to help prescribe future interventions and to determine to what extent results can be extrapolated to other contexts.

In this paper I explore two possible mechanisms for these results. First, conditional on the quality of available schools, the increased vouchers may allow families to choose better schools. Offering students of poor families the opportunity to attend better schools without having to pay the additional prices was often mentioned in the policy debate prior to its implementation. This discussion emphasized the demand-side channel through which students of poor families would attend schools of higher quality. Second, test scores could rise if schools improve their quality as a result of increased incentives to compete for the enrollment of poor students. The empirical analysis presented shows that more than two thirds of the policy effect came through the improvement of school quality and not through sorting of students to different schools. A difference-in-differences analysis shows that schools in the poorest neighborhoods improved their quality by 0.14 standard deviations relative to schools in less poor areas.

The explicit modeling of schools' choice of price and quality allows for a detailed analysis of how the policy changed the nature of competition in poor neighborhoods. On the demand side, the model estimates indicate that preferences for school characteristics are heterogeneous across socioeconomic groups, in particular with regard to prices and distance traveled to school. From the supply side, modeling schools' choice of prices and quality reveals that schools mark down their quality as a function of their local market power. Taken together, I show that schools located in neighborhoods with a large concentration of poor families, who are more price sensitive and are less willing to travel, will face demand that is less sensitive to changes in quality and will consequently have more local market power to markdown quality.

The larger voucher for poor students diminishes schools' local market power in poor neighborhoods by making better but more expensive schools attractive to poor students. The model estimates indicate that the introduction of targeted vouchers effectively raised competition in these neighborhoods by reducing the role of prices in limiting the choices of these families.

This is one of the first empirical analyses to explicitly consider both demand and supply in a market-oriented school choice system. This framework is useful to quantify the different mechanisms behind the large policy impact described here. It can also be used to further study how other sets of rules and regulation can affect the behavior of families and schools in this market. Future work can build upon the demand framework developed here to study entry and exit of schools and the estimation of schools' cost structure to further evaluate the role of alternative policies in equilibrium.

To develop this empirical model I have made several important assumptions regarding the educational production function and how families choose what school to attend. Given that the results presented show significant aggregate improvements in school quality, it is unlikely that these are driven by assumptions regarding peer effects or selection although future work I hope to expand the model to include some of these features. Another important assumption is that families make their choice of school knowing the options and characteristics of these options. In future work, policies that provide information can be evaluated, not only by looking at how they shift families school choice, but also by taking into account the general equilibrium effects on schools choice of price and quality.

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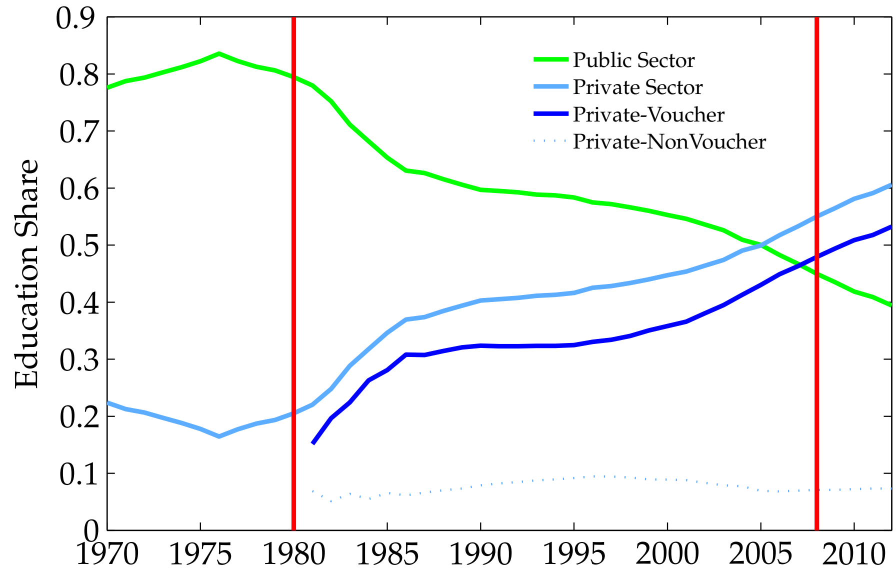
Appendix A Additional Results

Appendix A.1 Additional Descriptive Statistics

Figure A1: Primary Matriculation Shares Over Time



Note: This figure shows primary level matriculation across public and private schools in Chile from 1970 to 2012. The vertical line indicates the introduction of voucher school market in 1980 and the targeted voucher scheme in 2008. Private voucher schools include students attending for profit or non profit private schools. Non voucher private schools represent close to 8% of matriculation and charge tuition that is 4 to 10 times the size of the voucher.
Source: Several editions of Compendio Estadisticos published by the Ministry of Education MINEDUC and de Chile. Dirección de Estudios (2001).

Table A1: Difference in Differences Regression : Poor students catch up

	Coeff	Std Err.	t	P-value
Poorest 40% $\times T_{05}$	0.01	0.010	0.7	0.49
Poorest 40% $\times T_{06}$	0.01	0.010	1.56	0.12
Poorest 40% $\times T_{08}$	0.01	0.009	1.11	0.27
Poorest 40% $\times T_{09}$	0.08 ***	0.010	7.86	0.00
Poorest 40% $\times T_{10}$	0.12 ***	0.010	12.22	0.00
Poorest 40% $\times T_{11}$	0.20 ***	0.010	20.19	0.00
Poor	-0.57 ***	0.012	-46.56	0.00
T_{05}	0.01	0.008	1.35	0.18
T_{06}	0.03 ***	0.008	3.48	0.00
T_{08}	0.05 ***	0.008	6.47	0.00
T_{09}	0.07 ***	0.008	9	0.00
T_{10}	0.17 ***	0.008	21.05	0.00
T_{11}	0.15 ***	0.008	17.44	0.00
Constant	0.30 ***	0.012	25.63	0.00
N	1204102			
R^2	0.069			

Note: This table shows the results of a regression of test scores of 4th grade students on time and dummy variables indicating belonging in the 40% poorest of 4th grade students. The regression also includes interactions between time and poverty status.
Source: Ministry of Education MINEDUC.

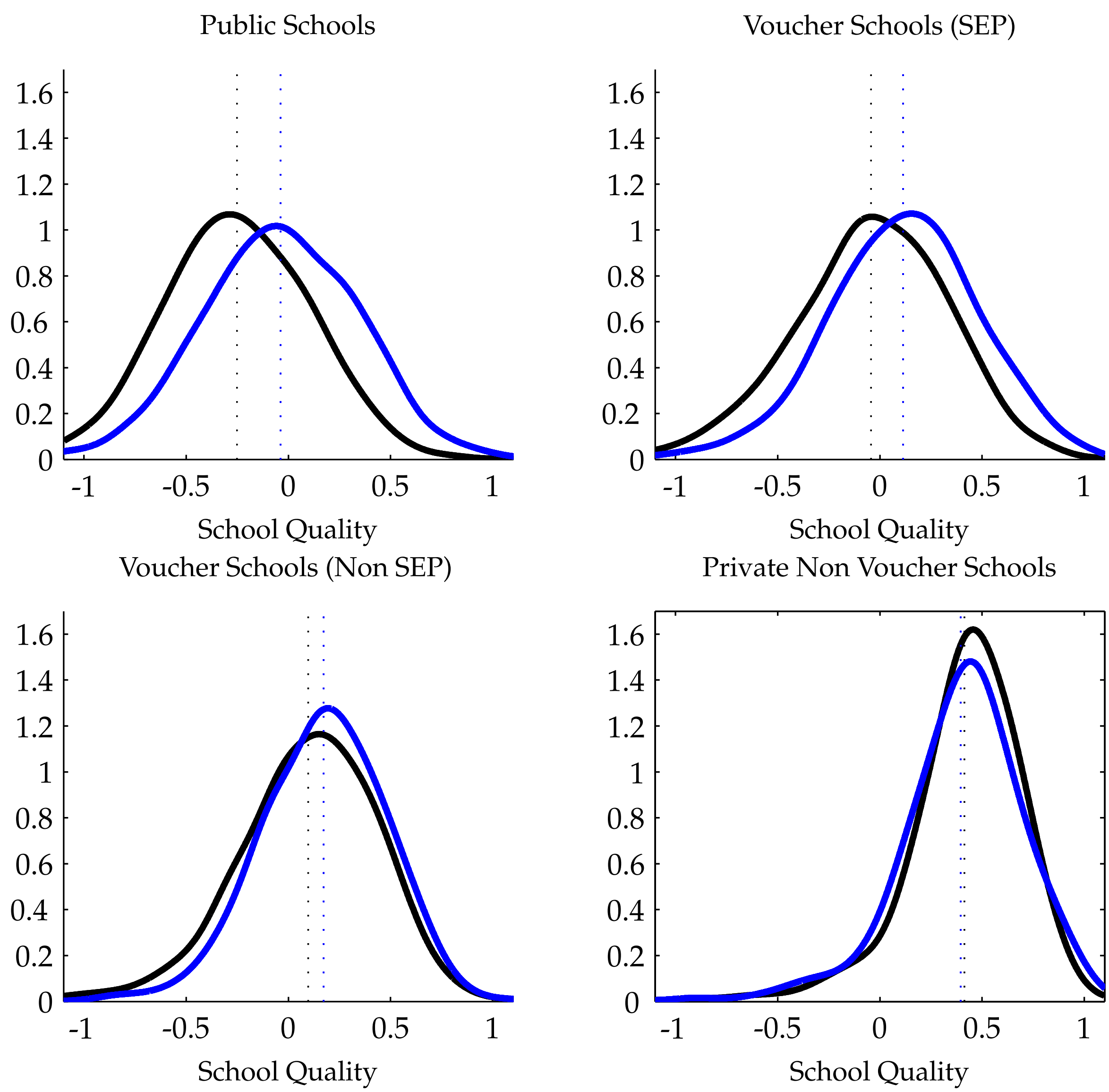
Table A2: Survey Evidence on School Choice

Reason	Total	Average by Quintile 1	2	3	4	5
Close to home	52%	65%	65%	62%	59%	50%
School infrastructure	23%	18%	22%	26%	31%	36%
Friends are there	10%	12%	12%	12%	11%	10%
Values of the school	29%	23%	28%	32%	38%	47%
Academic Excellence (SIMCE)	31%	25%	31%	37%	41%	49%
Had a technical area	3%	4%	4%	3%	3%	2%
It was the cheapest	21%	34%	32%	27%	21%	12%
Only school in the area	4%	7%	6%	4%	4%	3%
Was not accepted at others	2%	2%	2%	2%	2%	1%
Siblings went there	22%	29%	29%	26%	23%	21%
Bilingual School	5%	2%	3%	3%	4%	10%
Other reasons	26%	25%	29%	31%	33%	33%

Note: This survey question was given to parents of 4th grade students in the context of a broad household survey. They were asked to mark three reasons they chose the school where their child currently was matriculated.

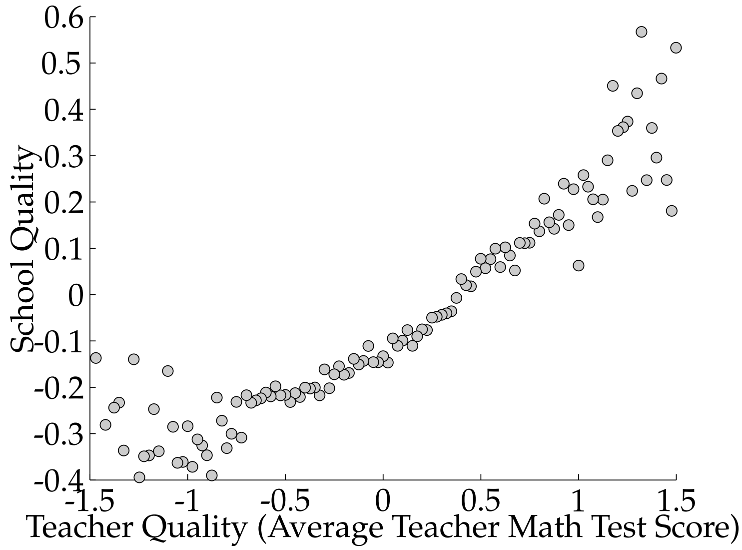
Appendix A.2 Additional Results - Estimated Quality

Figure A2: Distribution of School Quality in 2007 and 2011



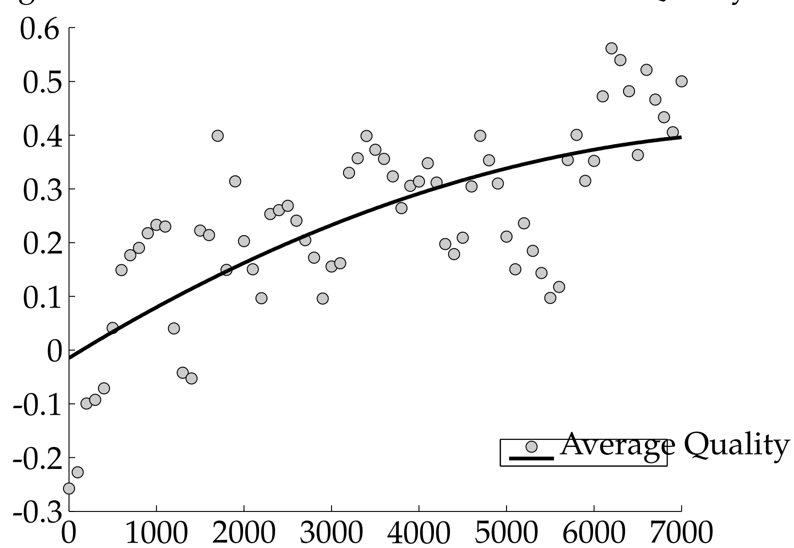
Note: This figure shows the student weighted distribution of school quality in 2007 and 2011.

Figure A3: Teacher Quality and Estimated School Quality



Note: This figure shows the averages of estimated school quality by bins of teacher test scores of 0.1 width, located at 0.1 intervals. Alvarado and Neilson (2013) show that teacher college entrance exam test scores are systematically related to several different measures of teacher quality when these measures are available. A schools average teacher test score is found to be postivily related to the estimated school quality in this figure.

Figure A4: School Price and Estimated School Quality



Note: This figure shows the averages of estimated school quality for voucher schools by bins of school price of $50 width, located at $50 intervals.

Appendix B Data

Table B3: School Sample Coverage, First Grade Matriculation 2005-2011

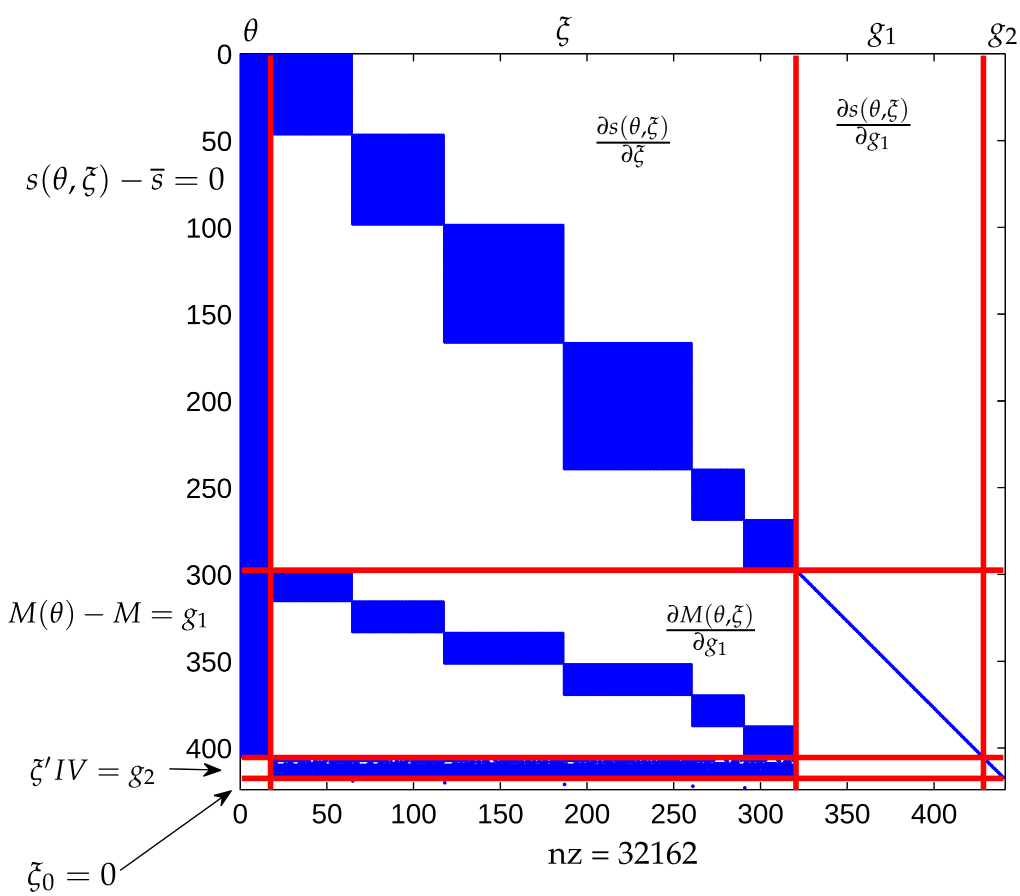
	2005	2006	2007	2008	2009	2010	2011
Urban, In Sample	217952	213839	218083	211698	201770	205709	205278
	0.82	0.83	0.83	0.84	0.83	0.83	0.83
Rural	35090	33278	33255	30991	29587	29778	28752
	0.13	0.13	0.13	0.12	0.12	0.12	0.12
Urban, Not in Sample	11190	11055	11431	10715	10489	10918	12681
	0.04	0.04	0.04	0.04	0.04	0.04	0.05

Source: MINEDUC and own calculations.
This table shows the representation of the sample of markets/schools used in the analysis presented in the paper. Urban, Not in Sample : These schools were not found to be inside the boarders of a defined market. This may be because the school was not geocoded on the map or because it is located outside the boarders of the city and is still categorized as urban because of a discrepancy between the census and MINEDUC definitions of rurality.

Appendix C Estimation Procedure

I augment the application in Dubé et al. (2012) to the case with additional micro moments and no outside option, which requires an additional normalization of ξ in each market and time period. The figure below shows the sparsity structure of the constraint Jacobian. This figure illustrates the parameters that are being estimated on the x-axis and the constraints on the y-axis.

Figure C5: Example Sparsity Structure of the Constraint Jacobian



Note: This figure shows the sparsity structure of the constraint Jacobian of the optimization problem described above. The columns represent parameters that are being estimated and the rows are the constraints.

The example presented in Figure C5 includes only three markets and two time periods. In practice there are over 200 markets and eight time periods. Estimates presented in the paper includes 20 markets and two time periods, 2007 and 2011. Ongoing estimation efforts look to cover more markets but initial robustness checks moving from 5 to 10 and 20 markets did not produce results that differed significantly.