ABSTRACT

Title of dissertation: ESSAYS ON HIGHER EDUCATION

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Higher education has changed dramatically in the last 40 years. What was the privilege of rich nations or poor countries' elites is now an integral part of international competition and development strategies. However, the rapid expansion in enrollment has posed significant challenges in terms of providing adequate financing, access and securing quality in higher education. This dissertation explores three aspects of these relevant issues.

The first chapter presents new estimates of the returns to higher education in two Latin American countries, Chile and Perú. Combining administrative records with a simple economic framework, I document large heterogeneity in the average returns to higher education, and I find negative net benefits of pursuing a number of degrees.

The second chapter studies a potential unintended consequence of student loans. Overall, student loans have proven to be effective in increasing college enrollment, especially among low-income students. Yet, loans' ability to improve student welfare depends on the pricing response of schools. If schools exert some degree of

market power and set tuition strategically, they may react to loans by raising tuition in order to capture some portion of the aid. This generates a negative externality on ineligible students, who have to pay higher tuition fees than if loans did not exist. I develop an econometric model of supply and demand for higher education and study this phenomenon in the context of a student loan program that was implemented in Chile in 2006. I find that, on average, schools raise tuition by 6% in response to loans, which generate an average externality of US$178 per student per year.

Finally, the third chapter studies the endogenous formation of centralized admissions to college and its potential benefits. Policymakers around the world have adopted market-design-inspired centralized matching systems for assigning students to public schools. However, the question of whether policy intervention is necessary for such adoptions has been little studied. Examining a setting with application costs and heterogeneity in college quality, I show that sizeable application costs and small heterogeneity in college quality may lead to a voluntary transition to a centralized matching system. Using a 2012 system change in Chile, I demonstrate the plausibility of our theoretical setting and show that the enlarged pool of colleges in the centralized admission is welfare-improving, particularly for those students facing high application costs.

ESSAYS ON HIGHER EDUCATION

by

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
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Dedication

To the most precious gift in my life: María José, Sofía and Tomás.

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Last, I am ever grateful to God, to whom I owe my very existence.

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Chapter 1: The Economic Returns to Higher Education in Latin America: The cases of Chile and Perú

Note: This chapter is coauthored with Sergio Urzúa.

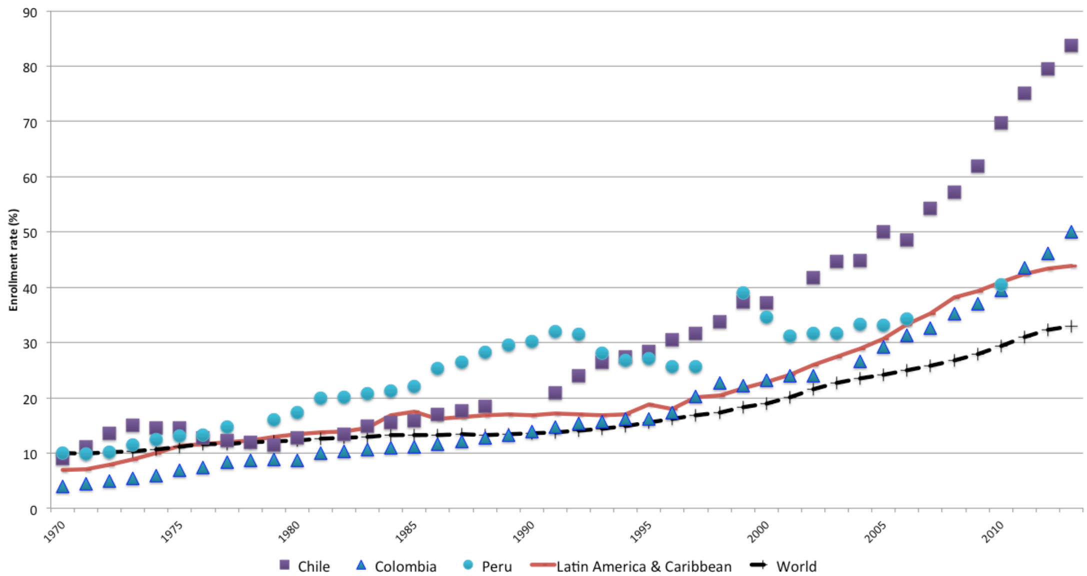
1.1 Introduction

During the last two decades, many countries in Latin America and the Caribbean (LAC) expanded their higher education coverage significantly. In 1991 the enrollment rate in post-secondary education (ISCED 5 to 8) in the region was only 17% but had reached 43.8% by 2013. Chile and Colombia emerge as two good examples of this trend. In the same period, their enrollment rate in higher education increased by 301% and 241%, respectively. By 2013 these rates had already reached 50% in Colombia and 83.8% in Chile, rates that are comparable to the levels observed in many developed nations. Figure 1.1 shows these trends, which also show that enrollment rates in LAC increased faster than the world average.

More recently, Perú had joined Chile and Colombia in their efforts to increase coverage. As Figure 1.1 shows, while in the middle of the 90s its enrollment rate was approximately 25% and by 2010 it had reached 40%.

These achievements have been received with optimism in the region, particu-

Figure 1.1: Enrollment in Tertiary Education (%)



Source: UNESCO Institute for Statistics (World Education Indicators Programme). See also González-Velosa et al. (2015).

larly among policy makers. Increases in higher education coverage were to a great extent the result of public policies designed to facilitate access to the system and promote human capital accumulation in economies characterized by large deficits of productive labor. Greater financial support for students and the geographical expansion of higher education institutions (HEI) (most notably Chile and Colombia) during the first decade of the new millennium are examples of these efforts.[1] And although Perú did not share those efforts then, the country is now eliciting similar efforts.

And, of course, a greater access to higher education was expected to bring

[1]Between 2009 and 2013, the amount of public resources allocated to student financial aid in Chile increased from US$495 million to US$1.458 million.

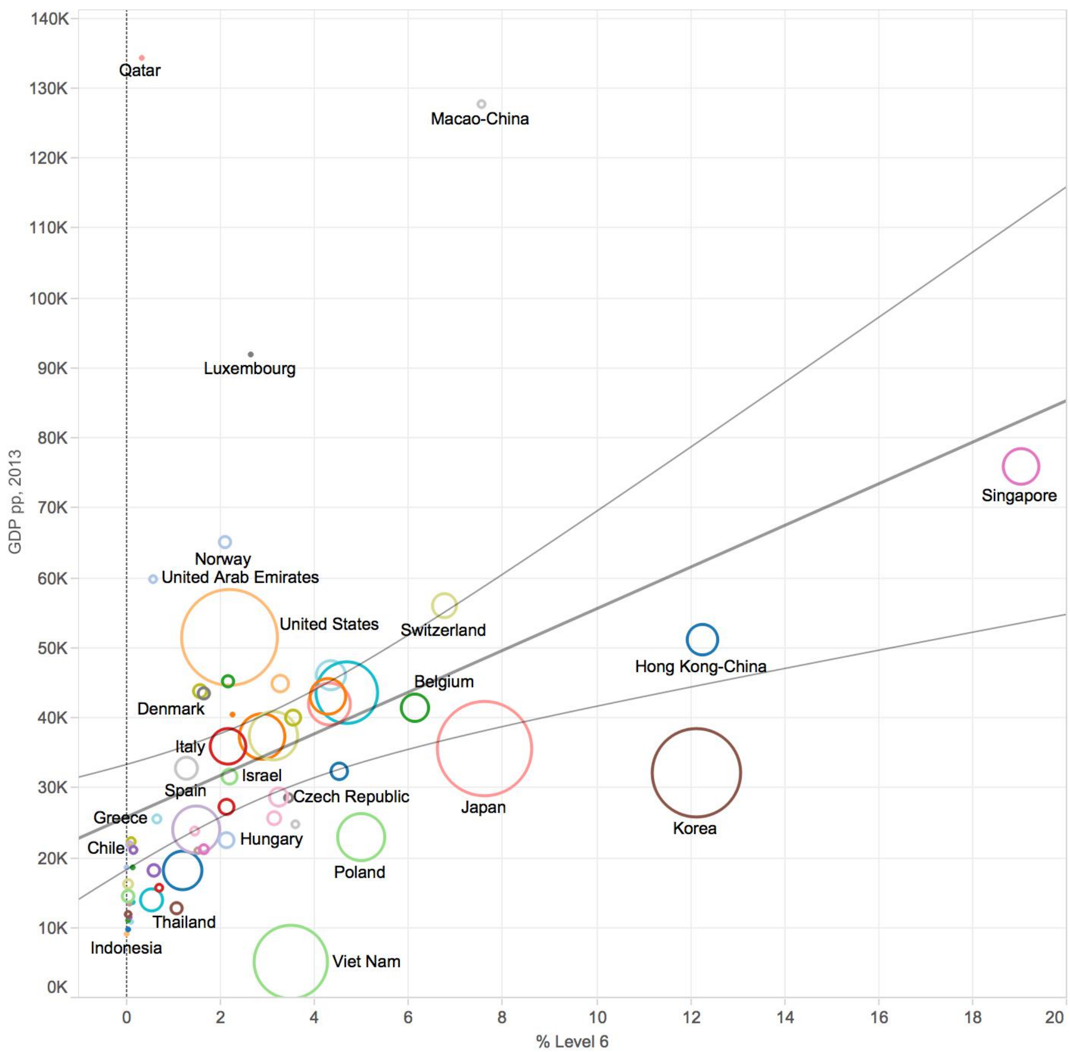
significant economic and equity gains. In particular, public policies were designed and implemented under the assumption that first generations of college graduates, particularly those coming from vulnerable households, would be shielded against the effects of poverty and inequality. However, this optimistic view is now being weakened. There is a growing concern that the expansion in coverage has been accompanied by deterioration in the quality of the system. This phenomenon explains, at least partially, the massive student protests observed in Chile and Colombia during the last five years.

Concerns about the decline in the quality of higher education are not limited to countries like Chile, Colombia or Perú, but extend to the rest of the region. The well-documented reduction in the returns to higher education in most countries in LAC could be explained, to some extent, by worsening in the quality of the system (Aedo and Walker, 2012; Lustig et al., 2013; Rodríguez et al., 2016). With coverage expansion, institutions and students of lower than marginal quality may have entered the system.[2]

The objective of this paper is to analyze the economic returns to higher education in Chile and Perú. By following Willis and Rosen (1979) and Heckman et al. (2006), we provide a theoretical framework to evaluate the returns to higher edu-

[2]Figure 1.2 illustrates this point. The figure shows the percentage of fifteen year-old students scoring at the top level in PISA test (level 6 in 2010) as a function of GDP. Low scores in in Latin America shows the lack of readiness among high school students few years before enrolling in college. We observe that Latin American countries are well behind most developed economies. The result, could explain why, in spite of the dramatic increases in educational coverage, labor productivity in LAC has grown at an exceedingly slow pace.

Figure 1.2: Top scoring students in PISA 2010 test and GDP



Note: Circle size shows the population of students in each country.
Data Source: OECD

cation. By using publicly available data on tuition costs and estimations for future earning for graduates from these two countries, we estimate the financial return to different higher education programs. These calculations allow evaluating the financial advantage of pursuing different degrees to alternative careers paths such as not pursuing postsecondary studies at all.[3]

The simple but comprehensive economic approach and the use of publicly available data make our methodology easy to understand. In this context, our calculations could potentially be replicated by families, students, researchers and policy makers. Our empirical results will have substantial implications for public policies. A first point that emerges from this is the importance of further efforts to construct and disseminate information on the performance of higher education graduates in the labor market. In this context, our results highlight the importance of using precise and reliable information on labor market outcomes in the design of higher education policies. This new evidence will also call into question the benefits of the policies implemented in Latin America, which aim at expanding coverage of higher education without assuring its quality and relevance of educational programs. There was a dramatic expansion in access to a system that often failed in its promise to improve the economic conditions of those who decided to invest in higher education.

This document is organized as follows. Section 1.2 introduces our empirical model and fits it in the context of the literature, Section 1.3 describes the sources

[3] The literature analyzing the returns to education is vast. Recent papers analyzing this topic includes: Andrews et al. (2014); Hastings et al. (2013a); Arcidiacono et al. (2012); Kaufmann et al. (2013); Gallego (2012), among others.

of information. Section 1.4 describes the empirical implementation. In section 1.5 we present our main results and Section 1.6 concludes.

1.2 Methodology

We follow the recent literature and postulate a simple econometric model allowing the estimation of the financial net returns to higher education (Urzúa, 2012; González-Velosa et al., 2015). As described below, we study the impact of labor market experience on future earnings using a Mincer-type regressions framework. Then, we combine these estimates with administrative information on labor market outcomes for recent cohorts of college graduates to predict the stream of earnings throughout life, which allows us to estimate the net returns to postsecondary degrees.

Importantly, our estimated returns must be interpreted with caution. They are intended to identify the average economic gain of those individuals graduating from a specific degree in a particular type institution versus their alternative of becoming a worker with a high school degree. In this context, our estimates neither represent the average effect of the marginal individual who is indifferent between college versus high school (Carneiro et al., 2011), nor the internal rate of return (Heckman et al., 2006).

Now, we present our framework to study the returns to postsecondary degrees. Let I be the set of programs and J the set of HEIs in a particular country. For simplicity, we assume that all programs are offered across all types of HEIs. Then, the overall supply of postsecondary degrees is the set of all possible tuples (i, j). Equation 1.1 presents our definition of the returns to pursuing program $i \in I$ in institution $j \in J$, for student k.

$$r_p(i, j, k) = \frac{NPV(i, j, k) - NPV_p(k)}{NPV_p(k)} \tag{1.1}$$

$NPV(i, j, k)$ denotes the expected net present value of earnings if pursuing program i in institution j for student k. $NPV_p(k)$ represents the present value of not pursuing higher education studies after high school for the same individual. The subscript p refers to the pth percentile of the income distribution of workers holding a high school degree (without postsecondary education).

Specifically, $NPV(i, j, k)$ is the discounted sum of all future expected earnings after graduating from program i in institution j, discounting the effective tuition costs, as defined by equation 1.2.

$$NPV(i, j, k) = \sum_{t=d_{i,j}+1}^{R_k} \frac{Y_{i,j}(t)}{(1+r)^t} - \sum_{t=1}^{d_{i,j}} \frac{C_{i,j}}{(1+r)^t} \tag{1.2}$$

,where $Y_{i,j}(t)$ is the average annual income of graduates from program i in institution j, t years after graduation. $C(i, j)$ is the annual direct cost of pursuing program i in institution j (tuition fees), which we assume do not change over time. r is the discount rate, $d_{i,j}$ is the program's formal duration and R_k is the number of years between the moment student k enters the program and his/her retirement.

On the other hand, the denominator of equation 1.1, $NPV_p(k)$, denotes the present value of earnings associated with the alternative of not pursuing higher education studies after high school. $NPV_p(k)$ is defined formally in equation 1.3.

$$NPV_p(k) = \sum_{t=1}^{R'_k} \frac{Y_p(t)}{(1+r)^t} \tag{1.3}$$

, where $Y_p(t)$ represents the income level at the pth percentile t after years high school graduation for those worker that did not pursue higher education studies. R'_k is the number of years between high school graduation and retirement.

Therefore $r_p(i, j, k)$ identifies the percentage increase in lifetime earnings of pursuing (i, j) versus the alternative of not pursuing any postsecondary degree. As extensively discussed in the literature, the self-selection of individuals into college prevents the interpretation of mean differences in labor income between individuals with and without postsecondary degrees as the effect of education on labor market outcomes. In this context, by modifying p we can empirically assess the potential role of selection.

1.2.1 Identification Argument

With the model of counterfactual outcomes we can proceed to define the treatment effect of interest. If we let $E[A|B]$ be the conditional expectation of A conditional on B, and $D(i, j, k)$ be an indicator function, such that $D(j, i, k) = 1$ if individual k graduates from program i in institution j, and $D(j, i, k) = 0$ otherwise. The treatment effect of interest is defined by Equations 1.4 and 1.5.

$$\Delta(i, j) = E[NPV(i, j, k)NPV(k)|D(i, j, k) = 1] \tag{1.4}$$

$$\Delta(i,j) = E[NPV(i,j,k)|D(i,j,k)=1] - E[NPV(k)|D(i,j,k)=1] \tag{1.5}$$

, where $NPV(k)$ is the expected net present discounted value associated with the alternative "high school degree" but calculated for those individuals with a college degree from program i in institution j. Notice that this term is unobserved. One alternative would be the substitution of this term by the average net present discounted value estimated from the sample of high school graduates without college experience. This, however, would produce biased and inconsistent results due to the selfselection of individuals into higher education degrees and institutions (Willis and Rosen, 1979). In this paper, we use a different approach. Following the institution in Neal (2004), we approximate $E[NPV_p(k)|D(i,j,k)=1]$ using different percentiles of the distribution of earnings, $NPV_p(k)$. Conceptually, this approach assumes that the relevant comparison group for those obtaining a college degree is not the average high school graduate, but high school graduates obtaining earnings in the p percentile of the distribution. In our empirical implementation, we use the 75th percentile.

1.3 Sources of Information

1.3.1 Chile

We employ three different sources of information for Chile. The primary dataset are administrative records from the Higher Education Information System

(SIES). The SIES is a public entity within the Ministry of Education that manages official higher education statistics, gathering information on all public and private higher education institutions in the country, including institutions offering two-year college degrees (Technical Training Centers), four-year college degrees (Professional Institutes) and five-year college degrees (Universities).

We use this data to obtain student-level enrollment data for the year 2012. For this years, we observe the program students are enrolled in. Importantly, the dataset includes, gender, age, region of residence, high school characteristics, SES background and high school GPA. Furthermore, the data contains substantial information on the characteristics of the programs, such as duration, geographical location and tuition costs.

Second, we use datat from the portal *mifuturo.cl*, which provides salaries for information after four years of graduation for 1069 degrees in Chile. Salaries are reported by institution and by field of study using the ISCED classification.

Finally, we use the 2013 Chilean household survey "CASEN", which allows us to estimate earning profiles for different types of graduates. It also allows us to estimate the salaries of workers that did not attend higher education (high school graduates).

Our empirical analysis is carried out using student-level data including the degree and institution in which students are enrolled, and individual background variables. We match their enrollment decisions with their corresponding expected salaries to estimate the returns for each student.

Table 1.1 shows descriptive statistics of our key variables.

Table 1.1: Summary Statistics: Chile

	Type of HEI		
	TTC (2yr degrees)	PI (4yr degrees)	Univ. (5yr degrees)
PANEL A. Supply Side			
# of HEIs	56	40	58
# of Field	191	141	434
Average tuition (USD)	$2,602	$2,694	$5,423
Average duration	2.42	3.18	4.6
# of campuses	167	178	219
Average years of accreditation	1.24	1.68	3.33
PANEL B. Demand Side			
# of students	62,282	111,240	152,832
% of total enrollment (market share)	19.10%	34.10%	46.80%
% female	52%	51%	52%
Average PSU score	406.55	412.06	519.95
Student Composition			
% Public Schools	45%	41%	28%
% Voucher Schools	53%	56%	56%
% Private Schools	2%	3%	16%
Total	100%	100%	100%

Source: Authors' calculations based on administrative records.
Note: "TTC" stands for Technical Training Centers, "PI" stands for Professional Institutes, and "Univ." for universities.

As previously explained, types of higher education institutions are defined by the types of degrees they offer. On the other hand, the taxonomy for fields of education follows the International Standard Classification of Education: Fields of Education and Training (ISCEF-F), and we incorporate some adjustments made by the Ministry of Education of Chile. In our analysis, we distinguish ten different fields of study across the three different types of higher education institutions.

1.3.2 Perú

Our primarily data source is the portal *ponteencarrera.pe*, an official website gathering detailed information on 3957 tertiary education programs in Perú.[4]

As explained below, this source allows us to identify the key input variables for the estimation of the returns to higher education, distinguishing three different types of HEIs: Universities, "Higher Education Technological Institutes"(IEST) and "Higher Education Institutes" (ISE). The latter two offer technical and vocational programs in different fields.[5] These programs are typically of shorter duration and less expensive than those offered by universities. For all our analysis the last two categories are merged into a category called "Vocational".

The website *ponteencarrera.pe* was launched in July of 2015 and reports information on variables such as: tuition costs, duration and total enrollment for each

[4]The portal *ponteencarrera.pe* is a joint initiative of the Department of Education, the Department of Labor and a private corporation (IPAE Acción Empresarial).

[5]*Institutos de Educación Superior Técnológico* and *Institutos Superiores de Educación*, respectively.

degree. It also includes information on their geographic location, field of study, as well as a measure of their selectivity. This index seeks to provide information on the demand for each specific degree, a proxy for quality, and it is constructed as the ratio of the number of admitted students to the number of applicants.

The dataset also contains information on graduates' salaries after graduation. However, this information is available only for 424 programs. Specifically, the website reports average monthly salaries over the first four years after high school graduation. Finally, salaries are reported at field of study-level (not a the program-level) within institutions. According to the official disclaim, this aggregation secures the representativeness of the information.

Our second data source is the 2014 Peruvian national survey "ENAHO". We use this household survey to construct counterfactual salaries for those individuals graduating from postsecondary institutions had they not attended college.

It is worth mentioning that unlike Chile, individual-level administrative information is not available in Perú. Hence, we only estimate returns at the field of study-level. We can identify 79 fields of study. For practical reasons, we collapse them into 6 broader fields that match the fields of work used in the ENAHO survey. Table 1.2 shows descriptive statistics of our level data.

1.4 Estimation

The main empirical challenge is the estimation of $Y_{i,j}(t)$, for $t = 1...R_k$. Our datasets include information on graduates' average earnings $\bar{t}$ years after graduation,

Table 1.2: Summary Statistics: Perú

	University	Vocational/Technical	Total
PANEL A: Institutions			
# of HEI	121	748	869
% Public	32.20%	47.30%	45.20%
Market Share (%)	55.50%	44.50%	-
PANEL B. Programs			
# of programs	1519	2438	3957
Duration (avg.)	5.13	3.05	3.85
Annual tuition (US$) (avg.)	1243.4	433.5	744.9
Enrollment (avg.)	120.2	62.2	85
Selectivity (%)	62.60%	82.60%	74.70%
Annual Salary (US$) (avg.)	4999	3449	4045

Source: *ponteencarrera.pe*.

say $Y_{i,j}(\bar{t})$, which we use to estimate age-earnings profiles until retirement (assumed to be at age 65). To do this, we follow the steps outlined bellow:

First, using household surveys we estimate the following Mincer equation:

$$\ln Y_i = \alpha + \beta_1 Age_i + \beta_2 Age_i^2 + \varepsilon_i \tag{1.6}$$

We include individuals 24 to 65 years old, with a post-secondary degree but who are no currently attending higher education institutions.

Then, we use $Y_{i,j}(\bar{t})$ and the coefficient estimates from equation 1.6 to predict $Y_{i,j}(t)$ for all $t \neq \bar{t}$ as show in 1.7

$$\hat{Y_{i,j}}(t) = Y_{i,j}(t-1)e^{\hat{\beta_1}+2\hat{\beta_2}\times(t-1)} \tag{1.7}$$

This procedure is replicated for workers with different types of degrees. Specifically, we estimate separate equations using the samples of workers with university degrees and non-university degrees. This allows us to estimate program-specific age-earning patterns. Finally, The earning of workers who do not attend tertiary education, $Y_p(t)$, is estimated non-parametrically using household surveys (average earnings at each experience level). Finally, in all our calculation, we use a discount rate of 6%.

1.4.1 Missing data

Datasets do not often report all income and tuition information, which are key variables to estimate the returns to education. Instead of restricting the sample size to programs with complete information, we rather predict the missing values of tuition or graduates' income. To do so, we estimate two simple linear model as shown in 1.8 and 1.9.

$$Y_{i,j}(\bar{t}) = \delta_0 + X_{i,j}\delta_1 + \varepsilon(i,j) \tag{1.8}$$

$$C_{i,j} = \theta_0 + X_{i,j}\theta_1 + \nu(i,j) \tag{1.9}$$

,where $\varepsilon(i,j)$ and $\nu(i,j)$ are idiosyncratic error terms, $X_{i,j}$ are program and institution characteristics, such as program's duration, HEI type, field of study fixed effects and institutions fixed effects. We the use the estimate from 1.8 and 1.9 to predict (linear projection) the missing values of $Y_{i,j}(\bar{t})$ and $C_{i,j}$.

Despite the limitations imposed by the underlying assumptions, the resulting estimates from equation 1.1 allows us to compare the net returns of pursuing a degree in field i in institution j, versus the alternative of not pursuing that specific degree and entering the labor force as a high school graduate instead. Our estimates take into account both the monetary (tuition fees) and opportunity costs of higher education (foregone earnings).

1.5 Results

1.5.1 Returns to higher education in Chile

We estimate the economic returns to all degrees in Chile. In order to match information on salaries with individual-level enrollment data, we aggregate the estimates by type of institution and fields of study.[6] This allows us to link labor market outcomes reported four years after graduation with information on the degree (defined by field and institution) pursued by students. In this context, although we are not fully exploiting the variation across the degrees available, we are able to capture heterogeneity given the differences in duration and costs(tuition fees) across fields and institutions.

As described above, to compute net returns we compare the average net present values of a specific field and institution with the alternative of not pursuing a higher education degree. For the latter, we use salaries for the 75th percentile of the distribution ($p = 0.75$ in Equation 1.3).

Table 1.3 shows the estimates of the Mincer regression (Equation 1.6) used to

[6] Previous studies have used student-level information on graduation, not enrollment.

estimate the age-earning profiles.

Table 1.3: Mincer Regressions: Chile

	CFT	IP	University
Age	0.062***	0.065***	0.094***
	-0.007	-0.006	-0.004
Age^2	-0.001***	-0.001***	-0.001***
	0	0	0
Constant	11.590***	11.566***	11.371***
	-0.152	-0.124	-0.093
R2	0.04	0.04	0.06
N	2,691	4,643	11,028

Note: Regressions only include workers age 24-65 who are not currently studying.

Table 1.4 shows the average returns by field of study and type of institution. These results suggest that the largest returns are associated with five-year college degrees in the fields of "Business and administration", "Law", "Science" and "Engineering and Technology". The latter concentrates the highest results across types of HEIs.

Two other remarkable features of the data emerge from Table 1.4. First, there is substantial heterogeneity both across fields of study and HEI type. For example, while the average student following a university degree in "Engineering and Technology" expects a return of more than 160%, the average student enrolled in the same type of institution but pursuing a degree in "Humanities" expects a return of 2.3%. Large differences are also observed across types of HEIs for a particular field. For example, while a degree in "Health" from a TTC has associated a return of 40%, a degree in the same field but from a university is expected to "deliver" an

Table 1.4: Average Returns by field of study and HEI type: Chile

	Type of HEI			
	TTC (2ry degrees)	PI (4yr degrees)	Univ. (5yr degrees)	Total
Business & Administration	57.10%	54.60%	126.80%	78.20%
Agriculture	35.30%	42.50%	62.70%	52.50%
Arts	66.10%	31.00%	49.00%	41.20%
Science	97.20%	115.50%	115.30%	113.60%
Social Sciences	34.50%	18.70%	47.00%	36.20%
Law	61.30%	38.60%	128.50%	115.10%
Education	-2.40%	9.50%	12.70%	9.60%
Humanities	-5.20%	12.10%	2.30%	4.10%
Health	40.50%	40.90%	101.50%	73.30%
Engineering and Technology	109.60%	99.80%	163.50%	125.80%
Total	66.20%	58.90%	97.50%	78.40%

Note: “TTC” stands for Technical Training Centers, “PI” stands for Professional Institutes, and “Univ.” for universities.

average return of 101%.

Second, returns in many fields and HEI (especially TTC) are negative. Pursuing an Education degree in a TTC has associated an average return of -2.4%. This means that, on average, students would have been better off (in financial terms) not pursuing that degree versus the alternative of entering the labor force after graduating from high school.

As shown in Table 1.5 roughly 10% of the students face negative returns in Chile when the counterfactual is $p = 75$. The fraction of students with negative returns is significantly higher in TTCs and PIs.

Figures 1.3 and 1.4 show estimated earning streams for students in education and technology/engineering majors compared to those of worker with completed

Table 1.5: Negative Returns to Higher Education: Chile

	p=50	p=75	p=90
Technical Training Centers	3.20%	15.20%	45.20%
Professional Institutes	2.10%	12.30%	52.20%
Universities	1.00%	5.00%	28.70%
Total	1.80%	9.40%	39.90%

secondary education (high school graduates, HSG) located at different levels of the income distribution. The former have relatively low earnings, which implies low o even negative returns. On the contrary, students pursuing degrees in technology and engineering have much higher salaries than those with a high school degree.

Finally, an in order to study to what extent the heterogeneity reported above was due to pre-college variables, we compute net returns by type of high schools.[7]

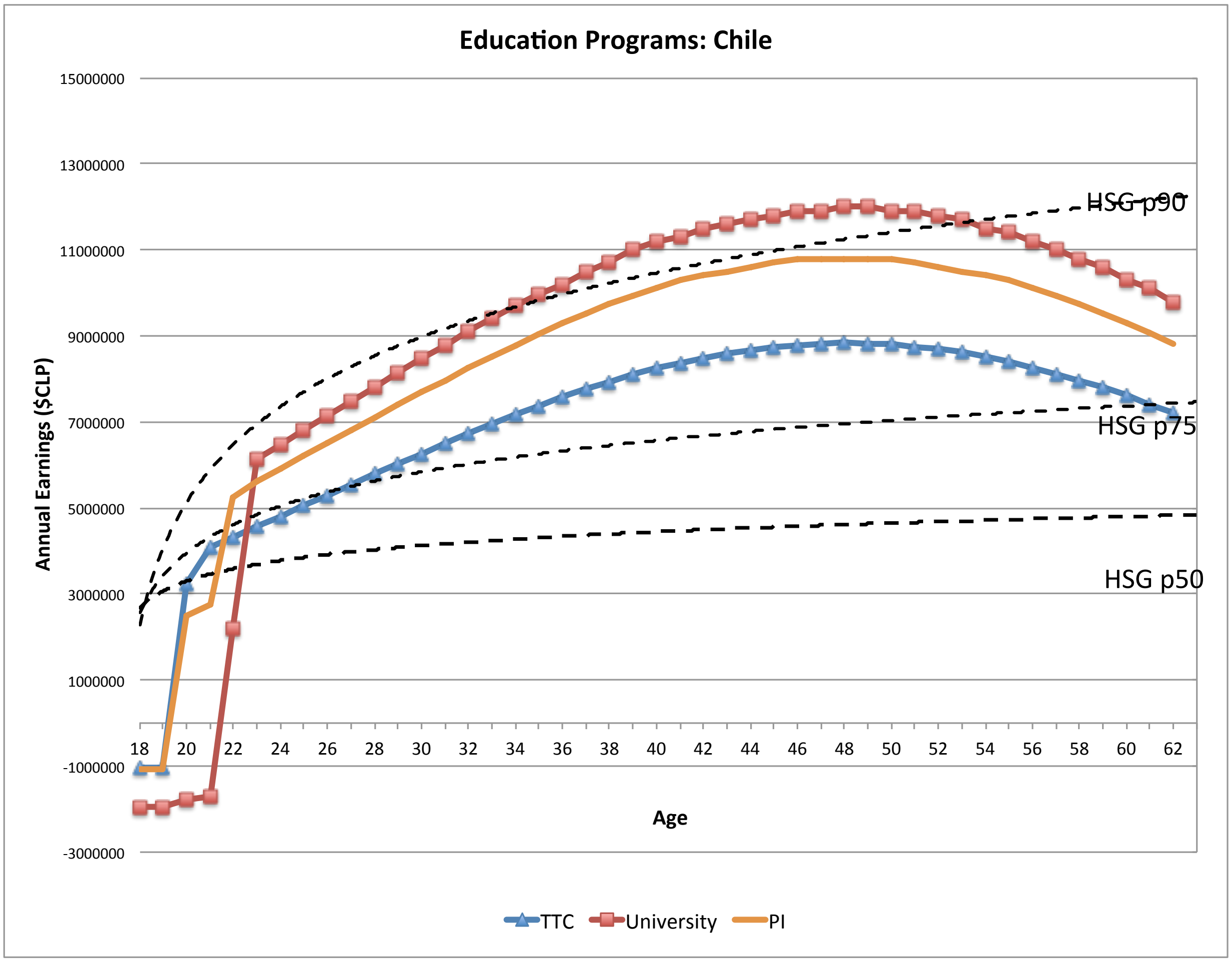
Table 1.6 shows the net returns to higher education across types of HEI and school type.

Table 1.6: Negative Returns to Higher Education: Chile

	Type of HEI		
	Technical Training Center (2ry degrees)	Professional Institutes (4yr degrees)	Universities (5yr degrees)
Public	71.39%	62.24%	93.66%
Voucher	73.92%	66.97%	97.75%
Private	70.42%	57.34%	133.60%

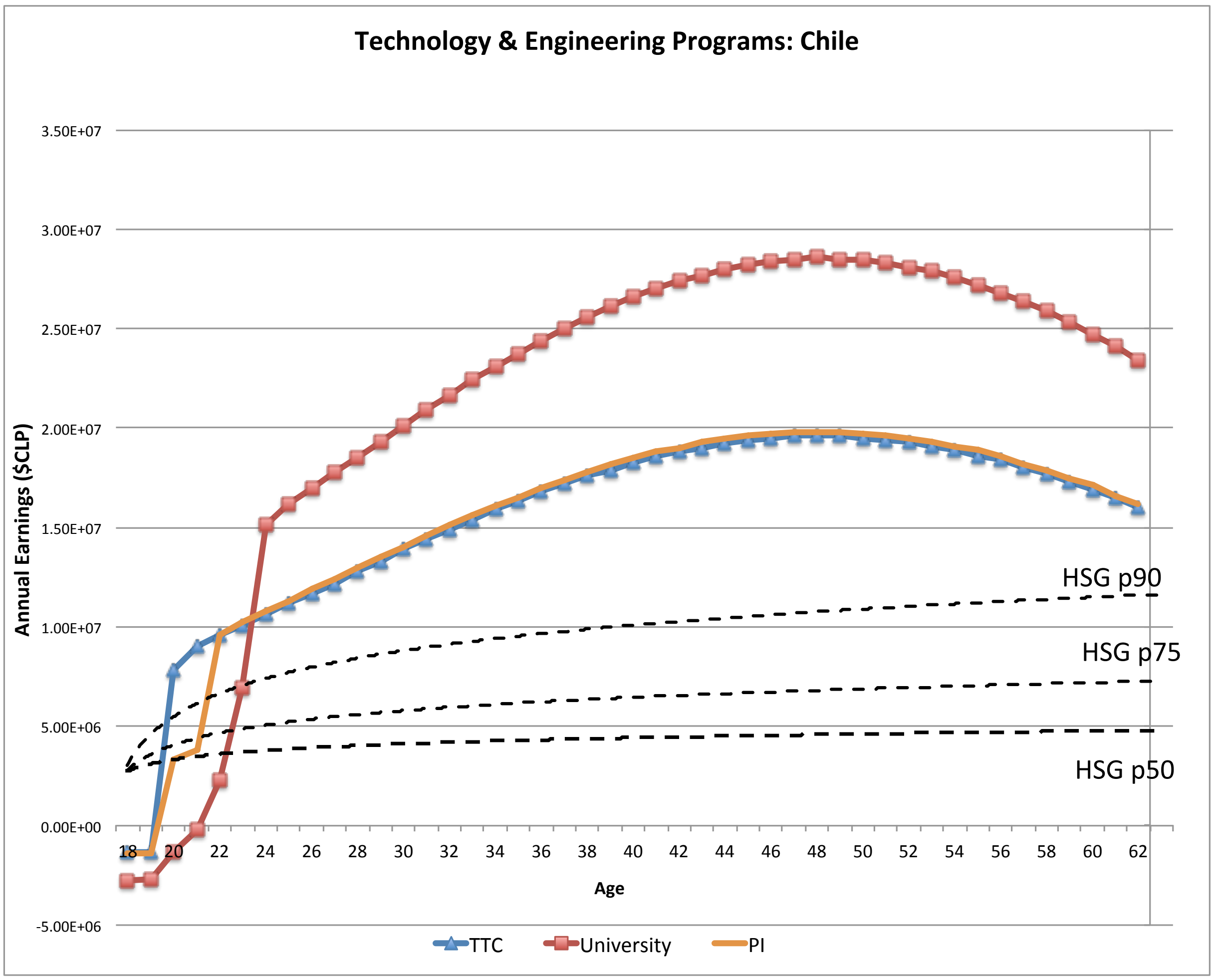
[7]Since the early 1980s, schools in Chile can be public, private or state-subsidized (voucher).

Figure 1.3: Age-Earning Profiles: Education Majors in Chile



Note: Dashed lines show earning trends for High School Graduates (HSG) whose earning belong to different percentiles of the income distribution (percentiles 90, 75 and 50).

Figure 1.4: Age-Earning Profiles: Technology and Engineering Majors in Chile



Note: Dashed lines show earning trends for High School Graduates (HSG) whose earning belong to different percentiles of the income distribution (percentiles 90, 75 and 50).

1.5.2 Returns to higher education in Perú

Table 1.7 presents the results from Mincer regressions used to estimate the age-earning profiles.

Table 1.7: Mincer Regressions: Perú

	Technical/Vocational	University
Age	0.038***	0.064***
	-0.009	-0.009
Age^2	-0.000***	-0.001***
	0	0
Constant	6.116***	5.992***
	-0.175	-0.182
R2	0.05	0.04
N	2,535	2,587

As shown in Table 1.8, in Perú returns are substantially lower on average than in Chile. The average return is 36.8%. Even though estimates still show some degree of heterogeneity across fields of study, they tend to be more homogeneous than in Chile. The field that exhibits higher returns is "Sciences/Engineering/Manufacturing" with a returns of 58% while Education degrees have negative returns. This evidence is consistent with the patterns found in Chile.

We also found significant differences between public and private institutions. As shown in Table 1.9, private universities have substantially larger returns and similar patterns are encountered in vocational and technical programs, respectively.

Next, we analyze the difference in returns across degrees with different levels of selectivity. In particular, we classify programs in three broad categories. We define a "highly-selective program" as a program that admits less than one third

Table 1.8: Average Returns by field of study and HEI type: Perú

	HEI Type		
	Vocational/Technical	University	Total
Social Sciences/Communications	11.6%	27.8%	27.6%
Education	-18.5%	-18.5%	-18.5%
Others	50.5%	33.0%	43.2%
Health	31.3%	7.1%	18.8%
Business & Administration	31.9%	24.3%	28.6%
Arts & Architecture	16.3%	47.9%	34.6%
Sciences/Engineering/Manufacturing	70.7%	49.4%	58.5%
Total	44.7%	30.5%	36.8%

Table 1.9: Returns in Private and Public Institutions: Perú

	Vocational/Technical		University	
	Private	Public	Private	Public
Social Sciences/Communications	12.4%	-8.4%	26.4%	31.4%
Education	-18.8%	-18.4%	-22.9%	-13.8%
Others	48.1%	57.6%	37.0%	14.1%
Health	27.8%	40.4%	6.3%	9.8%
Business & Administration	28.9%	44.6%	25.3%	20.2%
Arts & Architecture	15.6%	30.3%	47.6%	49.4%
Sciences/Engineering/Manufacturing	60.9%	80.0%	48.8%	50.5%
Total	36.1%	62.8%	30.0%	31.9%

of its applicants. Similarly, a "non-selective program" admits more than two thirds of its applicants. Finally "moderately selective programs" admit between one and two thirds of their pool of applicants. As shown in Table 1.10, we do find a significant return premium for highly-selective university programs. However, no such differences appear in Vocational/Technical institutions.

Table 1.10: Average Returns by program selectivity and HEI type: Perú

	Vocational/Technical			University		
	Highly Selective	Moderately Selective	Non-Selective	Highly Selective	Moderately Selective	Non-Selective
Social Sciences/Communications	-	56.6%	8.9%	38.6%	67.7%	15.3%
Education	-	-25.0%	-17.3%	-18.0%	-21.3%	-16.7%
Others	-	56.5%	55.1%		18.8%	35.6%
Health	32.5%	40.1%	30.3%	11.4%	6.7%	6.3%
Business & Administration	49.9%	44.6%	30.1%	23.4%	62.8%	18.4%
Arts & Architecture	5.0%	29.1%	16.5%	65.9%	39.4%	42.2%
Sciences/Engineering/Manufacturing	80.5%	75.9%	69.6%	60.4%	63.0%	41.6%
Total	66.1%	54.6%	43.0%	42.5%	45.6%	23.6%

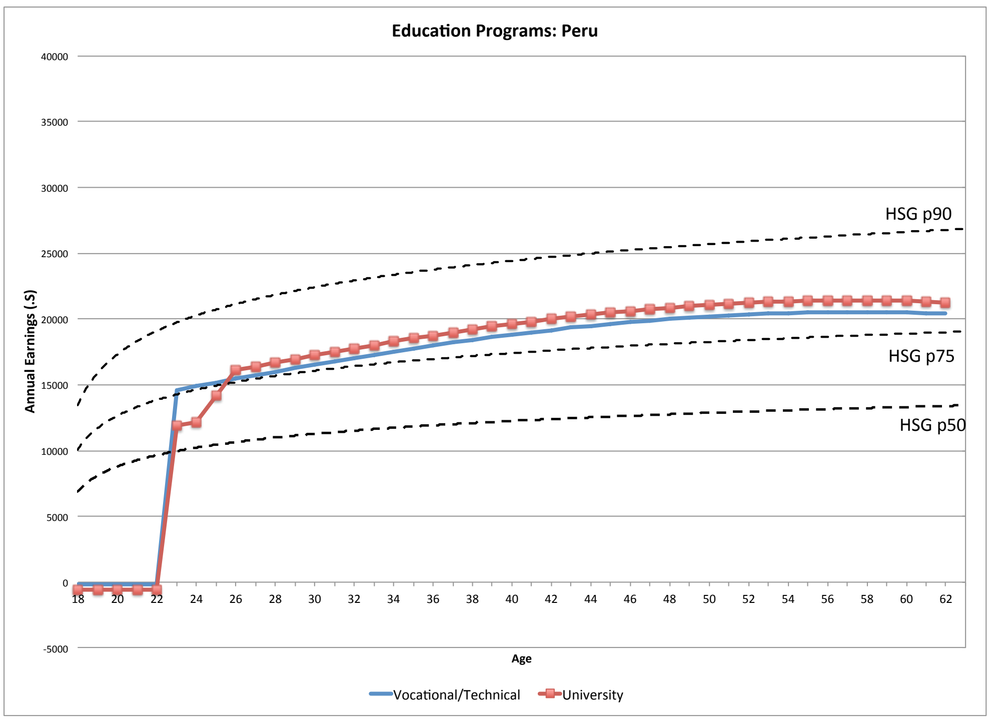
Finally, we show the age-earning profiles for two different types of programs. Figure 1.5 shows estimated earnings for students attending education programs. The dashed lines show earnings of workers with a high school diploma (HSG) at three percentile levels in the income distribution (90, 75 and the median). The figure illustrates how poorly these graduates perform in the labor market. Graduates earn higher salaries than those in the 75th percentile, but do never earn more than those in the 90th, except for the period while they study. Figure 1.6, on the other hand, shows estimated earnings of workers graduating from engineering and science degrees. These graduates earn substantially more than those holding a secondary education degree.

1.6 Conclusion

Many Latin American countries have implemented policies aimed at promoting access to higher education, and many more will continue doing so in the years to come. As a result of these changes, the characteristics of the infra-marginal student in the region has changed. Specifically, each year a larger fraction of individuals coming from vulnerable households enroll in higher education institutions in countries such as Chile, Colombia and Perú.

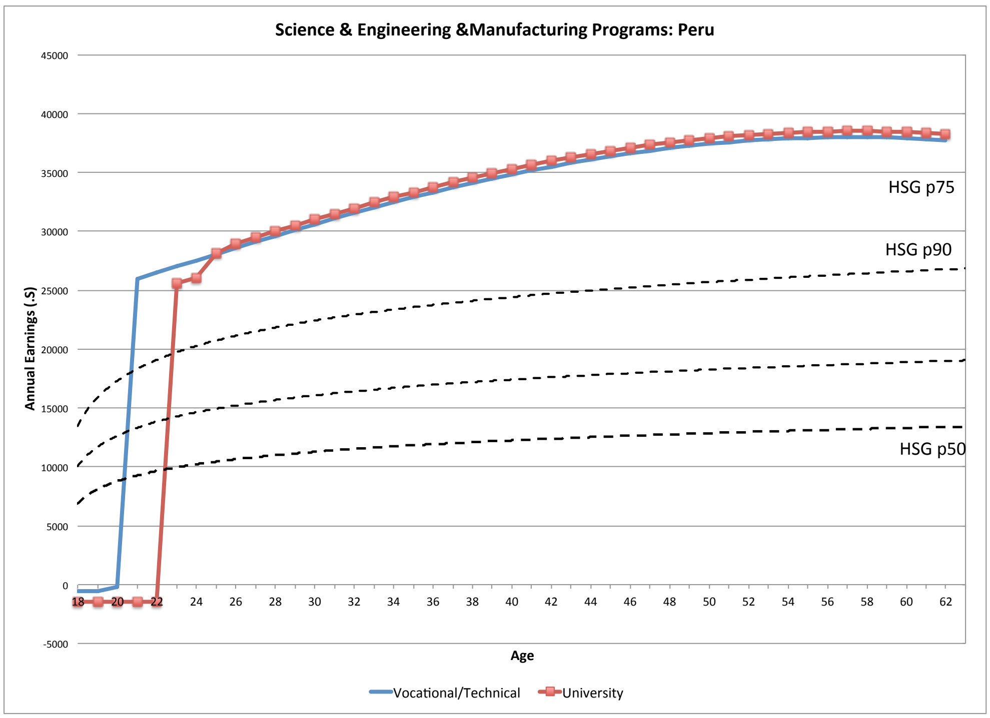
However, despite its political returns, the empirical evidence on economic returns to education suggests caution in continuing this strategy, particularly if quality assurance in education is not secured. The intuition is simple. To a large extent, the new generations of higher education students attended low-quality (primary and

Figure 1.5: Age-Earning Profiles: Education Majors in Perú



Note: Dashed lines show earning trends for High School Graduates (HSG) whose earning belong to different percentiles of the income distribution (percentiles 90, 75 and 50).

Figure 1.6: Age-Earning Profiles: Technology and Engineering Majors in Perú



Note: Dashed lines show earning trends for High School Graduates (HSG) whose earning belong to different percentiles of the income distribution (percentiles 90, 75 and 50).

secondary) institutions for many years. Therefore, for this group, not any higher education system would guarantee a more promising future. Only one of high quality, designed to effectively alleviate their lack of skills and provide them with the capacities to success in the labor market, would protect them against adverse economic circumstances. This paper seeks to shed light into this issue.

Using administrative information, complemented with household surveys, we estimate the returns to higher education in Chile and Perú. We focus our interest on a specific parameter, namely the return to education for those individuals obtaining college degrees (average treatment effect on the treated).

Consistent with previous studies, we document large heterogeneity in the returns in Chile, with a non-trivial fraction of students facing the possibility of negative net returns. In contrast to the literature, we document returns after controlling for pre-college variables, including type of high school and proxies for ability. In the case of Perú, we provide new evidence suggesting that the phenomena documented in Chile might not be an exception in the region.

Overall, when it comes to the future efforts in the higher education systems in developing countries, our evidence suggests that securing education quality and designing efficient financing policies must be top priorities.

Chapter 2: Loans for College: Strategic Pricing and Externalities

2.1 Introduction

Enrollment rates in higher education have increased significantly in the last decades. The world average enrollment rate increased from 13.1% in 1990 to 32.9% in 2013. In the U.S., for example, total enrollment has increased by roughly 250,000 students per year. Likewise, tuition has also risen at a surprisingly high rate. For instance, after controlling for inflation, average tuition and fees in the U.S. have tripled in the last 30 years. Governments have typically responded to rising tuition by increasing student financial aid through the form of grants, scholarships or subsidized loans, which have succeeded in increasing college enrollment, especially among vulnerable students.

Yet, financial aid's ability to improve the welfare of students depends in part on the response of schools. If schools exert some degree of market power, they may react to more financial aid by raising tuition in order to capture some portion of the aid. This strategic response of schools generates a negative externality on ineligible students, who have to pay higher tuition fees than if aid did not exist.

While most papers have focused on the economic impact of student aid on eligible students (see Kane, 2006; Pascarella and Terenzini, 2005), this paper focuses on the spillover effect of student aid on students who do not participate in the financial aid system.

I first present a simple theoretical framework to understand the mechanisms through which student aid, and more specifically student loans, can affect the welfare of both eligible and ineligible students. I model the choice of college incorporating student ability, liquidity constraints and heterogeneous returns to college. The model shows that if colleges have market power, they will strategically react to loans by raising tuition by an amount that is inversely proportional to the price elasticity of demand. Therefore, while loans may allow high-ability, low-income students to attend college, it reduces the welfare of non-eligible students by pushing tuition up. Thus, the overall effect on student welfare is ambiguous and remains an empirical question.

Then, I bring in an econometric model of supply and demand from the Industrial Organization literature to estimate the impact of student loans on tuition. On the demand side, I model student college choices using a random coefficients multinomial logit framework in the spirit of McFadden (1973) and Berry (1994). The indirect utility of choosing a certain school depends on observed and unobserved characteristics, as well as on individual-specific factors. Following Berry et al. (1995), I explicitly deal with the endogeneity of tuition arising from the fact that tuition is correlated with unobserved college characteristics. Since the availability of student loans may affect the demand elasticities for colleges, the model allows me to estimate the change in demand elasticities before and after the introduction of loans.

On the supply side, I model the pricing behavior of colleges. If tuition fees are optimally set, changes in the elasticities of demand will affect colleges' strategies. Thus, if demand becomes less tuition-sensitive due to loans, colleges may strategically set higher tuition fees. Therefore, the demand and supply model enables me to estimate the increase in tuition that can be explained by loans. Finally, since higher tuition fees are absorbed by all students, I can estimate the cost for ineligible students, who face higher tuition fees despite not receiving financial aid. There is one caveat for interpreting these results in light of the theoretical model. The empirical results allow me to estimate the effect of loans on tuition but do not allow me to estimate the effect on student welfare. There may be effects on other dimensions affecting student welfare that the model does not capture. For example, universities may increase the quality of their education services by re-investing the extra resources generated by loans. This effect on quality would off-set the short-run decrease in student surplus due to higher tuition fees. Also, there could be general equilibrium effects in the labor markets due to an increase influx of graduates. Therefore, the empirical results of this paper should be interpreted as short-run effects on student surplus when making college decisions.

I empirically estimate the econometric model in the context of a state-guaranteed student loan program (SGL) implemented in Chile in 2006. The Chilean higher education system provides a suitable environment to study colleges' response to loans. First, I have access to a rich dataset containing student applications to colleges running a centralized admission system. The data also allows me to identify the students who are eligible for loans. Second, there is detailed supply-side information on the tuition that schools set for different academic programs. Third, the SGL program was a clear episode of liquidity constraints reduction that allows for a clean identification of the effect of loans on tuition. I find that on average schools raise tuition by 6% in response to loans. This generates an average externality on ineligible students of US$178 per student per year, which aggregated across all students is estimated to be US$9.93 million.

My paper contributes to three strands of literature. First, it contributes to the literature analyzing college price responses to financial aid. After former U.S. Secretary of Education, William Bennett, declared in 1987 that "increases in financial aid in recent years have enabled colleges and universities blithely to raise their tuition, confident that Federal loan subsidies would help cushion the increase " (Bennett, 1987), a number of papers have studied the validity of this so called "Bennett Hypothesis", with mixed findings. Singell and Stone (2007) and Stoll et al. (2014), for example, find little support for financial aid increasing college prices. In contrast, Long (2004), Cellini and Goldin (2014), Gordon and Hedlund (2016), among others, find opposing evidence. Turner (2012) and Turner (2014) show that if colleges can price discriminate and offer various discounts to students through internal grants and scholarships, financial aid crowds-out institutional aid and does not necessarily push "list prices" up. In my sample, price discrimination is very limited.[1] In that sense, another advantage of the Chilean framework is that it provides a clear setting

[1]Price discrimination is not an extended practice in Chilean universities, although there is a limited number of scholarships that are used to attract high-performing students. Other than that, students pay the listed tuition and there are no formal price-discrimination mechanisms.

that shuts down the crowding-out channel that helps identifying more clearly the effect of loans on tuition.

My paper also contributes to a growing literature on the economic impact of student financial aid policies. For example, a number of studies show that liquidity constraints prevent some relatively able but poor students from enrolling in college (see Lochner and Monge-Naranjo, 2011; Belley and Lochner, 2007; Kane, 1996). Likewise, other studies show that student aid has allowed low-income students to access higher education (see Solis, 2016; Rau et al., 2013; Fack and Grenet, 2015; Dynarski, 2000, 2003; Van der Klauuw, 2002; Leslie and Brinkman, 1987; Ellwood and Kane, 2000; Heller, 1997; Nurnberg et al., 2012; Brown et al., 2012), although there is mixed evidence on the impact of financial aid on student college performance and persistence (see Ferreyra et al., 2016; Capelli and Won, 2016; Deming and Dynarski, 2009; Castleman et al., 2013; Gross et al., 2007; Cohodes and Goodman, 2014). As opposed to this literature, my paper emphasizes the spillover effects of student aid on ineligible students.

Finally, my study contributes to the stream of literature studying how financial aid affects college applications and college choices (see Abraham and Clark, 2006; Nurnberg et al., 2012; Bettinger et al., 2012). By taking advantage of the fact that I have access to data containing information on student applications, I am able to construct precise estimates for the demand for different colleges. Students in my sample submit a list with preferences to a clearinghouse that then assigns students to colleges using a student-proposed deferred-acceptance algorithm. Application data allows me to estimate demand for colleges abstracting from any student selection mechanism. In fact, if enrollment data were used to estimate student demand for colleges, these estimates would confound the effect of preferences with schools' capacities and selection processes. For instance, if a certain college has a high demand but very few seats, the number of applications will exceed the number of students actually enrolled. If demand were calculated using actual enrollment, we would be underestimating its true demand. My data allows me to separate these two effects and focus on the demand side and its pricing implications.

This paper proceeds as follows: In Section 2.2, I present a simple theoretical framework that highlights the mechanisms through which colleges may raise tuition in response to loans and consequently affect student welfare. Section 2.3 describes the econometric model of demand and supply of higher education. Section 2.4 describes the institutional background and the data for the estimation of the model. It also provides reduced form evidence that colleges reacted to the SGL by raising tuition fees. Section 2.5 presents the main results of the paper and Section 2.6 concludes.

2.2 A model of student loans and strategic college pricing

To understand the mechanisms through which loans create an externality on ineligible students, I present a present a simple theoretical model of student loans for college and optimal college pricing.

I model students' college choices and incorporate heterogeity in students' ability, liquidity constraints and returns to college. When colleges exert some degree of market power, they will strategically react to loans by setting a higher tuition. Therefore, while the loans allow high-ability, low-income students to attend college, it reduces the welfare of ineligible students who are no t eligible by pushing tuition fees up.

2.2.1 Setup

There is a infinitely lived continuum of students, indexed by i who differ in their innate ability, a_i. Ability follows a continuously differentiable strictly increasing cumulative distribution function G with density g with full support over the interval $[\underline{a}, \overline{a}]$. I assume that each student knows his/her own ability.

In time $t = 0$, students decide whether or not to get into college. This decision can only be taken in $t = 0$ and is assumed to be irreversible.

We assume that there is a single non-selective college (C), which offers a single degree of duration D and charges a total price $p > 0$ (tuition fees), to be paid at the moment of admission. We assume C can accommodate any demand and can exert control over tuition. The college optimally set p to maximize profits and has a marginal cost of c dollars per student.

In $t = 0$, when student decide whether or not to get into college, they maximize the present discounted value of lifetime earnings.

Let $V(a, \rho)$ be the net present value of labor earnings minus the opportunity cost of attending college, where ρ is a common inter-temporal discount factor. Let earnings in year t be $y_t(a)$, v the opportunity cost and ζ the non-pecuniary cost of attending college, then $V(a,\rho)$ can be written as shown in Equation 2.1.

$$V(a,\rho) = \int_0^\infty (y_t(a) - v(a) - \zeta(a))e^{-\rho t}dt \tag{2.1}$$

We assume that the gains from attending college versus non attending increases with ability, thus $V_a > 0$.

Students face short run liquidity constraints when entering college. They have a disposable income I_i in $t = 0$, which can be spent to pay for college education. Students whose income is lower that p cannot attend college. For simplicity, I assume that income is independent from ability ($I \perp a$), and that income follows a continuously differentiable strictly increasing cumulative distribution function F with density f with full support over the interval $\left[\underline{I}, \overline{I}\right]$. I also assume that $\overline{I}$ is sufficiently large so that there is at least a subset of students who is never capacity constrained ($p < \overline{I_i}$, for some i). Similarly, I assume that $\underline{I}$ is sufficiently small so that there are always students who face capacity constraints ($p > \underline{I_i}$, for some i) . Then, if $p \in \left[\underline{I}, \overline{I}\right]$, we avoid cases such as nobody attending college ($p > \overline{I}$, for all i) or everybody going yo college ($p < \underline{I_i}$, for all i).

Let C_i be an indicator function that takes the value of 1 if student i attends college, and 0 if not. We define U as the present discounted value of his/her lifetime earnings. Students are assumed to choose C_i to maximize:

$$U_i = \begin{cases} V(a_i,\rho) - p & \text{if } C_i = 1 \\ \\ 0 & \text{if } C_i = 0 \end{cases} \tag{2.2}$$

, subject to the short-run liquidity constraint $p \leq I$.

2.2.2 Equilibrium without Loans

If students cannot borrow to finance their studies, then only those who benefit from college and whose income is high enough to pay for tuition can join C. Thus, student i attends college only if the conditions in Equations (2.3) and (2.4) are satisfied. From now on, I suppress the subscript i.

$$V(a, \rho) - p \geq 0 \tag{2.3}$$

$$p \leq I \tag{2.4}$$

At a given price p, equation (2.3) defines the ability of the student that just benefits from college, $a^*(p)$, where

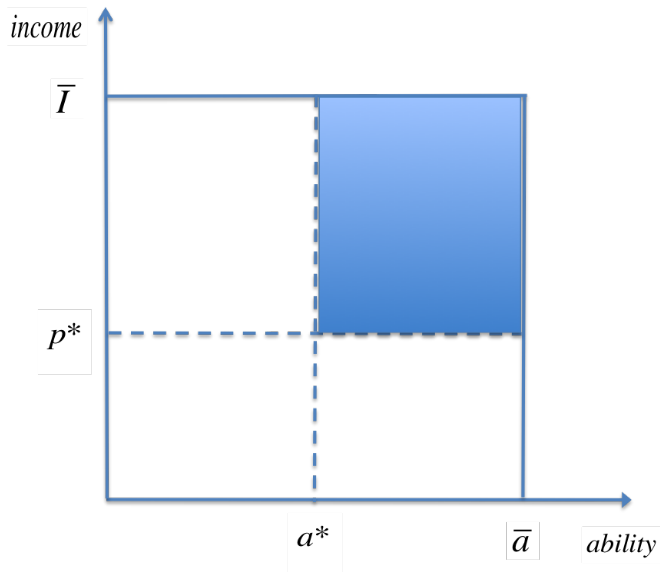
$$V(a^*, \rho) - p = 0 \tag{2.5}$$

Thus, only students satisfying $a \geq a^*(p)$ will consider attending college (solid area in Figure 2.1). Similarly, (2.4) defines the set of students who have the financial capacity to pay the fees.

The demand for college C when price is p is given by Equation 2.6.

$$D(p) = \int_{p}^{\overline{I}} \int_{a^*(p)}^{\overline{a}} g(x) f(y) dx dy = [1 - G(a^*(p))][1 - F(p)] \tag{2.6}$$

Figure 2.1: Equilibrium without Loans



Then, C will optimally set p in order to maximize profits (Equation 2.7.

$$max_p \ \pi(p) = (p - c)D(p) \tag{2.7}$$

The optimal price p^* satisfies the first order condition in equation (2.8).

$$p^* = c - \frac{D(p^*)}{D'(p^*)} = c + \frac{[1 - G(a^*(p))][1 - F(p)]}{G'(a^*(p))\frac{\partial a^*(p)}{\partial p}(1 - F(p)) + F'(p)(1 - G(a^*(p))}\Bigg|_{p=p^*} \tag{2.8}$$

2.2.3 Student Loans

Suppose now that loans became available to high-ability, low-income students. For simplicity, we assume authorities observe p^* and a^*, and anyone with $a \geq a^*$ (high-ability) and $I \leq p^*$ (low-income) is eligible for the loan. Let E be the set of eligible students and E^c its complement.[2]

The student loans relaxes the short-run credit constraint in (2.4) in exchange for a future repayment. Loans have an interest rate r and a fixed repayment period δ. Let $K(p) \equiv K(p, \rho, r, \delta)$ be the present value of the debt repayment which includes all accrued interests.[3] We assume the following:

Assumption 1. *For any p, $p \geq K(p)$: Financing tuition with a loan is more attractive than paying tuition upfront. This happens if, for example, students discount future earnings at a higher rate than the loan interest rate r.*

Assumption 2. *For any $p \in [p^*, \overline{I}]$, $K(p) < p^*$. The net present value of the loan repayment is smaller than equilibrium tuition without loans.*

Assumption 3. $F(p^*) > \frac{1}{2}$.

Students' decisions problem is now different and will depend on whether they are eligible for loans or not. Eligible students choose C_i to maximize:

$$U_i, i \in E = \begin{cases} V(a_i) - K(p) & \text{if } C_i = 1 \\ \\ 0 & \text{if } C_i = 0 \end{cases} \tag{2.9}$$

Let a_L be the ability level that solves Equation 2.10.

$$V(a_L) - K(p) = 0 \tag{2.10}$$

[2] I could have chosen different eligibility thresholds. However, it does not change the main implications of the model.

[3] If a student has an accumulated debt of $L(p)$ at the end of her studies and the loan installment are $\mu(L(p))$, then $K(p, \rho, r, \delta) = \int_D^{D+\delta} \mu(L(p))e^{-\rho t}dt$.

Notice that if Assumption 2 holds, $a_L(p) \leq a^*$. Then, the ability eligibility criteria binds, that is there is a mass of low-income students with ability below a^* that would like to take the loan but are prevented from it. Thus, all low-income students with $a \geq a^*$ will take the loan and go to college.

On the other, hand ineligible students choose C_i to maximize:

$$U_i, i \in E^c = \begin{cases} V(a_i) - p & \text{if } C_i = 1 \\ \\ 0 & \text{if } C_i = 0 \end{cases} \tag{2.11}$$

Similarly, let a_N be the ability level that satisfies $V(a_N) - p = 0$. Ineligible students will only attend college if $V(a_N) - p \geq 0$. Notice that for any p, $a_N > a_L$.

Therefore, under Assumptions 1, 2 and 3, the demand for college C, $D_L(p)$ is given by Equation 2.12.

$$D_L(p) = \int_{\underline{I}}^{p^*} \int_{a^*}^{\overline{a}} g(x)f(y)dxdy + \int_{p^*}^{\overline{I}} \int_{a_N(p)}^{\overline{a}} g(x)f(y)dxdy \tag{2.12}$$

Therefore, C chooses the optimal tuition level, p_L, that maximizes $\pi_L(p) = (p - c)D_L(p)$, which is shown in Equation 2.13.

$$p_L = c - \frac{D_L(p_L)}{D'_L(p_L)} \tag{2.13}$$

2.2.4 Implications on Student Welfare

The effect of the loan program on student welfare is heterogeneous.[4] The loan program increases the demand for education of low-income student with high-ability. All eligible students go to college when the loan is available. However, this increase in demand pushes sticker price up, which affects high-income students in the margin. In fact, high income students with ability $a \in [a^*, a_N]$ decide not to enroll college now that the price is higher. The net effect on demand depends on the magnitude of these two effects. Assumption 3 states a sufficient condition in order for the latter effect to be dominated by the former, so that that the net effect in demand is positive.

High-income students with ability $a \geq a_N$ still find profitable to go to college, but they pay a higher tuition now, which reduces their surplus.

Therefore, the overall effect of loans is that they push sticker price up, and allows eligible students to go to college. Now, we conduct a simple comparative statics analysis and compare the change in student welfare after the implementation of the loan program.

[4] If universities invest some of their profits, it is possible that the quality of education also increases. The definition of welfare in my model does not take into account this effect. Thus, it can be interpreted as a short-run or direct effect on student welfare.

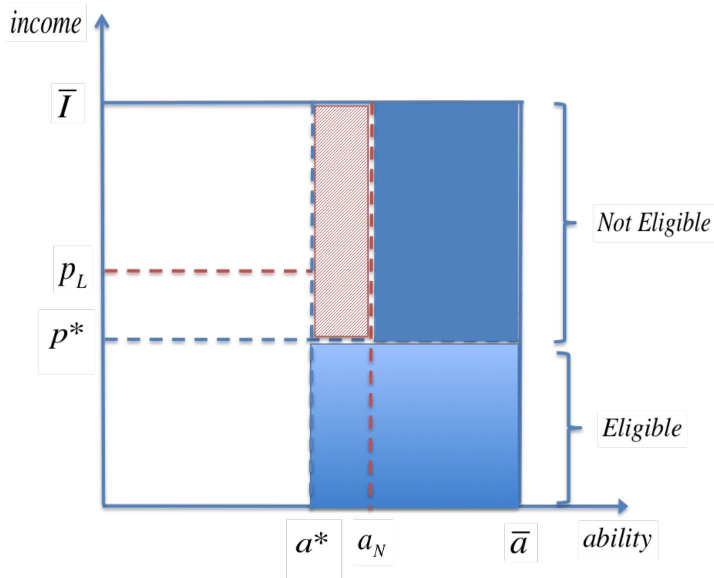
Equation (2.14) shows the overall change in student welfare, ΔW_s:

$$
\begin{aligned}
\Delta W_s = {} & F(p^*) \int_{a^*}^{\overline{a}} \left(V(x) - K(p_L)\right) g(x) dx \\
& - (1 - F(p^*))(1 - G(a_N))(p_L - p^*) \\
& - (1 - F(p^*)) \int_{a^*}^{a_N} \left(V(x) - p^*\right) g(x) dx
\end{aligned}
\tag{2.14}
$$

The first term in (2.14) corresponds to the increase in utility for eligible students, which raises from 0 (without loans they do not go to college) to $V(a_i) - K(p_L)$ (lower solid area in Figure 2.2). The utility of high-income students with ability $a \geq a_N$, decreases by $p_L - p^*$ due to the price increase (upper solid area in Figure 2.1). The second term in (2.14) shows to the overall change in utility for students in this group. Finally, high-income students with ability $a < a_N$ are driven-out of the market and cannot afford to go to college (see dashed area in Figure 2.2). Their utility decreases from $V(a) - p^*$ to 0. It is worth mention that loans have no impact on ineligible students with ability $a < a^*$, since they do not attend college in either scenario.

The model shows that a loan program that targets low-income and high ability students, like the one presented in this section, has an undetermined effect on total student welfare. It increases enrollment among the target population, but it also drives sticker price up, which hurts ineligible students. The main underlying assumption is that colleges can exert some market power through pricing, which is taken from granted if the college is a monopolist. The introduction of competition, for example through more and potentially differentiated colleges, should reduce this

Figure 2.2: Equilibrium with Loans



price effect, and reduce the losses through that channel.

2.3 Econometric Model

2.3.1 Demand Side

I model the choice of a degree (or academic program) using a random coefficients multinomial logit framework in the spirit of McFadden (1974) and Berry et al.(1995). The indirect utility of choosing a certain program depends on observed and unobserved characteristics, as well as on individual-specific factors. In a particular year, students are faced with a number of programs they can apply to.

Let I_t be the set of applicants and J_t the set of options in market t, where each market is a different academic year.

The indirect utility of student i from choosing program j in market t is modeled as a function of observed and unobserved program characteristics, denoted by x_{jt}

and ψ_{jt}, respectively, and the tuition charged by program j in market t, p_{jt}, as shown in (2.15).

$$u_{ijt} = p_{jt}\alpha_i + x_{jt}\beta_i + \psi_{jt} + \varepsilon_{ijt} \tag{2.15}$$

$$i = 1...I_t, \;\; j = 1...J_t, \;\; t = 1...T.$$

The coefficient α_i is student i's marginal disutility from tuition (price), and β_i, a vector of individual-specific taste coefficients which, following Nevo(2000), are modeled as follows:

$$\begin{pmatrix} \alpha_i \\ \\ \beta_i \end{pmatrix} = \begin{pmatrix} \alpha \\ \\ \beta \end{pmatrix} + \Pi D_i + \Sigma v_i \tag{2.16}$$

, where $D_i \sim \hat{P}_D(D)$ is a vector of known student characteristics, Π is a vector of coefficients indicating how tastes vary with student characteristics (D), Σ a vector of parameters, and finally $v_i \sim \hat{P^*}_v(v)$ is a normally distributed error term.

The most common empirical challenge when estimating (2.15) is that tuition, p_{jt} is likely correlated with unobserved program characteristics, ψ_{jt}, which would bias the estimate for α_i. This correlation arises because colleges know ψ_{jt} and take it into account when setting prices, p_{jt}. To overcome this identification issue, I follow Berry (1994) and Berry et al. (1995) (henceforth BLP), which provides us with a method to instrument for the endogeneity of p_{jt} in this random-coefficient logit framework.

The BLP method has at least two advantages over traditional discrete choice models. First, and more importantly, it allows to correct for the endogeneity of tuition. BLP constructs a Generalized Method of Moments (GMM) estimator using a proper set of exogenous instruments for p_{jt},[5] and a contraction mapping that allows to find the unknown coefficients in (2.15) and (2.16) numerically (see Nevo, 2000). Second, the random coefficients allows to estimate richer and more realistic substitution patterns among alternatives. Under a standard logit model, the price elasticities of demand are proportional to market shares, and predicts a higher markup for low-priced programs, which can only happen if low-priced programs have proportionally lower marginal costs than more expensive programs. This arises because the standard logit model exhibits the Independence of Irrelevant Alternatives property (IIA), which restricts the substitution pattern among alternatives. In the BLP model, in contrast, and by letting s_{jt} be the market share of program j in market t, own and cross price-demand elasticities (η_{jjt}, η_{jkt}, respectively) are determined as shown in Equations 2.17 and 2.18.

$$\eta_{jjt} = \frac{\partial s_{jt} p_{jt}}{\partial p_{jt} s_{jt}} = -\frac{p_{jt}}{s_{jt}} \int \alpha_i s_{ijt}(1 - s_{ijt}) d\hat{P}_D(D) d\hat{P^*}_v(v) \tag{2.17}$$

$$\eta_{jkt} = \frac{\partial s_{jt} p_{kt}}{\partial p_{kt} s_{jt}} = -\frac{p_{kt}}{s_{jt}} \int \alpha_i s_{ijt} s_{ikt} d\hat{P}_D(D) d\hat{P^*}_v(v) \tag{2.18}$$

,where s_{ijt} is the estimated probability of individual i choosing program j in market t.

[5] I use as instruments the sum of the observed product characteristics of other programs offered by the same school and the sum of observed characteristics of programs in the same field offered by other schools

2.3.2 Supply Side

I combine the demand model specified in (2.15) and (2.16) with a model of optimal college pricing. I assume that in each period universities set the tuition for each of the programs they offer to maximize profits.

Specifically, suppose that university f, $f = 1...F$, offers a subset S_{ft} of the $j = 1...J_t$ available programs in period t.

Hence, profits of university f in period t are specified in Equation 2.19.

$$\Pi_{ft} = \sum_{j \in S_f} (p_{jt} - c_{jt}) M_t s_{jt}(p_t) - C_{ft} \tag{2.19}$$

, where c_j is the marginal cost of enrolling a student in program j, M_t is the size of the market t. $s_{jt}(p_t)$ is the market share of program j, which depends on the vector of tuition in market t, p_t. Finally, C_{jt} is a fixed cost.

We assume that a pure-strategy Bertand-Nash equilibrium is reached in each period. Therefore, each university sets the tuition of the programs it offers taking the tuition of programs offered by other universities as given. The set of First Order Conditions (FOCs) that satisfy the Bertand-Nash equilibrium and characterize the equilibrium price vector p_t are shown in Equation 2.20.

$$s_{jt}(p_t) + \sum_{r \in S_f} (p_{rt} - c_{rt}) \frac{\partial s_{rt}(p_t)}{\partial p_{jt}} = 0 \tag{2.20}$$

$$\forall j \in S_f, \quad t = 1...T$$

The FOC in (2.20) can be written in matrix form as follows:

$$s_t = \Omega_t(p_t - c_t) \tag{2.21}$$

The matrix $\Omega(p_t)$, which defines the set programs that are offered by different universities is as follows:

$$\Omega_t(j,r) = \begin{cases} -\frac{\partial s_{jt}(p_t)}{\partial p_{rt}}, & \text{if } \exists f : \{r, j\} \subset S_f \\ 0, & \text{otherwise} \end{cases} \tag{2.22}$$

Since market shares and prices are observed, and $\Omega(p_t)$ can be derived from(2.17) and (2.18), we use (2.21) to recover the vector of marginal costs in each period (Equation 2.23).

$$\hat{c_t} = p_t - \Omega_t^{-1} s_t \tag{2.23}$$

2.3.3 Counterfactual

Let $t = 0$ be the period before the loan program was implemented, and $t = 1$ the period after. I conjecture that eligible students will be less price-sensitive in $t = 1$, which should imply, on average, lower price elasticities of demand. That is, $\eta_{jj0} > \eta_{jj1}$, for most j. The main objective is to estimate the tuition that universities would have set in the absence of loans in $t = 1$ (counterfactual). I can use the estimated marginal cost in $t = 1$, $\hat{c_1}$, to find the tuition vector that is consistent with the FOC in (2.20) if the demand were as inelastic as in a period without loans. Therefore, I use the estimated elasticities in $t = 0$ (pre-loan) to build counterfactual prices in $t = 1$ that are consistent with current market shares and universities' cost structure.

$$\hat{p_1} = \hat{c_1} - \Omega_0^{-1} s_1 \tag{2.24}$$

Finally, counterfactual tuition fees are used to estimate the externality of loans on ineligible students. Specifically, the difference between actual and counterfactual tuition can be interpreted as the externality that arises once loans become available.

2.4 Data and Sample

2.4.1 Institutional Background

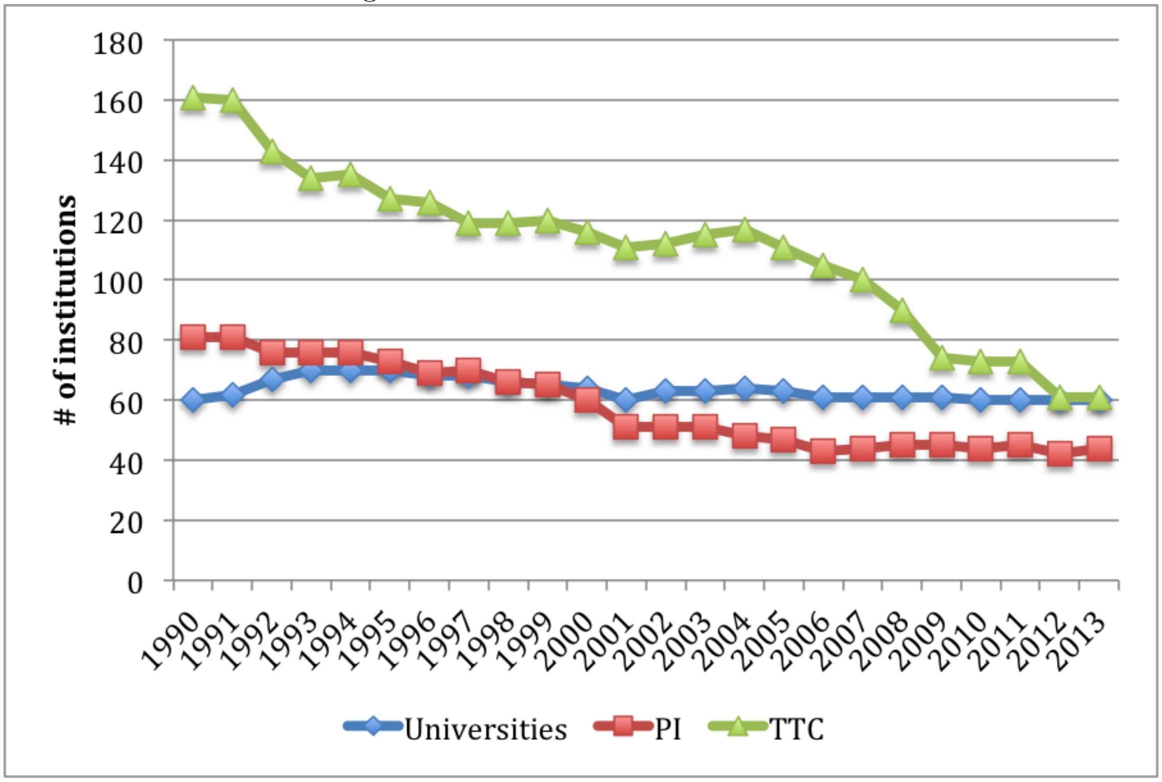
The Chilean tertiary education system has experienced significant changes during the last 30 years. Until 1981, the higher education system was composed by only eight universities, two of which were public, and most of them offered only four and five-year degrees. Higher education was tuition-free and it was primarily financed by direct subsidies from the federal government to the institutions. Historically, gross enrollment rates did not surpassed 10-15% and the system was predominantly for the elites,[6] and students from the richest families, who generally outperformed those from most disadvantaged ones in admission tests, filled most of the vacancies.

[6]The gross enrollment rate in tertiary education is defined by UNESCO as the "total enrollment in tertiary education (ISCED 5 and 6), regardless of age, expressed as a percentage of the total population of the five-year age group following on from secondary school leaving".

A major reform in 1981 established a new higher education framework. With the purpose of increasing competition, it introduced substantial market-based changes that last until these days. First, the reform encouraged the entry of new private participants. Thus, between 1981 and 1990, 40 privates universities were created. Second, two new types of private higher education institutions (hereafte HEIs) were introduced: Technical Training Centers (TTC or *Centros de Formacion Técnica*) and Professional Institutes (PI or *Institutos Profesionales*). TTCs generally offer two to three-year technical and vocacational degrees and IPs generally offer four-year professional degrees. Third, the two public universities were divided into multiple regional institutions. These new universities and the pre-reform private universities formed a consortsium called CRUCH (*Consejo de Rectores de las Universidades Chilenas*) to differentiate themselves from the newly formed private universities (hereafter, non-CRUCH). The main structure of the higher education system has remained almost unchanged ever since.

Under this new configuration, HEIs were relatively free to expand and offer a variety of new degrees, expanding significantly the supply of higher education. The number of HEIs peaked 303 in 1991 and has steadily declined to a total of 147 in 2015 (see Figure 2.3). Gross enrollment rate has increased to 74% (in 2014) and the number of students in the higher education system has increased more than 6-fold (see Figure 2.4).

Figure 2.3: Number of Institutions



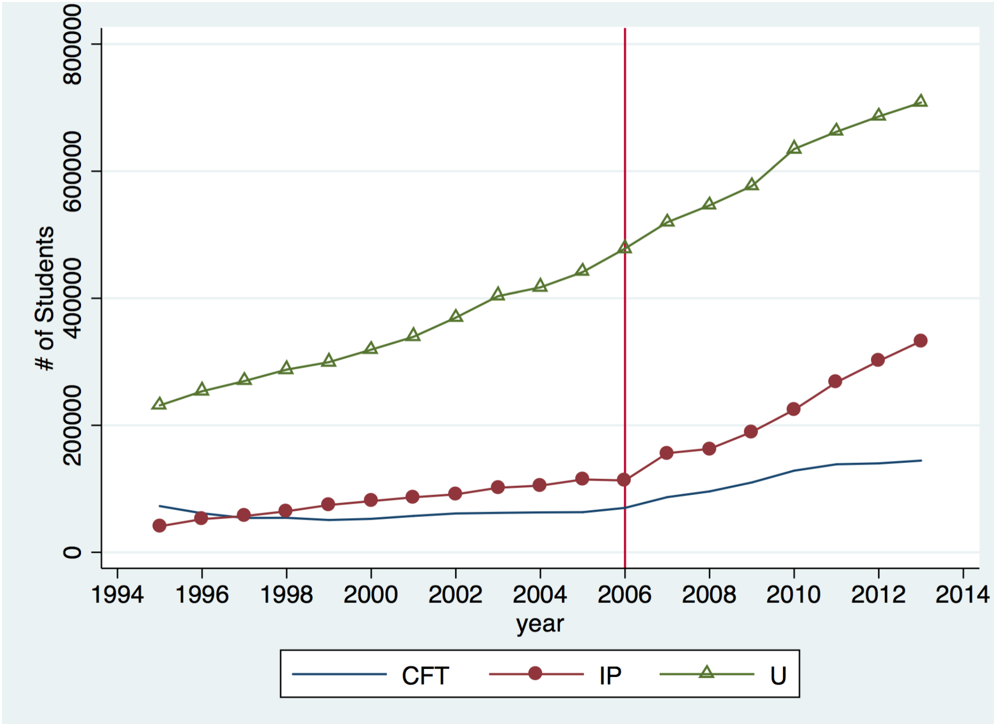
Note: Author's Calculation. Source: CNED.

2.4.2 Higher Education Financing

The main source of funding for all HEIs, is student fees. In fact, according to (OECD, 2014), the share of private expenditure in higher education is 76% and the rest is financed by the State. The State funds the system through three main channels. First, it provides direct subsidies to the 25 CRUCH universities (called AFD or *Aporte Fiscal Directo*).[7] These funds are non-competitively allocated. They are in relation to historical market shares and have not changed much in 30 years. Second, the State provides a one time, per-student transfer to HEIs for enrolling top-scoring students in the college admissions test (PSU). This subsidy is called AFI

[7]Non-CRUCH universities, TTCs and IPs do not receive AFD.

Figure 2.4: Enrollment



Note: Author's Calculation. Source: CNED.

o *Aporte Fiscal Indirecto*.[8] Although all HEI are eligible for AFI, according to the Ministry of Education of Chile, 87.6% is assigned to CRUCH universities, 12.1% to non-CRUCH universities and less than 1% to IPs and CFTs. Third, the State offers a loan at a 2% subsidized rate to students in CRUCH institutions (FSCU or *Fondo Solidario de Crédito Universitario*). Loans are re-payed contingent on income during a fixed number of years. Students in institutions outside the CRUCH are nor eligible for the FSCU. Hence, it has historically served less that 10% of the student population. Finally, the State offers scholarships to capable student with financial needs.

[8]The amount of the subsidy is set by tranches of PSU. The amount of the per-student subsidy in the top tranche is 40% of the average tuition in Chile.

2.4.3 State-Guaranteed Loan Program

The Chilean higher education system made great progress during the 90s, allowing thousands of students to pursue a postsecondary degree. However, access was still highly unequal. On one hand, students from disadvantaged backgrounds faced adverse borrowing conditions. As in any human capital accumulation problem, the lack of collateral makes it almost impossible for a needy student from a poor background to obtain a loan in standard financial markets. On the other hand, the combination of relatively high tuition fees (see OECD, 2014; Solis, 2016) and the pressing need to generate income, forced students from poorer backgrounds to enter the labor market instead of pursuing a college degree.

In an effort to promote a more equal access to higher education, and to support qualified students from disadvantaged backgrounds in financing their postsecondary studies, the State launched a massive loan program in 2006. The so called State-Guaranteed Loan (SCL) or CAE for its Spanish initials[9] is a standard mortgage-type student loan issued by private financial institutions but guaranteed by the State. The CAE is administered by a special commission named *Ingresa*.

The SGL does not require families to provide a collateral to secure the debt. HEIs guarantee a fraction of the debt until the students graduation, and the rest is guaranteed by the State. The State, in fact, guarantees 90% of the debt after graduation. The remaining 10% of the debt is no guaranteed, and banks bear that risk.

[9] Crédito con Garantia Estatal.

The SGL requires students and HEIs to meet certain eligibility criteria. First, students must provide proof of financial need. After filling an application form containing information on family income and socio-economic conditions, the *Ingresa* commission determines whether a student qualifies for the SGL or not. In addition to this, students must meet minimum academic merit, which is set at 475 average points on the college admissions test (PSU), which corresponds to 25% of SD below the national average. Students who do not take the PSU must have graduated from high school with a minimum GPA of 5.27 (in a 1 to 7 scale).

As opposed to FSCU, any HEI can participate in the SGL. The only requirements are that they must be accredited and that must agree to the terms regarding the guarantee of the loans before students graduate. As of 2015, 96 HEIs participate in the loan program.

Loans' real interest rate remained stable around 5.5% during the period 2006-2012. Then, a reform in 2012 fixed the rate at 2%. Loans can only finance tuition fees. Stipends and other expenses cannot be covered by the SGL. The amount of the loan is capped at a "reference tuition" set by the Ministry of Education. The annual reference tuition is calculated based on sticker price but also weights some quality indicators such as student-faculty ratios, drop-out rates, among others. References tuition is on average 90% of the sticker price. The difference between sticker price and reference tuition (if any) has to be financed by students by other means.

Students' debt begins to accrue interest immediately, but students have no financial obligations while they remain studying. The loan is repaid on a monthly basis after graduation, and the repayment period can be 10, 15, or 20 years depending on the type of degree and the amount of the loan. Payments can be suspended in case of unemployment or if installments surpass 50% of graduates' monthly income. All unpaid debt is borne by the State. Finally, the bank that owns the debt can call the State guarantee if students stop paying for more than three consecutive months and after some collection effort has been demonstrated.

2.4.4 Data

I employ four different databases in this study. First, I use application data to CRUCH universities in 2005 and 2007. The former year is one in which the SGL was still not implemented, while 2007 is the second year of operation of the SGL. Universities in CRUCH run a centralized admission process, in which students rank the academic programs they are applying to. Specifically, students submit an ordered list containing up to 8 options to a clearinghouse. Students do not apply to universities but rather to specific programs within universities. Therefore, an option is defined as a university-major pair (henceforth, a program). For example, "Engineering at University A" or "Political Science at University B". Once preferences are collected, a clearinghouse runs a student-proposed Deferred-Acceptance algorithm (or Gale-Shapley) that assign students to programs according to their score, preferences and the number of seats available.[10] My dataset contains student-level application to universities in CRUCH and I observe the ranking list submitted to the clearinghouse by each student.

Second, I use individual records from the college admission test (PSU) in

[10]See Espinoza et al. (2017) for further details on the Chilean admission system.

years 2005 and 2007. The data contains information of the scores in each PSU subject. This dataset also includes a rich characterization of students, including demographic information such as gender, age, the high school from which they graduated, and high school GPA. It also includes a rich description of students' socio-economics status, including variables and such as family income, family size, parental education, among others.

The third dataset contains administrative records from the Higher Education Information System (SIES) which is the governmental body within the Ministry of Education that manages and discloses official tertiary education statistics. This student-level data tracks students over time, and indicates which programs students are enrolled in each academic year. This dataset and covers the period 2005-2013.

Finally, I use a dataset from the Chilean National Education Council (CNED) containing supply-side information. Specifically, the dataset contains administrative information on the programs that are offered by all HEIs in Chile. From this database I extract information on the characteristics of the programs, including tuition (sticker price), duration of the program and geographical location. This dataset also contains information on the characteristics of HEIs, such as such as total enrollment, number of campuses, and accreditation status. This dataset covers the period 2005-2013.

Table 2.1 shows some descriptive statistics of the application dataset. The sample includes 157,436 students who applied to universities in CRUCH through the centralized matching system. Panel A shows that students are on average 19.5 years old and roughly 50% are woman.

Table 2.1: Descriptive Statistics

	Year 2005 (Pre-Loan)	Year 2007 (Post-Loan)
Panel A. Demand Side		
Number of Applicants	72,995	84,441
Age	19.52	19.51
(std.)	(1.95)	(1.94)
Female (%)	49.92	51.16
Public Schools (%)	19.75	17.18
Voucher Schools (%)	42.49	46.21
Private School (%)	37.44	36.23
From Santiago (%)	33.65	34.00
N. of options listed	5.22	5.01
Use all option (%)	23.45	20.39
Panel B. Supply Side		
# of universities	25	25
# of programs offered	869	951
Programs in Santiago (%)	33.80	34.09
Tuition (2007 USD)	3,572.20	3,847.68
(std.)	(1,176.68)	(1,219.95)

Standard deviation of selected variables are shown in parenthesis.

Although students from privates schools (richer students) represent only 10% of total high school enrollment, they represent more that 36% of my sample. This means that students from high socio-economic status are over represented in the higher education system. In terms of application behavior, although they can list up to 8 options the average number of applications is 5.22, and only one out of five students uses the maximum number of options to list. Panel B in Table 2.1 show descriptive statistics of the supply side. The average tuition rose by 7.7% in the two years window. The number of programs offered varies a slightly from one year to the other (869 in 2005 and 951 in 2007), and roughly one third of the programs are located in the largest metropolitan area in Chile (Santiago).

In 2007, the SGL was awarded to 24,240 first-year students in all higher education institutions and to 1,574 first-year students in CRUCH universities, corresponding to 2.5% of students who are offered admission through the centralized matching system.

2.4.5 Pricing Behavior

In my main analysis, I use applications to CRUCH universities to estimate price-demand elasticities for different programs, which are used to estimate counterfactual pricing scenarios. However, CRUCH universities are not a representative sample of Chilean higher education institutions. First, CRUCH universities are the oldest universities in Chile. All 25 universities in CRUCH were created before 1981, and have a long history and prestige (comparable to Ivy League colleges in the U.S).

CRUCH gathers all state-owned universities (16) as well as 9 private universities. Also, they only offer 4 to 5-years degrees (no technical or vocational degrees). Table 2.2 shows descriptive statistics for each type of institutions. CRUCH universities are comparable to universities outside the CRUCH (non-CRUCH) in several dimensions, including average tuition and student composition. However, they differ in the average years of accreditation and on the PSU score of the students they enroll. However, CRUCH universities are not comparable in most dimensions to institutions offering 2 and 4-year degrees (TTCs and PIs). For example, tuition fees at those institutions are considerably lower. Students at TTCs or PIs enroll students with lower PSU scores and a vast majority come from either public or voucher high schools.

Table 2.2: Types of HEIs

	TTC (2yr-degrees)	PI (4yr-degrees)	non-CRUCH Univ. (5yr-degrees)	CRUCH Univ. (5yr degrees)
PANEL A. Supply Side				
# of HEIs	56	40	33	25
# of Field	191	141	228	206
Average tuition (USD)	$ 2,602	$ 2,694	$ 5,401	$ 5,345
# of campuses	167	178	148	71
Years of accreditation (Avg.)	1.24	1.68	2.20	4.80
PANEL B. Demand Side				
# of students	62,282	111,240	88,087	64,751
% of total enrollment (market share)	19.1%	34.1%	27.0%	19.8%
% female	52%	51%	52%	47%
Average PSU score	406.55	412.06	487	560
Student Composition				
% Public Schools	45%	41%	27%	30%
% Voucher Schools	53%	56%	56%	55%
% Private Schools	2%	3%	16%	16%
Total	100%	100%	100%	100%

Source: CNED, 2014

In this section, I analyze the evolution of tuition in the overall Chilean higher education system and provide reduced-form evidence of whether the SGL may have caused HEIs to raise tuition. Since eligible HEIs decided whether or not to joing the SGL, I hypothesize that colleges that joined the SGL raised tuition more than colleges that didn't join.

Tuition fees charged by HEIs have been steadily rising during the last decade, averaging a 4.5% annual increase over the period 2005-2015. In this section I study to what extent the implementation of the SGL program might have contributed to this phenomena. It is worth noting that Chile has one of the most expensive higher education systems among OECD countries. Total expenditure per student per year reaches roughly 50% of GDP per capita (OECD, 2014) and can be compared to the US and Korea in this dimension. Moreover, roughly two thirds of total expenditure is paid by students and their families with limited contribution from the State.

Students loans for attending higher education can trigger a tuition increase. Loans targeting students who face short-run liquidity constraints increase the demand for higher education, since now more individuals can now afford to pay the cost of attending college. It also can make students less price-sensitive. Colleges can respond by raising tuition, provided they exert some degree of market power.

I aggregate academic programs by field and institution. For each observation, I calculate the percentage tuition increase during the period 2005-2010.[11] Table 2.3 shows the average, minimum and maximum tuition increase during the 5-year span for programs in institutions that joined the SGL versus programs in institutions

[11] The sample is restricted to group of programs that were offered in both periods.

that did not the SGL.

Table 2.3: Change in Tuition 2005-2010 by Type of HEI

	Not in SGL (1)	In SGL (2)	Diff (2)-(1)	p-value
TTC	0.248	0.383	13.5%	0.0002
	[-0.076,0.79]	[-0.05,0.744]		
PI	0.193	0.279	8.6%	0.0449
	[-0.191,0.691]	[-0.103,1.153]		
University	0.244	0.379	13.5%	0.00
	[-0.399,1.216]	[-0.209,1.828]		
All	0.237	0.365	12.8%	0.00
	[-0.399,1.216]	[-0.209,1.828]		

Programs in institutions that joined the SGL increased tuition 12.8% more than in institutions that did not joined it (36.5% versus 23.7% on average). Most differences are statistically different at the 5% level.

Universities increased tuition up to 180% in five years (minimum and maximum per type of HEI are shown in brackets). Tuition in TTCs and PIs that joined the SGL also increased between 2005 and 2010, although there is observe less variability than in universities. Tables 2.4, 2.5 and 2.6 show similar statistics by field of study for TTC, PIs an universities, respectively. They report report large heterogeneity across field and type of HEI.

To formally test the hypothesis that the SGL programs raised tuition, I perform a simple regression analysis based on a difference in differences approach.

Table 2.4: Average Tuition Change by Field of Study: Technical Training Centers (x 100 %)

Field of Study	In SGL	Not in SGL	Difference	p-value
Business & Administration	0.26	0.42	0.15	0.06
Agriculture	0.32	0.42	0.10	0.67
Arts & Architecture	0.19	0.33	0.14	0.21
Sciences				
Social Sciences	0.35	0.72	0.38	
Law	0.16	0.27	0.11	0.14
Education	0.25	0.32	0.06	0.45
Humanities				
Health	0.22	0.41	0.19	0.09
Technology	0.28	0.38	0.11	0.30

Table 2.5: Average Tuition Change by Field of Study: Professional Institutes (x 100 %)

Field ofs Study	In SGL	Not in SGL	Difference	p-value
Business & Administration	0.19	0.28	0.09	0.42
Agriculture	0.28	0.24	-0.04	
Arts & Architecture	0.04	0.33	0.29	0.04
Sciences				
Social Sciences	0.16	0.28	0.12	0.47
Law	0.69	0.11	-0.58	
Education	0.26	0.24	-0.02	0.83
Humanities				
Health				
Technology	0.09	0.35	0.26	0.11

Table 2.6: Average Tuition Change by Field of Study: Universities (x 100 %)

Field of Study	In SGL	Not in SGL	Difference	p-value
Business & Administration	0.19	0.41	0.22	0.06
Agriculture	0.17	0.39	0.21	0.04
Arts & Architecture	0.47	0.37	-0.10	0.24
Sciences	0.49	0.37	-0.13	
Social Sciences	0.19	0.40	0.20	0.04
Law	0.46	0.43	-0.03	0.85
Education	0.23	0.34	0.11	0.09
Humanities	0.04	0.34	0.30	0.02
Health	0.12	0.36	0.24	0.02
Technology	0.11	0.36	0.25	0.06

Specifically, I estimate the following regression model:

$$\log p_{ijt} = \alpha + \beta post_t + \gamma Joined_j + \delta(post_t \times Joined_j) + \omega X_{ijt} + \varepsilon_{ijt} \qquad (2.25)$$

Where p_{ijt} is the tuition charged by program i in institution j in year t. We define the binary variable $post_t$ taking the value 1 in years after the institution joined the SGL and zero otherwise. Similarly, the dichotomous variable J_j indicates whether institution j joined the SGL or not. X_{ijt} is a set of controls including time and institution fixed effect, and ε_{ijt} is an idiosyncratic error term. The parameter of interest is δ, which captures the effect of the SGL on the log of tuition at institutions that joined the SGL. Columns (1) and (2) in Table 2.7 shows that after the SGL, participating institutions raised tuition 4 to 5% compared to non-participating institutions. Columns (3)-(8) shows differential effects across different types of institutions.

Table 2.7: Difference-in-Difference regression Results: Tuition Increase

	All	All	TTC	TTC	IP	IP	Univ.	Univ
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post x Joined$_{jt}$	0.046**	0.041**	0.067**	0.070***	0.052	0.030	0.033	0.030
	(0.020)	(0.019)	(0.028)	(0.025)	(0.046)	(0.039)	(0.029)	(0.028)
Year Fixed-Effect	YES	YES	YES	YES	YES	YES	YES	YES
HEI Fixed-Effect	YES	NO	YES	NO	YES	NO	YES	NO
Field Fixed-Effect	YES	NO	YES	NO	YES	NO	YES	NO
R^2	0.93	0.97	0.88	0.93	0.83	0.93	0.79	0.92
N	4284	4284	1059	1059	643	643	2582	2582

Note: The unit of observation is program by year. Regression models additionally include university fixed effects and year fixed effects. Standard errors are clustered by year. The asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

2.4.6 Model Implementation

The estimation of the BLP random coefficients logit model requires that market level-data, including prices and market shares. We define a market as a given academic year. I use data from the application processes 2005 and 2007. The former is a pre-loan period and the latter is one when the loan systems was already in place. It is important to mention that all universities in CRUCH participated in the loan program in 2007.

Since students rank individual programs, I use the top-ranked option for each student to calculate program market shares. For instance, if all students rank a program as their top-choice, its market share would be 100%, independent on whether they were finally admitted. In fact, market shares calculated using stated preferences differ from post-selection market shares because seats are limited, and therefore a fraction of the applicants are not accepted in their most preferred option. In this context, data on applications allows me to estimate demand elasticities abstracting from the fact that final enrollment reflects not only preferences but also program capacities. For instance, if there exists a program that is highly demanded but with very few seats, the number of applications will exceed the number of students actually enrolled, and if market shares were calculated using actual enrollment we would be underestimating its true demand.

The estimation also requires to calculate the market share of an "outside good", which is used as *numeraire*. In each period, its market share is calculated as the percentage of students who decide not to apply to a program in the CRUCH. Market shares of the outside good in 2005 and 2007 are 57% and 60.3%, respectively.

The BLP method constructs a GMM estimator using a proper set of exogenous instruments for p_{jt}. Unfortunately, is difficult to find variables that shift the costs and are uncorrelated with the demand shock. Instead, I follow Bresnahan (1981) and Bresnahan (1987), to define the set of instruments, which have been extensively used in the literature. I assume that the characteristics of programs is exogenous or determined before students make decisions about which program to apply to. I use the sum of the observed product characteristics of other programs offered by the same university and the sum of observed characteristics of programs in the same field offered by other universities as instruments. One of the main advantage of these instruments is that they vary program by program.

2.5 Results

Table 2.8 shows the results of the demand model from 15 and 16. The model in column (2) allows the coefficient α to depend on student demographic characteristics, while the model in column (1) does not. The table shows the means of the distribution of marginal utility on tuition (α) as well as for other covariates. University fixed-effects are also included. As expected, the coefficient on tuition is negative, which implies a disutility of higher tuition fees, conditional on program characteristics (observed and unobserved). My preferred specification (column 2) allows the coefficients to depend on student observed characteristics. I include whether or not the student is eligible for the loan, and dummy variables indicating the type of high

Table 2.8: Demand Estimation

	Model 1	Model 2
	(1)	(2)
Tuition	-0.85	-11.57*
	(6.39)	(0.799)
Quality proxy	0.018***	0.021***
	(0.002)	(0.003)
Duration	0.008*	0.085
	(0.068)	(0.075)
HEI Dummies	YES	YES
N	704	704

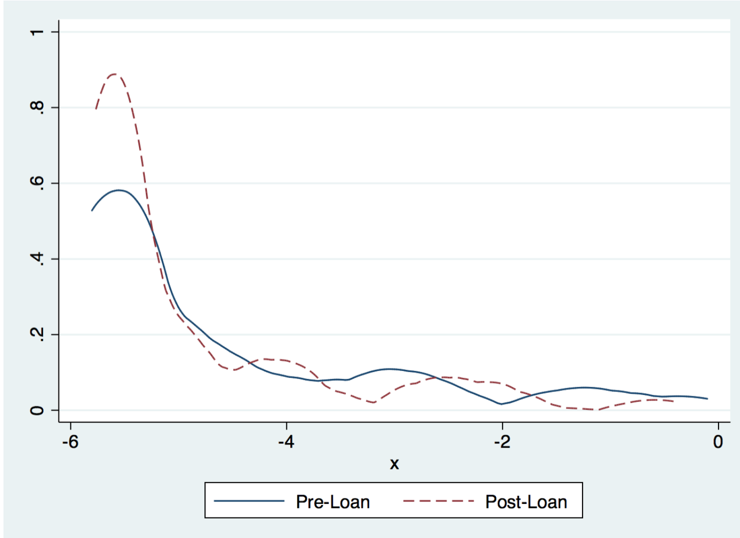
school students graduated from (private, public of voucher), which proxies student socioeconomic status.[12]

These estimates are used to calculate own and cross-price elasticities of demand in both periods (before and after loans) using equations (2.17) and (2.18). Table 2.9 shows descriptive statistics of the elasticities in both periods for programs in different fields of study. The average own price-demand elasticity is -4.08 in my sample, although some heterogeneity emerges across programs in different fields. For example, programs in the fields of education and humanities exhibit a relatively high price-demand elasticity. In contrast, programs in the health or law sector exhibit substantially lower elasticities. [13] However, it is important to note that the

[12] A standard robustness check for these types of models is to check how well they predict students' second choices. The correlation between the predicted market of share of students' second choices and market shares that can be calculated using the application data is 0.6.

[13] To the best of my knowledge, the literature has not reported elasticities to which I can compare

Figure 2.5: Distribution of Elasticities



random-coefficients model used does not restrict these elasticities to fully depends on markets shares, such as in a standard logit framework. On the contrary, differences in elasticities are mainly driven by changes in the underlying demand for different program, and by the price sensitivity of students.

More importantly, the average elasticity is lower in the period with loans than in the period without loans (average of -4.36 versus -3.80, respectively). This suggests, as expected, the loans made students less sensitive to tuition. Figure 2.5 shows the overall distribution of elasticities in years 2005 and 2007. Similarly, Table 2.9 shows the same results stratified by field of study.

We use the estimated elasticities shown in Figure 2.5 to estimate the marginal costs that are consistent with pricing strategies in 2007. Specifically, I back up the marginal costs using equation (2.23). I find that the average markup of price over marginal cost went up from 22.52% in 2005 to 30.06% in 2007. Table 2.10 shows

my results. Furthermore, the comparison would not be trivial due to idiosyncratic factors

Figure 2.6: Distribution of Elasticities by Field

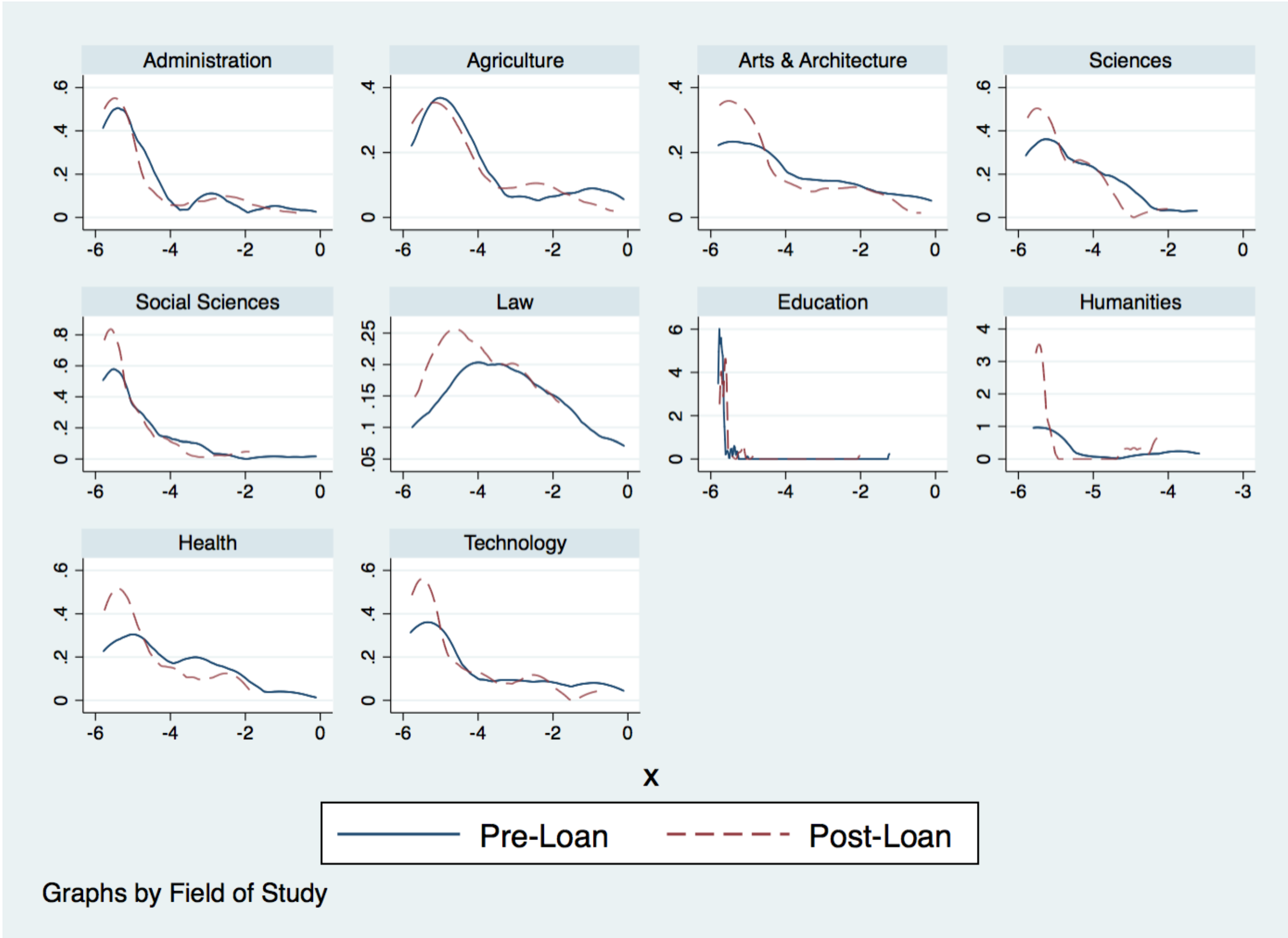


Table 2.9: Average Elasticities by Field

	Year 2005 (Pre-Loan)	Year 2007 (Post-Loan)
Administration	-4.34	-3.69
Agriculture	-3.78	-3.24
Arts & Architecture	-4.12	-3.19
Sciences	-4.53	-4.02
Social Sciences	-4.51	-4.09
Law	-3.23	-2.33
Education	-5.55	-5.63
Humanities	-5.39	-5.27
Health	-2.49	-0.70
Technology	-4.35	-3.85
Total	-4.36	-3.80

markup heterogeneity across different fields in the pre and post-loan period.

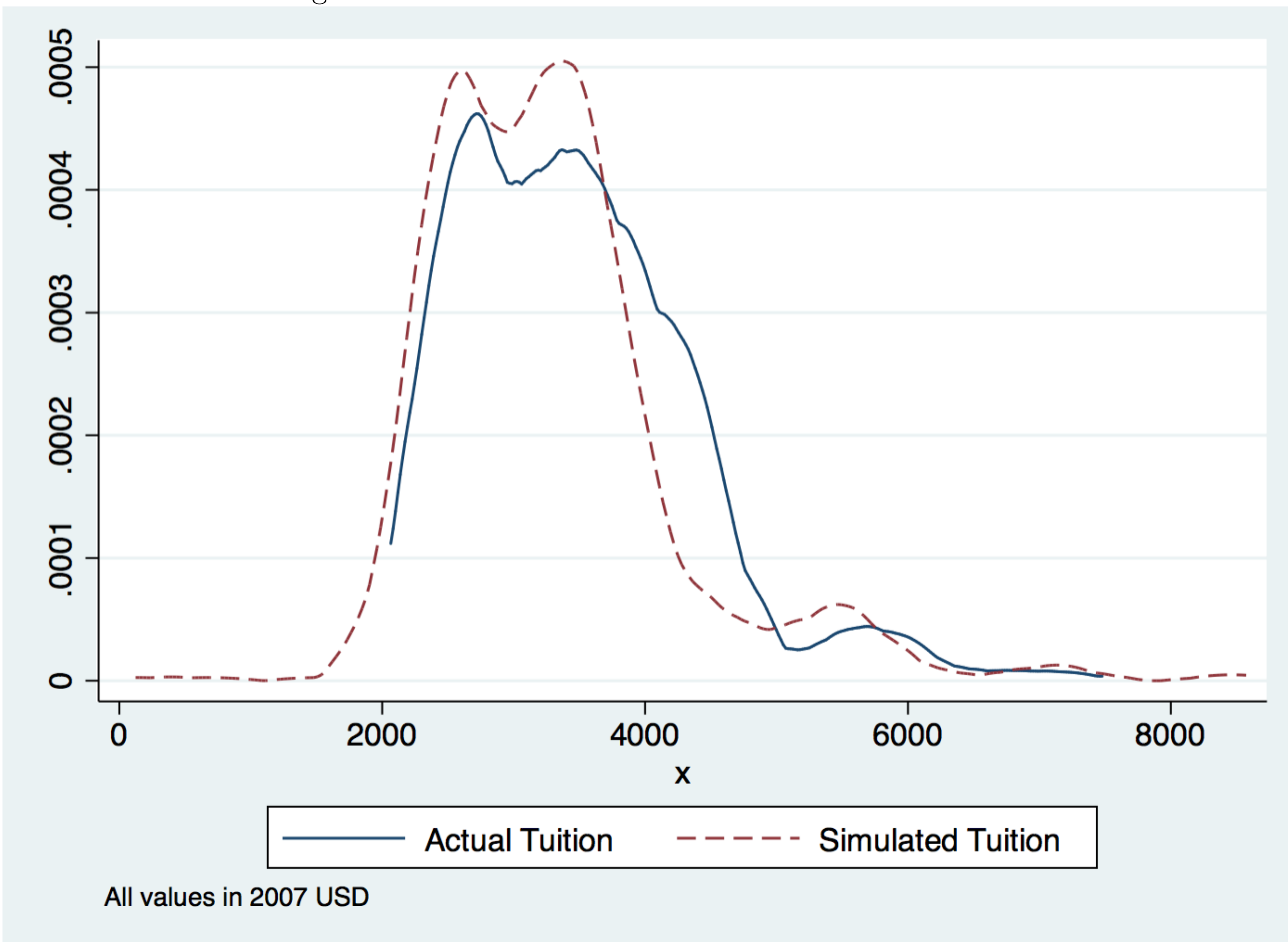
Table 2.10: Markups

	Year 2005 (Pre-Loan)	Year 2007 (Post-Loan)
Administration	0.27	0.20
Agriculture	0.27	0.28
Arts & Architecture	0.29	0.38
Sciences	0.27	0.45
Social Sciences	0.24	0.28
Law	0.46	0.32
Education	0.23	0.27
Humanities	0.23	0.25
Health	0.20	0.37
Technology	0.16	0.30
Total	0.22	0.31

I use Equation (2.24) to simulate the pricing strategy in the post-loan period. I use the estimated elasticities in the pre-loan period to simulate prices that are consistent with the post-period structure. This allows me to find counterfactual prices in the post-loan period under the assumption that the distribution of price elasticities of demand equals that of the pre-loan period.

I find that the median program sets a tuition 5.9% higher than would have set without loans. Figure 2.7 shows the distribution of actual and simulated prices in 2007. Since the demand is more inelastic in the post-loan period, universities raised tuition after the loan program. The dotted line in Figure 2.7 shows the counterfactual distribution of tuition fees, i.e. those that universities would have set in 2007 if loans were never been implemented. Table 2.11 shows average actual and simulated prices stratified by field of study. The average difference between actual

Figure 2.7: Actual and Simulated Tuition



tuition and its counterfactual is $174 USD.

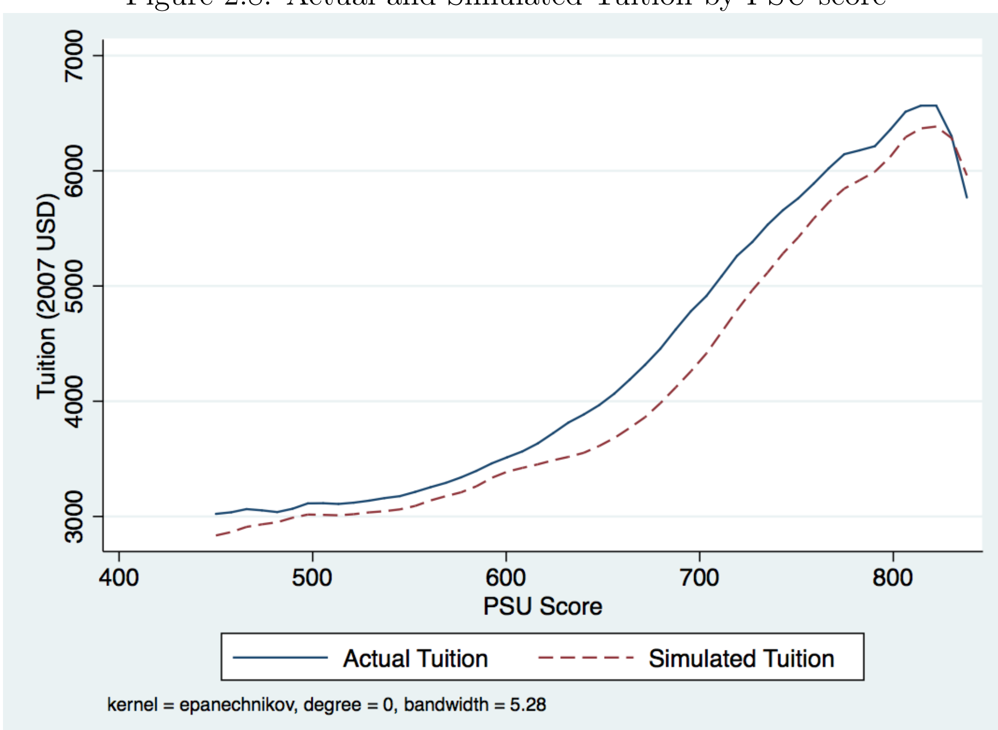
I use the simulated and actual prices to estimate the burden imposed by loans on ineligible students. Using the estimates from Table 2.11, I found that the average ineligible student paid US$178 per year more than he would have paid in a year without loans. Figure 2.8 shows the tuition differential for students with different PSU scores. We observe that the tuition differential is higher for students with higher scores.

The sum of this price differences over all ineligible students yields a total of

Table 2.11: Actual vs. Simulated Tuition (2007)

	Actual Tuition	Simulated Tuition
Administration	$ 3,553	$ 3,464
Agriculture	$ 3,888	$ 3,694
Arts & Architecture	$ 3,709	$ 3,481
Sciences	$ 3,645	$ 3,482
Social Sciences	$ 3,507	$ 3,341
Law	$ 4,094	$ 3,651
Education	$ 2,608	$ 2,535
Humanities	$ 3,126	$ 3,007
Health	$ 4,235	$ 3,984
Technology	$ 3,580	$ 3,366
Total	$ 3,468	$ 3,294

Figure 2.8: Actual and Simulated Tuition by PSU score



\$9.93 million per year or \$47.6 million over the duration of the studies [14]. This amount can be interpreted as the externality that is imposed on ineligible students. In 2007, a total of 1543 loans were granted to first-year students in CRUCH, for a total amount of \$2.85 million. Therefore, for every federal dollar spent in loans ineligible students end up paying roughly 3.5 dollars more.

My empirical model assumes that institutions maximize profits when setting their optimal tuition. However, universities in Chile are not allowed to be for-profit (although IPs and TTCs are). Nevertheless, there could be several reasons to believe that the profit-maximization assumption can be valid in the Chilean setting. For example, the fact that universities are non for-profit institutions does not mean that they do not maximize the difference between revenues and cost. In a context of competition for quality or reputation, it may be optimal to maximize profits so that these can be reinvested, for example by building new campuses, libraries, laboratories or hiring more faculty. To test this, I use use data from publicly reported profits and expenditures[15] to test whether profits are correlated with investments that could lead to higher quality. Table 2.12 reports the results of simple regressions attempting to test such correlations. The explanatory variable is annual profits. The independent variables are changes between the year the profits were made and the year after it. In Columns 1 and 2, I use the change in salary expenditure (faculty and staff, respectively). For Column 3, I use the change in the number of full-time faculty. Finally, for columns 4 and 5, I use the change in the number of buildings

[14] The average program duration in my sample is 4.8 years

[15] Source: SIES, Ministry of Education of Chile

and total classroom area (squared meters). The sample includes all universities (private and public) in the period 2013-2015. The coefficients in columns 1-3 show a positive correlation between university profits in year t and changes between year t and $t+1$ of total faculty and staff salary and total faculty. However, the results show no effects of profits on short-run investments in infrastructure (columns 4 and 5). Table 2.12 shows evidence that universities' profits are correlated with expenditure in items that may be positively related with education quality (e.g. more and better faculty).

Table 2.12: Profits and Investment

	Annual Change				
	Total Faculty Salary	Total Staff Salary	Full Time Faculty (x1000)	Number of Buildings (x1000)	Classroom Surface(x1000 m^2)
	(1)	(2)	(3)	(4)	(5)
Profits	0.260***	0.232***	0.003**	-0.000	0.016
	(0.039)	(0.044)	(0.001)	(0.000)	(0.062)
R^2	0.31	0.24	0.07	0.07	0.03
N	116	116	100	98	98
Year Fixed-Effects	YES	YES	YES	YES	YES
Public Dummy	YES	YES	YES	YES	YES

Data Source: SIES, Ministry of Education of Chile.
Note: Sample include all universities in the period 2013-2015.

2.6 Conclusion

The ability of financial aid policies to increase student welfare depends on colleges' pricing reaction. While most of the literature has focused on the benefit of financial aid on eligible students, my paper focuses on the estimation of the negative spillover on ineligible students that arises when colleges strategically raise tuition to capture some portion of the student aid.

Using data on a Chilean state-guaranteed loan program, I find that non-eligible students pay 5.9% higher tuition than they would have paid in the absence of loans. The size of the externality imposed on non-eligible students in my sample is estimated at $218 USD per student per year for a total of $9.93 million per year.

The literature shows that loans can significantly increase college enrollment, especially among disadvantaged students. In most cases, a college degree translates into better labor market outcomes. Thus, loans have the potential to increase the welfare of its beneficiaries and in cases when college attendance fully depends on the loan, gains can be substantial. In that sense, proper estimates of the return to education for different college degrees (see (Hastings et al., 2013b; Rau et al., 2013; Espinoza and Urzúa, 2016)) can shed light of the overall welfare effect of the SGL.

The escalating tuition level is a worldwide trend that compromises the capacity of expanding higher education to most vulnerable students and the weakens the role of higher education as a source of social mobility.

My findings highlight one unintended consequence of student loans for college that is usually ignored and that partially offsets the gains that can be achieved by student loans. In that sense, my results could be of particular interest to policy-makers, who should take this into account when designing and implementing such policies.

Chapter 3: Endogenous Market Formation: Theory and Evidence from Chilean College Admissions

Note: This chapter is coauthored with Soohyung Lee and Héctor López.

3.1 Introduction

Over the past two decades, lessons from market design have been actively adopted in organizing real-world markets, including goods auctions, labor markets, and organ allocation. Student-school matching markets have shown perhaps the most dramatic changes due to market design. Starting with New York City's public school assignment, numerous cities across America and around the world have adopted market-design inspired centralized assignment schemes in assigning children to public schools.[1] The benefits of adopting such centralized assignment schemes are well recognized among researchers and practitioners: these schemes produce efficient and fair assignment of students, a feature enjoyed by school officials, families

[1] More than 15 cities across America use (or are in the process of adopting) a version of the deferred acceptance algorithm. The theoretical challenges of these implementations are well documented in several papers, for example: Abdulkadiroğlu and Sonmez (2003); Abdulkadiroğlu et al. (2005a,b, 2015); Abdulkadiroglu et al. (2011).

and schools alike. However, such transitions to centralized assignment schemes have been the product of policy intervention by local authorities and not the initiative of market participants. Furthermore, a sizable number of schools, such as charter or private schools in the US, have decided not to participate in these centralized assignment schemes.

The necessity of policy intervention is well grounded in theory, as formation of a centralized market faces two challenges. First, some participants might prefer an inefficient market institution in which they can exploit a market failure. Second, others might be better off exploiting their market power after the centralized market has been formed. These two problems are accentuated in markets in which the gains from moving to an efficient market structure cannot be freely distributed among participants.[2]

Despite the challenges, there is evidence that some centralized markets are organized and maintained by market participants.[3] Thus, studying the conditions under which such formation is possible is of major importance. This paper makes progress in this direction by presenting a theoretical setting in which agents voluntarily adopt a transition to a centralized market and supporting empirical evidence.

[2] Starting with Roth's contributions (Roth, 1982, 1984a; Roth and Xing, 1994), it has been recognized that forming and staying in a centralized stable clearing house might or might not be a Nash equilibrium. In particular, agents with multiunit demand might find it profitable not to participate and to transact earlier or later (see Ekmekci and Yenmez, 2016) than the centralized market.

[3] The most famous examples are markets for new physicians in the United States and the United Kingdom, as documented by Roth and Xing (1994); Roth (1984b, 1991); Roth and Peranson (1999).

In our setting, the key mechanism facilitating the transition is the close competition among agents and moderate level of costs in the process of matching. This mechanism can explain the voluntary adoption and maintenance of a centralized market and its expansion when new participants enter into the market. The intuition is straightforward. Consider a simple case of student-school matching in which there are only two schools. When two market participants are similar, the inefficiencies created by decentralization are equally distributed between the two; thus, the two participants equally enjoy the gains of centralization by expanding the pool of applicants and reducing the number of vacant seats. We investigate this market force and its consequences in the context of college admissions in Chile.

The Chilean college admission process has experienced a transition to a (more) centralized system twice since 1960. The first episode of centralization occurred when all non-technical colleges, a total of 8 at that time, adopted a centralized admission system based on the Gale-Shapley mechanism. These colleges branched out into 25 colleges, often referred to as CRUCH, and ran a centralized admission system until 2012, when they decided to invite other colleges to join the centralized system. In 1960, the share of admissions processed in the centralized assignment scheme was 100 percent; however, by 2010, this share dropped to 50 as new colleges and (bigger cohorts of) students entered the market. In 2012, the original CRUCH colleges decided to invite other colleges to join the centralized admission system. Eight of the non-CRUCH universities accepted the invitation, leading to an increase in coordinated college admissions from 50 to 70 percent in 2012. The colleges that accepted the invitation are roughly equivalent, in terms of quality and prestige, to the original CRUCH colleges.

The purpose of this paper is threefold. First, we provide a theoretical model that accounts for the adoption, maintenance, and expansion of a centralized admission system. The model shows that close competition by colleges, when application costs exist, is crucial for the adoption of a centralized system by market participants. Second, we empirically demonstrate the relevance of this market force using micro-level administration data from Chile. We show that those colleges that accepted the invitation were in fact those that had closely competed with the original CRUCH colleges. Third, we study how centralization affected students' welfare and show that low-income students benefited the most from the change. That is, in Chile, the centralization simplified application procedures and also reduced the monetary costs associated with applications, which may be particularly useful to students from a low socioeconomic background.

In our model, there is a continuum of students and two colleges (C_1 and C_2). Students are assumed heterogeneous in terms of preference over the colleges, test scores, and resources to cover application costs. Preferences regarding the two colleges are stochastic. Based on the proportion of students that find C_1 better than C_2, we measure the college quality of C_1 relative to C_2. For example, if that proportion is one half, the two colleges are considered of equal quality. Regarding resources, there are two types of students; when the two colleges run decentralized admission processes, one type of student can afford to pay the applications costs of the two colleges, while the other type can afford only one college application. When the two colleges adopt a centralized admission, both types of students can apply to the two colleges with only one application cost.

Colleges admit students based only on their test scores, and their utility is captured by the sum of the number of enrollees weighted by their test scores. When admissions are decentralized, students face a portfolio problem, and many find it in their best interest to apply to more than one college. If admitted, this strategy ensures that they can enroll in their favorite college. This strategy is costly and not all students can afford it. While some students are admitted to none, others are admitted to multiple colleges, creating inefficiency.

Under a centralized admission that produces optimal, stable matching, students are admitted to at most one college and no seats are left empty, provided that someone applied for them. Colleges might find it optimal to join or not to join a centralized admission system. When colleges run a centralized system, the applicant pool is the largest. This enlarged pool may benefit a college by increasing the number of enrollees and/or enrollees with higher test scores. However, this benefit might be offset if the college loses applicants to competing colleges of higher quality. This loss especially affects colleges that are able to enroll high-scoring students who cannot afford to apply to many colleges in the decentralized system.

In our model, when colleges are of equal quality, the benefit of participation outweighs the cost, while the opposite is true if the heterogeneity is sufficiently large. From the students' point of view, the wider coverage of the centralized admission may improve some students' welfare by enabling them to gain admissions to a higher quality college and pay a lower application cost. This result implies that the benefit from the centralized admission may be especially important for students of low-income backgrounds who cannot afford multiple application fees, and students who are crowded out of admissions by high-ranking students who can afford multiple applications.

The empirical analysis in this paper shows the relevance of our model assumptions and tests the model predictions using Chilean administrative data. Our primary data sources are application and enrollment data provided by Chile's Ministry of Education and other national agencies. From 2010 to 2013, we obtain detailed information on college applicants such as their test score, the list of colleges and majors they applied to, socioeconomic background, and actual enrollment. Our sample includes two years of college admissions prior to the 2012 change and two years after the change. Comparing the pre and post-period outcomes allows us to examine the changes in student and colleges'outcomes.

Consistent with our model, the 8 colleges that decided to join the centralized admission are very similar to CRUCH universities in terms of average test scores and student enrollment, relative to the universities that rejected the offer. After the 2012 change, both CRUCH and the 8 non-CRUCH universities showed an increase in the sum of enrollees' test scores, with comparable magnitude. Relatedly, the vacancy rate, the share of quota unfilled, among CRUCH was reduced from 14 percent in 2011 to 7 percent in 2012.

As for students, we find that, compared to the 2012 change, students, particularly those of low economic status, are more likely to enroll in the 8 non-CRUCH universities relative to CRUCH. As for student welfare analysis, we measure the quality of a student's major within the college (namely option) with the ranking based on the average test scores among enrollees from 2007 to 2009. We find that, after the 2012 change, students are on average able to enroll a more prestigious major option and such a benefit is particularly large for students of low socioeconomic status.

The remainder of our paper proceeds as follows: Section 3.2 presents the set of literature closely related to this paper and our contribution to it. In Section 3.3, we describe the institutional background, explaining changes in the Chilean college admission setting. In Section 3.4, we present a theoretical model accounting for the Chilean setting and changes. Section 3.5 discusses our data, sample and empirical approach, and in Section 3.6, we present empirical results testing model assumptions and implications, including the impact of widened coverage of the coordinated assignment on student-college sorting. Section 3.7 discusses the sensitivity of our analyses and implications, and Section 3.8 concludes.

3.2 Related Literature

This study contributes to the market design literature on student-school matching, particularly the ones that examine potential efficiency gains of a centralized matching, in comparison to a decentralized one. Examples of recent research in this literature includes Che and Koh (2016); Hafalir and Kübler (2016); Ekmekci and Yenmez (2016); Abdulkadiroğlu et al. (2015). Che and Koh (2016) and Hafalir and Kübler (2016) theoretically examine schools' strategies in attracting students and compare the market efficiencies across several admission settings including a centralized matching based Gale-Shapely algorithm and decentralized admission. Both studies examine richer theoretical settings and support their theoretical assumptions or results using observational or experimental data. Although our theoretical setting is designed simple to capture the key features of the Chilean college admission, this paper complements to these existing studies in twofold. One is that our theoretical setting explicitly examines the distributional impact of the matching system from the students' perspective because students may differ in their ability to exploit the inefficiency of the decentralized admission system. The other is that different from these studies, we conduct a micro-econometric analysis to empirical examine the impact on students as well as colleges.

Our paper is closely related to Ekmekci and Yenmez (2016) because it theoretically examines a school's payoffs to participate in a coordinated admission. Different from our findings, they find that the school has no incentive to join the coordinated admission. This opposite finding is due to the two key difference in the models: timing of the admission decisions and the application costs. In Ekmeki and Yenmez, the school can postpone its admission process until all the rest have finished admitting students and then go after students who have already been admitted by other schools. In contrast, our setting abstracts time, thus all schools run their admissions at the same time. In addition, in our setting, students need to pay costs to apply for a college that runs a decentralized admission while in Ekmekci and Yenmez (2016) , there is no application costs. These differences in modeling choices are rooted from the unique institutional settings. The US setting in Ekmekci and Yenmez (2016) does not involve pronounced admission costs and some charter schools run admission decision at the different time from the public schools. In contrast, in Chile, students need to pay time and monetary costs to apply for a college outside the centralized admission and such a college starts the admission decision at the same time or earlier than those in the centralized admission. It is worth noting that even if we allowed the possibility that a school may choose the timing of its admission decision, we may still find the school's incentive to join the centralized admission. That is because, if a sizable number of the students with talents cannot afford the application costs, then reaching out students after the centralized admission might not lead to the enrollment; thus joining the centralized admission may be more attractive to that college because it enlarges the pool of applicants.

Another closely related paper is Abdulkadiroğlu et al. (2015). It studies high school assignment in New York City and shows showing a sizable welfare gain of a coordinated single-offer system (i.e., centralized assignment) relative to an status-quo uncoordinated assignment system. Our paper is closely related to Abdulkadiroğlu et al. (2015) in that we also report sizable gains from the expansion of the centralized assignment. However, our paper is substantially different from it because our focus is on explaining the mechanism explaining the voluntary adoption and expansion of the centralized admission, in the context of Chile, and also highlights the heterogeneous impact based on students' family background that could affect the extent to which they could get around the market inefficiency.

The market design studies examining the phenomenon of *unraveling* is another literature this paper contributes to.

Besides these two strands of market design literature, our paper is related to a growing number of applied microeconomics studies using the Chilean college admission setting. Examples include Beyer et al. (2015); Bordon and Fu (2015); Hastings et al. (2013a); Espinoza and Urzúa (2015); Lafortune et al. (2016); Kaufmann et al. (2013); Rau et al. (2013); Rodríguez et al. (2016); Turner (2014); Rios et al. (2014). Most of these studies exploit the Chilean coordinated assignment setting to construct counterfactuals of student outcomes by comparing those whose test scores were just above the cutoff point for admissions with those whose test scores were just below the cutoff. To the best of our knowledge, this paper is the first to examine both coordinated and uncoordinated assignment in the Chilean college admission setting and to empirically examine the impact of the 2012 expansion of the coordinated assignment on both college and students' outcomes.

3.3 Institutional Background

3.3.1 Universities

Chilean universities are classified into two groups: CRUCH *(Consejo de Rectores de las Universidades Chilenas)* and the rest (herein, non-CRUCH).[4] The CRUCH universities, a total of 25, have a long history and prestige in Chile similar

[4]In Chile, there are three types of institutions provide tertiary education: universities (*Universidades*), Professional Institutes (*PI, Institutos Profesionales*), and Technical Training Centers (*TTC, Centros de Formación Técnica*). We study student-college matching only for the case of universities because PIs and TTCs are designed for technical or vocational training, and they accept virtually all applicants regardless of their academic performance. Throughout this document, we use "university" to refer only to *Universidades*, not to PI or TTC.

to Ivy League colleges in the US. They coordinate student selection, which will be described in detail in Section 3.3.2. In contrast, non-CRUCH universities, a total of 34 as of 2013, are relatively new, mostly established in between 1988 and 1990. This difference in the year of establishment is due to the fact that the Chilean government had strictly restricted the establishment of new universities but relaxed the restriction in 1988.[5]

3.3.2 College Admission System: General

Each academic year, universities publicly announce the number of vacancies for every major program they offer and how they evaluate applicants. The Chilean universities in our study evaluate students based almost entirely on a student's academic performance on a nationwide test called the *Prueba de Selección Universitaria* (PSU), which is typically conducted at the beginning of December. The PSU consists of 4 subjects: math, language, science, and social sciences, and the weight that

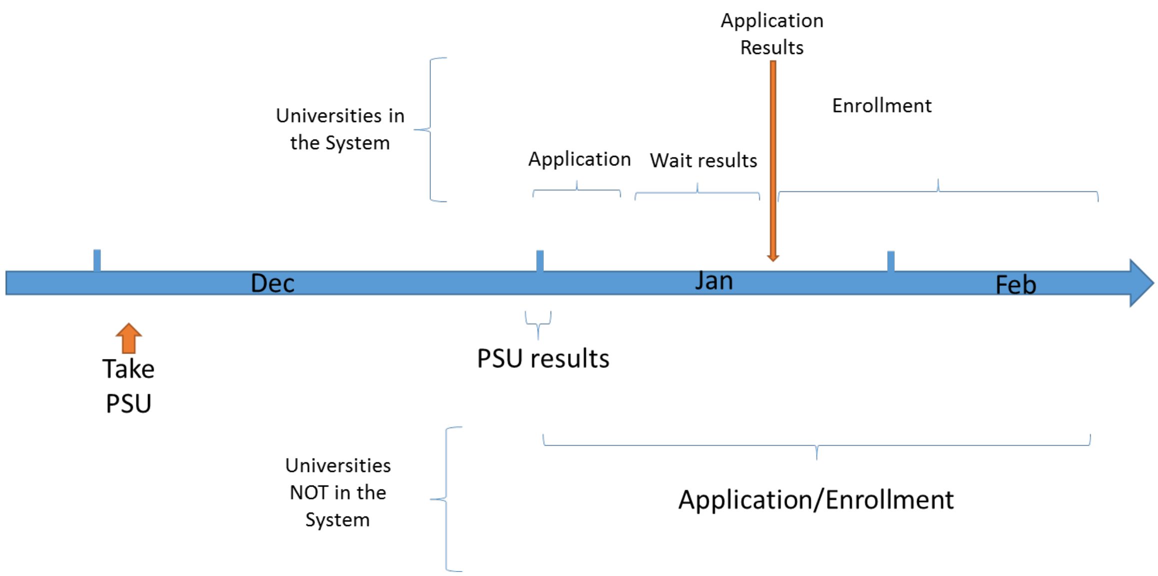
[5]Prior to 1981, the Chilean government strictly restricted the establishment of universities. Although the legal change in 1981 relaxed this restriction, establishing a university was still difficult until 1988. This is because the Chilean government had substantial discretion regarding whom it would allow to establish a university. For this reason, only 5 universities were established between 1981 and 1987. However, from 1988, the Chilean government allowed an entity to establish a university as long as it satisfied pre-determined requirements. This relaxation sparked new universities. For example, between 1988 and 1990, 35 universities were established. Some universities have been established or have closed since 1990. As of 2013, there were 34 non-CRUCH universities; all except one were established by 1990. The only non-CRUCH university was established in 2012, and we exclude it from our analysis.

each program puts on each subject varies program by program. The test score for each subject is standardized to have a mean of 500 and a standard deviation of 110. The PSU score is released in mid to late December and, with their PSU score, students apply to colleges.

The coalition of CRUCH universities accepts college applications by early January and announces the results within 2 or 3 weeks. The admission procedure is based on a centralized matching system as follows: until 2011, a student needed to submit his/her preference by ranking up to 8 options, that is, 8 unique combinations of university and college major; since 2012, it has been 10 options. Once the student's rank orders are collected, the board runs the student-proposed deferred and acceptance (DA) algorithm and notifies the student of the results approximately 2 to 3 weeks later.

In contrast, the admission process of the non-CRUCH universities is such that a student's chance of being admitted depends not only on his/her PSU score but also on when he/she applies. Specifically, a non-CRUCH university announces the number of vacancies and the minimum PSU score in each major it offers before the application process takes place. It starts to accept applications the day after the PSU score is released. To apply, except for a few universities, students and their representatives (e.g., parents, siblings) need to physically visit a university's admissions office. When a student meets with a college admissions officer, the officer informs the student whether he/she can get an admission for a particular major on the spot. If the student is not accepted for that major, he/she can apply for another major right away. Figure 3.1 shows a timeline of both application processes.

Figure 3.1: Timeline of the Admission Process



Note: This figure illustrates the timeline of college admission processes in Chile. The top panel illustrates the process of the universities that use the centralized matching system (namely, CRUCH until 2011 and CRUCH and 8 non-CRUCH universities from 2012). The bottom panel illustrates the admission process of the universities that joined the centralized matching system.

An applicant to such a college will be accepted as long as the following three conditions are satisfied. First, the applicant's PSU must be above the minimum score the university specified for the applicant's chosen major. Second, the number of accepted applicants for that specific major must be fewer than the number of vacancies in that program, as set by the university. Third, the applicant must show financial proof that he/she can afford tuition and must pay a deposit to secure a space, amounting to about 28% of the average household income in Chile as of 2013.[6] Because the second condition constitutes a type of first-come, first-served rule, it creates an incentive for applicants to enroll as soon as possible once the PSU scores are announced. The photos in Appendix A illustrate how chaotic the decentralized application process can be. Numerous individuals line up in front of a university the night before the day the university accepts applications (this is typically the same day that the PSU score is released), and they submit their applications in a first-come, first-served fashion.[7]

If the applicant decides not to enroll in the major, he/she must notify the university within 10 days of the date that the CRUCH admission results are publicly announced. Article 3 in the Consumer Protection Act, grants universities the right

[6] The amount of the deposit can vary not only by university but also by major. For example, the deposit for Medicine at *Universidad del Desarrollo* was 125% of the average household income in 2013.

[7] Typically, PSU scores are announced on a Sunday at midnight and students start enrolling in non-CRUCH universities at 6:00 or 7:00 am the following Monday in order to secure a slot. In the most highly demanded universities, the situation is chaotic. Crowds of people congregate at the admissions office at dawn and others spend the night waiting for the office to open.

to retain an amount equivalent to 1% of total annual tuition fees. The amount of the deposit varies across universities and majors but is generally 10% of total annual tuition fees. That is, if an applicant decides not to enroll, the university keeps roughly 10% of the deposit and reimburses the rest within 10 days from when the student notified the university of his/her decision.

3.3.3 College Admission System: The change in 2012

Prior to the 2012 college admission cycle, the centralized matching system was only for CRUCH universities because centralized matching was the result of voluntary coordination among the CRUCH universities. On April 29, 2011, the association of the CRUCH universities announced that they would invite all non-CRUCH universities to join the centralized matching system. The deadline for responding to the invitation was May 25, 2011. Eight non-CRUCH universities accepted the invitation and became a part of the centralized matching system starting with the 2012 college admission cycle.[8] The rest of the non-CRUCH universities remained outside the centralized matching system.

[8] *Universidad Adolfo Ibañez, Universidad de los Andes, Universidad del Desarrollo, Universidad Andrés Bello, Universidad Alberto Hurtado, Universidad Diego Portales, Universidad Finnis Terrae, Universidad Mayor.*

3.4 Theoretical Analysis

3.4.1 Setting

We consider an environment in which there are two groups of colleges. The *centralized* colleges jointly admit students using the student-proposing Gale-Shapley algorithm from a common pool of applications. The *decentralized* colleges admit students independently. We assume that students face uncertainty in the application process. In particular, after submitting their preferences to the centralized group, students do not know if the assigned college in the centralized system will be better or worse than their best achievable option in the decentralized group. This uncertainty provides incentives for some students to apply to both groups. A student admitted to one college in each group can select his favorite one. This strategy, however, has two social costs. First, some students will not be admitted to a college that otherwise would admit them. Second, some colleges will be left with vacant seats. This section shows that these two effects can incentivize both groups of colleges to form a unique centralized admission system.

We model this environment with only two colleges, C_1 and C_2. In this model, C_1 represents the centralized group of colleges and C_2 represents the decentralized group. Although C_1 and C_2 are single colleges in the model, the student uncertainty model is used to ensure that C_1 represents a group of colleges using the student-proposing Gale-Shapley algorithm and C_2 represents a group of colleges running independent admission processes. We compare the outcomes of C_1 and C_2 running independent admission systems and a joint admission system. We study the conditions under which both C_1 and C_2 have incentives to use the student-proposing Gale-Shapley algorithm from a common pool of applications.

In the general situation, when the centralized and the decentralized colleges run their admission systems independently, students applying to the centralized group use their (weakly) dominant strategy and submit their true preferences. At the same time, they can use their expected assigned college to determine if it is profitable to apply to a specific college in the decentralized group. Before enrollment, the assignment in the centralized group is revealed and the student can choose between the assigned college in the centralized group and the chosen college in the decentralized group. When C_1 and C_2 are modeled as a single college, these features are introduced by assuming that students' preferences are drawn after applying but before enrolling.

In the case of a joint admission system that uses the student-proposing Gale-Shapley algorithm, students use their (weakly) dominant strategy and submit their true preferences for all colleges. When C_1 and C_2 are modeled as a single college, this feature is introduced by assuming that the students' preferences are drawn before applying.

There is a unit-mass continuum of students. Students take a national exam before the admission process and each student knows his score s before applying. Scores follow a continuously differentiable and strictly increasing cumulative distribution function F with density f with full support over the interval $[\underline{s}, \overline{s}]$, $F(s)$ is the mass of students with score less than or equal to s. We identify students by their score, so student s has a score of s. Student preferences are stochastic. Independent of test scores or other students' preferences, each student prefers college C_1 to $C2$ with probability $p \in [0, 1/2]$. For all students, their most preferred college provides a utility of u^1, strictly greater than the utility of their second choice u^2. That is, p portion of students have utilities u^1 for C_1 and u^2 for C_2, and the rest u^2 for C_1 and u^1 for C_2. Being unassigned has a value of zero.

Colleges admit the best ranked students who applied, up to their quota. Thus, students with sufficiently high test cores can enroll in their most preferred colleges with certainty. Without loss of generality, we omit such students from our analysis and define a quota in each college as the remaining number of seats after netting out those students. We assume that C_i can enroll up to q_i students and the sum of the two is less than the student mess (i.e., $q_1 + q_2 < 1$). Thus, there is always a mass of students who cannot get enrolled in any college. Applying to C_1 is free and accessible to everyone, but applying to C_2 has an application cost of k and not everyone can apply due to the cost. The proportion of students who can cover this cost, the "wealthy students", is n. Since applying to C_1 has no cost, we assume that every student applies to C_1. Colleges value the quality and quantity of the students they admit. In particular, colleges derive utility of $u(E) = \int_E xf(x)dx$ from enrolling the set of students E.

Colleges C_1 and C_2 decide simultaneously whether or not to form a centralized admission system that uses the student-proposing Gale-Shapley algorithm. The cost of organizing the centralized admission system is $M \geq 0$ for each college.

In our setting, the Gale-Shapley algorithm generates student optimal matching

- that is, based on their test scores, students choose their most favorite college among those with available seats. Let s_i be the admission cutoff score for college C_i. Based on the Chilean setting, we focus on equilibrium outcomes satisfying $s_2 \geq s_1$. This order obtains if the proportion of wealthy students is sufficiently big relative to the ratio of college quotas. Hence we assume that there are enough wealthy students i.e., $\frac{q_2}{q_1} \leq n$.

An enrollment outcome is a triple of pair-wise disjoint sets $E = (E_0, E_1, E_2)$, where E_i for $i = 1, 2$ is the set of students enrolled at college C_i and E_0 is the set of students who were not admitted to any college. The enrollment of student s is denoted by $E_s \in \{\emptyset, C_1, C_2\}$. The enrollment outcome (E_0, E_1, E_2) is efficient if there is no enrollment outcome E' such that $u_s(E_s) \leq u_s(E_s^{'})$ for all s and $u(E_i) \leq u(E_i')$ for $i = 1, 2$ with strict inequality for at least one college or a positive mass of students.

3.4.2 Market Structure

3.4.2.1 Descentralized enrollment outcomes

This section analyses enrollment outcomes when C_1 and C_2 run independent admission systems. Let $s_2 \geq s_1$ be the cutoff scores of each college. Given these cutoff scores, students decide to apply to colleges. Application decisions are as follows. All students with score $s \geq s_1$ apply to college C_1. Applying to both C_1 and C_2 gives students the possibility of choosing their most preferred colleges among those that admitted them, but has a cost of k. A student with score $s \geq s_2$ applies to both C_1 and C_2 if $u^1 \geq u_p + k$, where $u_p = u^1 p + (1-p)u^2$. It is assumed that k satisfies the inequality. Applying only to C_2 is dominated by applying to both. A student who gets admitted to both C_1 and C_2 gets a utility of $u^1 - k$; a student who gets admitted only to C_1 gets an expected utility of u_p.

The equilibrium cutoff scores s_1^D, s_2^D are defined by the following two equations:

$$1 - F(s_1^D) = q_1 \tag{3.1}$$

$$n(1 - F(s_2^D)) = q_2 \tag{3.2}$$

Preference uncertainty is resolved after applying but before enrollment. Students who got admitted to more than one college have the option to enroll in their most preferred college, leaving a seat vacant at the least preferred college. Total enrollment in C_1 is given by three groups of students: i) the students who could have been admitted to C_2 but did not have the resources to apply, ii) those who applied and were admitted to both C_1 and C_2 but preferred C_1, and iii) those who got admitted only to C_1. Enrollment in C_2 is given by the students who have the resources, applied, got admitted to C_2, and prefer C_2 over C_1. We use E_i^D to denote the mass of students enrolled in college i when they use a decentralized admission system. Enrollment masses are as follows:

$$E_1^D = (1-n)(1 - F(s_2^D)) + np(1 - F(s_2^D)) + F(s_2^D) - F(s_1^D) \tag{3.3}$$

$$E_2^D = n(1-p)(1 - F(s_2^D)) \tag{3.4}$$

The basic consequences of the decentralized admission system on enrollment are summarized in the following proposition.

Proposition 1. *In the decentralized admission system, total enrollment is q_1 and there are q_2 students that would like to be enrolled in either college and that would be admitted, but did not get a seat in the admission process.*

Proof. Direct addition of equations (3) and (4) reveal that total enrollment is equal to q_1. Since being unassigned has a value of zero, every student would like to being admitted to a college. At the moment of enrollment, college C_1 finds out that $(1-p)q_2$ admitted students did not enroll. Similarly, C_2 discovers that pq_2 admitted students did not enroll. Hence, there are q_2 students that would be admitted after enrollment decisions have been made. □

We call "inefficient assignments" those admissions given to students that later do not enroll, $(1-p)q_2$ for C_1 and pq_2 for C_2. Colleges' and students' (ex-post) welfare follow directly from the enrollment equations. We measure colleges' utility by the number of admitted students, weighted by their score. This metric takes into account both the quantity and quality of enrolled students. Students' welfare is measure by the utility they obtain from enrolling in a particular college. u_1^D, u_2^D represent C_1 and C_2 payoffs, respectively. u_n^D, u_{1-n}^D represent aggregate students welfare for the wealthy and non-wealthy students, respectively.

$$u_1^D = (1-n+np)\int_{s_2^D}^{1} xf(x)dx + \int_{s_1^D}^{s_2^D} xf(x)dx \tag{3.5}$$

$$u_2^D = n(1-p)\int_{s_2^D}^{1} xf(x)dx \tag{3.6}$$

$$u_n^D = n(1-F(s_2^D))u^1 + n(F(s_2^D)-F(s_1^D))u_p \tag{3.7}$$

$$u_{1-n}^D = (1-n)(1-F(s_2^D))u_p + (1-n)(F(s_2^D)-F(s_1^D))u_p \tag{3.8}$$

3.4.2.2 Centralized enrollment outcomes

This section analyses the outcomes of a centralized admission system, the student-proposing Gale-Shapley algorithm. Let $s_2 \geq s_1$ be the cutoff scores of each college. Applying to the centralized system is denoted as applying to C and has no cost. In the centralized admission process, students can send their college preferences and apply to both C_1 and C_2 in order of preference. In this section, it is assumed that the preference uncertainty is resolved before applying; thus, the preferences list reflects true ex-post preferences. Application behavior is as follows.

All students with score $s \geq s_1$ apply to college C by sending their preference ranking over C_1 and C_2. In the centralized system, admission and enrollment coincide; thus the mass of students enrolled in each college and the cutoff scores are defined by the same equations. The equilibrium cutoff scores s_1^C, s_2^C and enrollment masses E_1^C, E_2^C are defined by:

$$E_1^C = p(1-F(s_2^C)) + F(s_2^C) - F(s_1^C) = q_1 \tag{3.9}$$

$$E_2^C = (1-p)(1-F(s_2^C)) = q_2 \tag{3.10}$$

The left hand side of these equations describes enrollment. Total enrollment in C_1 is given by the students who i) could have been admitted to C_2 but preferred C_1 and ii) those who got admitted only to C_1. Enrollment in C_2 is given by the students who got admitted to C_2. The allocation of students to colleges is efficient. Colleges' and students' aggregated payoffs are as follows:

$$u_1^C = p\int_{s_2^C}^{1} xf(x)dx + \int_{s_1^C}^{s_2^C} xf(x)dx \tag{3.11}$$

$$u_2^C = (1-p)\int_{s_2^C}^{1} xf(x)dx \tag{3.12}$$

$$u_n^C = n(1-F(s_2^C))u^1 + n(F(s_2^C) - F(s_1^C))u_p \tag{3.13}$$

$$u_{1-n}^C = (1-n)(1-F(s_2^C))u^1 + (1-n)(F(s_2^C) - F(s_1^C))u_p \tag{3.14}$$

Proposition 2. *The centralized admission system produces an efficient enrollment outcome.*

Proof. Let E be the outcome of the centralized admission system and suppose E' is another enrollment outcome that Pareto dominates E. Hence there is a mass of students that have a different enrollment in E than in E'. Consider this to be the case for $E_1' \setminus E_1$; other cases are analogous. This group of students strictly prefer C_1

over their assignment in E. Hence they were rejected by C_1 during the admission process. It follows that all of these students have strictly lower scores than students $E_1' \setminus E_1$. In addition, $E_1' \setminus E_1$ mass is at most the mass of $E_1' \setminus E_1$. □

3.4.3 Equilibrium analysis

The existence of efficiency gains with the adoption of a centralized admission system seems to suggest that colleges, in general, will have a natural tendency to be centralized. However, this is not the case. In fact, just the opposite is true. A lot of admission systems are run independently and sometimes centralization occurs after there is intervention by a policy maker. In this section we study when colleges have incentives to join a centralized admission system.

Motivated by the Chilean setting, we introduce the two additional assumptions into our equilibrium analysis. In Chile, there are CRUCH colleges that are very desirable for their quality; hence, there are wealthy students that prefer to apply to and enroll in those colleges. In this model, CRUCH colleges are represented by C_1. Thus we assume that C_1 is of "sufficient quality" to attract wealthy students, i.e., $1 - n \leq p$. Another feature of the Chilean setting that we include in our analysis is that the cutoff scores of Type 2 colleges decreased after they joined the centralized system, but not to the level of CRUCH cutoffs before centralization. Hence we assume that C_2 is also of "sufficient quality" i.e., $\frac{q_2}{q_1} \leq 1 - p$.

Proposition 3. *Cutoff scores are characterized as follows:*

- *Suppose there are enough wealthy students i.e., $\frac{q_2}{q_1} \leq n$, then $s_1^C \leq s_2^C$ and*

$s_1^D \leq s_2^D$.

- *Suppose there are enough wealthy students and C_1 is of sufficient quality i.e., $1 - n \leq p$, then $s_2^C \leq s_2^D$.*
- *Suppose there are enough wealthy students and C_2 is of sufficient quality i.e., $\frac{q_2}{q_1} \leq 1 - p$, then $s_1^D \leq s_2^C$.*

Proof. Direct comparison of equations (1), (2), (9) and (10). □

We analyze equilibrium behavior next. The two colleges play a simultaneous game: C_1 and C_2 have to decide whether or not to join a centralized admission system. The equilibrium of this game depends on p, the proportion of students that prefer C_1. When p is large (close to 1/2), it is common knowledge that students regard C_1 and C_2 as having the same quality (we assume that preferences are derived from quality) since half of the population prefers one to the other. In this case, inefficient assignments are equally distributed and efficiency gains equally captured; hence, both C_1 and C_2 have an incentive to join a centralized admission system. When p is small (close to 0), C_2 suffers little inefficiency (the inefficiencies suffered by C_1 are the greatest), and joining a centralized matching does not allows C_2 to capture any efficiency gain; hence, C_2 would not join the centralized system.

When C_1 has decided to join, C_2 faces incentives characterized by the following function:

$$J_2(n,p) = (1-p)(1-n)\int_{s_2^D}^{1} xf(x)dx + (1-p)\int_{s_2^C}^{s_2^D} xf(x)dx \tag{3.15}$$

$J_2(n,p)$ is the difference in payoff between joining the centralized admission system and remaining decentralized for college C_2. When college C_2 joins the centralized system with college C_1, it gains access to high-scoring students who would be enrolled in college C_1 if the system were decentralized. In addition, the efficient centralized system would avoid the admission of students who would not enroll later on, expanding the possibility of admitting students with scores below the decentralized cutoff score.

Proposition 4. *Suppose there are enough wealthy students and the cost of organizing the centralized market is low i.e.,* $M \leq J_2(n,p)$ *and* $M \leq \int_{s_1^C}^{s_1^D} x f(x) dx - J_2(n,p) = J_1(n,p)$*; then, it is a Nash equilibrium (NE) for* C_1 *and* C_2 *to join a centralized admission system.*

Proof. Follows directly from the definition of $J_2(n,p)$ and $J_1(n,p)$. □

$J_1(n,p)$ identifies the incentives faced by college C_1. When C_1 and C_2 run a centralized admission system, C_1 can admit students who were previously rejected because of the admission of high-scoring students who eventually did not enroll. However, C_1 loses its exclusivity with high-scoring-low-income students who can only apply to it. In addition, C_1 loses students who would be rejected by C_2 in the decentralized system but are admitted in the centralized system due to the more efficient process. We begin our equilibrium analysis with the symmetric case: C_1 and C_2 are identical in all respects with the exception of p. In all cases, the cost of organizing the centralized system needs to be below certain threshold i.e., a high cost of organizing the market could prevent the centralization even if, absent the cost, both colleges would like to join the centralized admission system. In this case, the threshold is half the total college utility to be gained i.e., $\frac{1}{2}\int_{1-2q}^{1-q} F^{-1}(t)dt$.

Proposition 5. *Suppose both colleges C_1 and C_2 are identical in all respects but their probability of being preferred, i.e., every student can afford both types of colleges $n = 1$ and both have the same quotas $q_1 = q_2 = q$. Suppose the cost of organizing a centralized admission system is less than $\frac{1}{2}\int_{1-2q}^{1-q} F^{-1}(t)dt$. Then there are two types of equilibria:*

- *If $M < \min\{J_1(1,p) : p \in [0, \frac{1}{2}]\}$, then there is p^* such that for all $p \in [p^*, \frac{1}{2}]$ C_1 and C_2 organizing a centralized admission system is a Nash equilibrium (type 1).*
- *If $M \geq \min\{J_1(1,p) : p \in [0, \frac{1}{2}]\}$, then there are p^1, p^2 and p^3 such that for all $p \in [p^1, p^2] \cup [p^3, \frac{1}{2}]$ C_1 and C_2 organizing a centralized admission system is a Nash equilibrium (type 2).*

Proof. The first and second derivatives of J_2 with respect to p are as follows, respectively: $\frac{\partial J_2(1,p)}{\partial p} = F^{-1}(1-\frac{q}{1-p})\frac{q}{1-p} - \int_{1-\frac{q}{1-p}}^{1-q} F^{-1}(t)dt$ and $\frac{\partial^2 J_2(1,p)}{\partial p^2} = \frac{-q}{(1-p)^3 f(F^{-1}(1-\frac{q}{1-p}))} < 0$. Direct evaluation reveals that $J_2(1,\frac{1}{2}) = \frac{J_1(1,0)}{2}$ and $\frac{\partial J_2(1,0)}{\partial p} > 0$. If $M < \min\{J_1(1,p) : p \in [0,\frac{1}{2}]\}$, then C_1 would like to join a centralized admission system with C_2 for all p. If $\frac{\partial J_2(1,\frac{1}{2})}{\partial p} \geq 0$; then $J_2(1,p)$ is a continuous and strictly increasing function in the interval $[0,\frac{1}{2}]$; thus, there is p^* such that $M = J_2(1,p^*)$ and $J_2(1,p) \geq M$ for all $p \geq p^*$. If $\frac{\partial J_2(1,\frac{1}{2})}{\partial p} < 0$, then there is $p^{**} \in (0,\frac{1}{2})$ such that $\frac{\partial J_2(1,p^{**})}{\partial p} = 0$. $J_2(1,p)$ is a strictly increasing function in the interval $[0,p^{**}]$;

thus, there is p^1 such that $M = J_2(1, p^1)$ and $J_2(1, p) \geq M$ for all $p \geq p^1$. If $M \geq \min\{J_1(1, p) : p \in [0, \frac{1}{2}]\}$, then necessarily $J_1(1, p)$ is a strictly decreasing function in the interval $[0, p^{**}]$ and strictly increasing in the interval $[p^{**}, \frac{1}{2}]$; thus, there are p^2 and p^3 such that $M = J_1(1, p^2) = J_1(1, p^3)$ such that $J_1(1, p) \geq M$ for all $p \leq p^2$ and for all $p \geq p^3$. $\square$

Both equilibria confirm the basic intuition. When colleges are of equal quality, half the population likes one better than the other; then inefficient matches are evenly distributed in the decentralized system, and the efficiency gains created by the adoption of a centralized admission system are equally captured. Equilibrium type 1 confirms the converse intuition: when p is small, then C_1 would benefit a lot from running a centralized admission system; C_2, however, gains little since it suffers little inefficiency as most admitted students actually enroll. Equilibrium type 2 also confirms the basic intuition: when p is close to $1/2$ but it also displays centralization for an interior region. In this region, C_1 faces similar incentives as in equilibrium type 1, but now C_2 also benefits from joining because the students who are enrolled in the centralized admission system have a high score.

When not all students are wealthy, $n < 1$, a new kind of equilibrium arises. If the cost of centralization is low enough, equilibrium type 1 prevails. However, if the cost of running a centralized system is high, then C_1 might find it in its best interest not to invite C_2 to join because that would imply losing good students who are accessible only to C_1.

Proposition 6. *Suppose that there are enough wealthy students, $n < 1$, $M <$*

$\frac{1}{2}\int_{1-q_1-q_2}^{1-q_1} F^{-1}(t)dt$ and $n > n$' such that $\int_{1-q_1-q_2}^{1-q_1} F^{-1}(t)dt = 2[\int_{1-q_2}^{1} F^{-1}(t)dt - n' \int_{1-\frac{q_2}{n'}}^{1} F^{-1}(t)dt]$; then the equilibria are as follows:

- *If $M < \min\{J_1(1,p) : p \in [0, \frac{1}{2}]\}$, then there is p^* such that for all $p \in [p^*, \frac{1}{2}]$ C_1 and C_2 organizing a centralized admission system is a Nash equilibrium (type 1).*

- If $J_1(1, \frac{1}{2}) \geq M \geq \min\{J_1(1,p) : p \in [0, \frac{1}{2}]\}$, then there are p^1, p^2, p^3 such that for all $p \in [p^1, p^2] \cup [p^3, \frac{1}{2}]$ C_1 and C_2 organizing a centralized admission system is a Nash equilibrium (type 2).

- *If $M \geq J_1(1, \frac{1}{2})$, then there are p^4, p^5 such that for all $p \in [p^4, p^5]$ C_1 and C_2 organizing a centralized admission system is a Nash equilibrium (type 3).*

Proof. The assumption about n guarantees that $J_2(n, 0) < \frac{1}{2}\int_{1-q_1-q_2}^{1-q_1} F^{-1}(t)dt < J_1(n, 0)$. Direct computation shows that $J_1(n, \frac{1}{2}) < \frac{1}{2}\int_{1-q_1-q_2}^{1-q_1} F^{-1}(t)dt < J_2(n, \frac{1}{2})$. Since J_2 is a concave function (derivative given in proposition 4), there is $p^* \in (0, 1/2]$ such that J_2 is a continuous and strictly increasing function. Thus, there is $p^{**} \in (0, p^*)$ such that $J_2(n, p^{**}) = J_1(n, p^{**})$. *If* $M < \min\{J_1(1,p) : p \in [0, \frac{1}{2}]\}$, then there is p^* such that for all $p \in [p^*, \frac{1}{2}]$ both $J_2(n,p) \geq M$ and $I(n,p) \geq M$. *If* $J_1(1, \frac{1}{2}) \geq M \geq \min\{J_1(1,p) : p \in [0, \frac{1}{2}]\}$, then there are p^1, p^2 and p^3 defined by $M = J_2(n, p^1) = J_1(n, p^2) = I(n, p^3)$ such that $p^1 < p^2 < p^* < p^3$. If $M \geq J_1(n, 1/2)$, then there are p^4, p^5 such that for all $p \in [p^4, p^5]$ such that $M = J_2(n, p^4) = J_1(n, p^5)$ and $p^1 < p^2 < p^*$. □

We next analyze matches between students and colleges. High-income students will be denoted as H students and low-income students as L students. Based on their test scores, we classify students into 4 groups. Group 1 consists of students whose test score is higher than the cutoff of type 2 colleges before type 2 colleges joined the centralized system (i.e., s_2^D). Group 2 consists of students whose test score is between s_2^C and s_2^D. Group 3 consists of students whose test score is between s_1^D and s_2^C. Group 4 includes students whose test score is between s_1^C and s_1^D. We denote by I_g, students in income group $I \in H, L$ belonging to test score group $g \in 1, 2, 3, 4$. The centralization of the college admission affects each group as follows:

- H1 – There is no change in matching quality for these students. Before type 2 joined the centralized system, these students were able to enroll in their most favorite college by using multiple applications. In the centralized system, their score is all they need to get into their most favorite college.

- L1 – These students are matched to better colleges after type 2 colleges join the centralized system. Only the fraction for whom a type 2 college is better obtains this benefit. Their benefit comes directly from the lower application costs.

- H2 – These students are matched to better colleges after type 2 colleges join the centralized system. Only the fraction for whom a type 2 college is better obtains this benefit. These students benefit from the more efficient centralized system.

- L2 - These students are matched to better colleges after type 2 colleges join the centralized system. Only the fraction for whom a type 2 college is better obtains this benefit. These students benefit from the more efficient centralized system.

- H3 - There is no change in matching quality for these students. Their score is not high enough to be admitted to type 2 colleges; hence, there are matches to CRUCH colleges in both systems.

- L3 - There is no change in matching quality for these students. Their score is not high enough to be admitted to type 2 colleges; hence, there are matches to CRUCH colleges in both systems.

- H4 – These students get into a better college under the centralized system. Before centralization, these students were admitted by type 3 colleges and by CRUCH colleges after the change.

- L4 – These students also get into a better college after the change, but the increase is bigger than for H4 students, since they go from no-college to CRUCH colleges.

3.4 Application to the Chilean Setting and Testable Implications

We analyze the equilibrium characterization in the context of the Chilean setting. First, we consider what may account for the fact that CRUCH universities formed a centralized admission system in the first place. In our model, p, the share of students who prefer college 1 the most, is sufficiently close to $1/2$; then C_1 will invite the rest of schools and may form a coalition. In the context of real college admission, we can view this condition as the one under which college quality is sufficiently homogeneous across CRUCH universities. We will examine this condition by comparing college quality in 1967, when the centralized admission system was established. Second, we consider what may account for the fact that the CRUCH invited the rest of the universities in 2012, more than a decade after the non-CRUCH universities were established. In the context of the model, we can consider C_1 as CRUCH as a whole, C_2 as the 8 non-CRUCH that joined the coordination, and the rest of the non-CRUCH as outside options that are dominated by C_1 and C_2. When enough students prefer CRUCH universities to other universities (i.e., sufficiently high p), there is little incentive to invite them since there are only a small mass of students who would have been admitted to CRUCH but were not. If the 8 non-CRUCH colleges increased in quality over time, students started to prefer those over CRUCH colleges, implying p's decrease. Therefore, eventually p reached a level at which joining a centralized admission system was the best for both types of colleges. With data, we will examine the extent to which college qualities are comparable between CRUCH and non-CRUCH. The data will show that on average both CRUCH and the 8 non-CRUCH should be better off after the 2012 change. Third, all else being equal, the 2012 change will improve student welfare, much more so for the students of low socioeconomic status. In our model, the centralized admission improves efficiency relative to the decentralized admission because it eliminates offers that are not accepted by applicants and thus are not filled. This prediction implies, in the Chilean context, that on average applicants can get admission to a more prestigious option (i.e., a specific combination of college and major) due to the 2012 change. In our model, this positive effect on applicants is larger for those who could not afford application costs of C_2 because under the centralized admission, they can no longer pay application costs. Relatedly, removing the application costs will increase the enrollment of those students in C_2.

3.5 Data, Sample, and Empirical Strategy

In testing our model predictions, we use both qualitative and quantitative analyses depending on data availability. Specifically, examining Prediction 1 requires historical information from the 1960s, and we rely on existing studies for this analysis because there is no data source we can access. In contrast, the rest of the predictions require recent information, which we can directly test using the data below.

3.5.1 Data Source

We compile our sample for the 2007-2013 college admission cycles, based on administrative datasets from three different sources: CNED (*Consejo Nacional de Educacion*), SIES (*Servicio de Información de Educación Superior*), and DEMRE (*Departamento de Evaluación, Medición y Registro Educacional*).[9] The CNED provides major level information such as number of faculty members, amenities a college offers, tuition, and expected duration of study. The SIES provides university

[9] The SIES is compiled by the Chilean Ministry of Education. The DEMRE is an administrative body within the *Universidad de Chile* that develops and administers the PSU and runs the centralized matching system. CNED is an independent and autonomous public organization that licenses new universities and provides assistance to the Ministry of Education when implementing new educational policies.

enrollees' information. Specifically, we obtain information on students who were freshmen at a university between 2007 and 2013. For each college enrollee, we observe his/her PSU score, major and university, high school GPA, age, residential location, and type of high school (private, private with voucher, or public).[10] Finally, the DEMRE provides information on the students' application behaviors in terms of the universities participating in the centralized matching. This information includes each applicant's PSU score, socio-economic characteristics, and, more importantly, the rank order of options.

3.5.2 Sample and Outcome Variables

We construct a dataset covering 55 universities, 25 CRUCH and 30 non-CRUCH, and all students who enrolled at one of the universities between 2007 and 2013. The 4 non-CRUCH universities operating as of 2013 are omitted from our data.[11] The reason is that one non-CRUCH was established in 2012 and thus lacks information prior to the admission system change. As for the remaining 3 non-CRUCH universities, one of which joined the centralized matching, the SIES does not include the information on their enrollees.

Our outcomes of interest are quality of enrollees, for university-level analyses,

[10]School types are highly correlated with students' socioeconomic background. Wealthier students typically attend private schools without vouchers, and poorer students typically attend public schools (see Elacqua and Santos, 2013)

[11]The three non-CRUCH universities that lack enrollee information are *Universidad Mayor* (which joined the centralized system), *Universidad Gabriela Mistral*, and *Universidad los Leones*. The university established in 2012 is *Universidad la Araucana*.

and prestige of an option for which a student was able to enroll, for student-level analyses. For the former, we characterize an enrollee's quality as his/her PSU score, defined as the simple average between the scores in the math and language subjects. We use this measure do student quality for two reasons. First, since the math and language subjects are mandatory the simple average is a statistic that can be computed for all students. Second, since the weight that each program puts on each of the four subject varies program by program, students can easily be compared to each by looking at their math and language scores. Finally, this statistics is widely used for official purposes. For example, the government grants a subsidy, called AFI, to all institutions enrolling the top 27.500 PSU scores, and uses the average between math and language to rank students.

A college's utility is defined as the sum of enrollees'PSU scores. For the prestige of an option, we construct a relative ranking of an option across all available options as follows. Across the three-year period (2007 to 2009), we take the average of an option's minimum PSU scores (i.e., cutoffs) with which an applicant could get admission to the option in a given year. We then sort options in ascending order and use the percentile into which an option falls (among the distribution of the average cutoffs) as our measure of "prestige". In our sample, we have on average 1,467 unique options in a given academic year. The option whose prestige is 1 in our prestige index ranked the lowest, while the option whose prestige is 100 ranked the highest. We decide to use this statistic for student outcomes for two reasons. One reason is practicality. That is, if we knew applicants' preferences across options from CRUCH and non-CRUCH universities, we could construct an alternative statistic based on the preference ranking. However, we can infer students' preferences only from applications through centralized matching (CRUCH and some of non-CRUCH after the change). Therefore, for about 31.2% percent of options as of 2012 (i.e., share of type 3 options out of all options in 2012) we do not have relevant information, making it difficult to analyze student outcomes. In sum, the two are highly correlated, supporting the relevance of our prestige variable. The other reason concerns labor market opportunities. Although our measure of prestige does not incorporate an individual-specific preference over options, it may reflect average monetary returns from college education either because students on average apply more to the well-paying options, pushing the PSU scores of admitted students higher, and/or because, as the ranking is well correlated with the average cognitive skills of admitted students, students may use it as signaling device to get better labor market outcomes after college graduate.

Table 3.1 reports summary statistics for Chilean universities. In our sample period, 2010 to 2013, our dataset includes 25 CRUCH universities and 30 non-CRUCH universities (Panels A and B, respectively). In general, the two groups of universities are comparable in terms of the number of newly enrolled students and average PSU scores among enrollees. Although CRUCH universities on average impose smaller tuition fees and offer more majors than non-CRUCH, there exist sizable variations within each group, resulting from sufficient overlaps in distribution of each characteristic. However, we observe noticeable differences in terms of the share of students residing in metropolitan areas and the types of high schools enrollees graduated from. Specifically, on average, 42 percent of enrollees in CRUCH universities resided in the three most heavily populated regions (Metropolitan Region, V Region and VIII Region), which are where the three largest metropolitan areas are located: Santiago, Valparaíso-Viña del Mar and Concepción, respectively. This is roughly 30 percentage points lower compared to average non-CRUCH universities. This difference may be driven by two factors: one is that the most non-CRUCH universities are located in the metropolitan areas. The other is that to apply to a non-CRUCH university, an applicant has to be physically present at the university, implying that students residing in the metropolitan areas may find it easier to apply to one compared to their counterparts who have to travel.

Regarding high schools, we classify high schools into three groups – private, voucher, and public. The share of enrollees who graduated from a private high school is much higher in non-CRUCH universities compared to CRUCH universities. It is important to highlight that the type of high school a student attends is well correlated with his/her parental background and also that school quality may substantially vary across types.[12]

[12]Our empirical analysis uses the ownership of each high school as a proxy for the socio-economic status of their students. High schools can be private with no subsidies (high socioeconomic status (SES)), private with voucher (Medium SES) and public (low SES). This SES measure has been largely used in the Chilean context to characterize SES. To show the relevance of our approach to the Chilean context, we obtain the additional data from the Ministry of Education of Chile (MOE). For each high school, the MOE collects the following student information: mother's years of schooling, father 's years of schooling, family income and student vulnerability. A student is classified as vulnerable if she lives in extreme poverty according to the government's standard. Following Agencia de Calidad de Educación (2012), each variable is averaged at the school level and then schools are clustered into the five SES categories : High, Medium High, Medium, Medium-

Table 3.1: Universities: Summary Statistics (2010-2013)

	Average (1)	S.D. (2)	Min (3)	Max (4)
Panel A. CRUCH				
Tuition	4,205.93	899.56	2586.66	7027.8
Number of majors offered	33.38	12.06	14	67
No of newly enrolled students	2,208.36	1400.52	448	6404
Average PSU among enrollees	583.5	43.88	517.53	697.11
Sum of enrollee's PSUs	1,256.89	882.01	208.42	3826.13
Student composition				
- (%)age over 20	24.49%	6.66%	10.08%	41.80%
- from 3 metropolitan areas	41.96%	38.19%	2.56%	90.81%
- from private schools	11.26%	13.28%	0.52%	62.58%
- from voucher schools	54.29%	10.26%	22.00%	73.53%
Panel B. Non-CRUCH				
Tuition	6,656.17	1067.75	4550.33	8203.91
Number of majors offered	26.04	15.4	5	63
No of newly enrolled students	2,779.46	2620.42	776	9665
Average PSU among enrollees	609.08	32.53	556.14	659.24
Sum of enrollee's PSUs	1,485.93	1273.86	382.16	4843.41
Student composition				
- (%) age over 20	41.52%	18.02%	10.32%	92.38%
- from 3 metropolitan areas	70.11%	18.41%	20.15%	91.21%
- from private schools	19.57%	23.99%	0.00%	85.51%
- from voucher schools	49.53%	17.54%	6.62%	78.57%

Note: The unit of observation is university by year (2010 to 2013), total of 220. The sample include all 25 CRUCH universities and 30 non-CRUCH universities. Unweighted averages are reported. Tuition is reported in 2009 USD. The 3 metropolitan areas are XIII (Metropolitan), VIII Region (Concepción), and V Region (Valparaíso-Viña del Mar). "Students from private schools" and "Students from subsidized schools" refer to the share of enrollees who graduated from a private high school without any government subsidy, and from a voucher school, that is, a private school whose tuition is subsidized by the Chilean government. The omitted category is a public high school.

Table 3.2: High School Types and SES

High School Types	SES Categories by MOE				
	Low	Medium-Low	Medium	Medium-High	High
Public	79.30%	53.10%	29.10%	10.80%	0.00%
Voucher	20.70%	46.90%	70.90%	84.80%	7.10%
Private	0.00%	0.00%	0.10%	4.50%	92.90%

Private high schools are the most expensive, followed by voucher schools (similar to charter schools in the US), and then public high schools. Naturally, parents who send their children to private schools are mostly well off compared to those who send their children to voucher or public schools (see Gallego and Hernando, 2009; Bravo et al., 2010; Elacqua, 2012). Table 3.3 reports summary statistics of college enrollees between 2010 and 2013. Panel A reports the average characteristics of college enrollees depending on the types of high schools they graduated from (columns 1 to 3). Our dataset includes over 0.4 million enrollees. Twenty percent of the enrollees graduated from private high schools, and voucher high school graduates account for 54 percent. To get a sense of the selection into college, we report the ratio of college enrollees over the total number of high school seniors in a given type of high schools. Note that the ratio may exceed 100 percent because high

Low, and Low. Therefore, a high school's category does not depend directly on the high school ownership type, but rather on the characteristics of its students. Table 3.2 shows the distribution of high school types given an SES category using the 2012 MOE data. For example, among the lowest SES high schools, public high schools account for 79%, while the remaining 21% are voucher high schools. The table shows that on average students from private high schools come from higher SES families while students from public high schools have on average the lowest SES.

school graduates may take some time off before applying to college. The reported ratio in the second row shows that the share of high school graduates enrolling in a university is much larger at private high schools, followed by voucher schools and then public high schools. We use both raw PSU scores and standardized scores, i.e., standardized PSU scores among new enrollees in each year. There is a noticeable difference in average test scores of enrollees between private high schools and the rest. However, the variation within a type is so large that the distributions of enrollees' scores overlap. Panel B reports the average characteristics of the options enrollees signed up for in the period 2010-2013. Students from private high schools enrolled in relatively better-ranked programs (higher prestige) and were much more likely to enroll a non-CRUCH college. On the other hand, students coming from voucher and public schools were substantially less likely to enroll a college that joined the centralized system in 2012.

3.5.3 Empirical Strategy

We use two strategies to examine model predictions. One is based on simple statistics comparing the outcomes before and after the 2011 admission system change. Specifically, we split our data into two periods: 2010-2011 and 2012-2013. The period between 2012 and 2013 is under the new college admission regime, in which the 8 non-CRUCH universities joined the centralized matching (i.e., post-period). We select the same number of years right before the change, i.e., 2010 and 2011, to study the decisions and outcomes of universities and students under the

Table 3.3: College Enrollees: Summary Statistics (2010-2013)

	High School Type		
	Private	Voucher	Public
	(1)	(2)	(3)
Panel A. Enrollees characteristics			
Number of enrollees	84,091	240,139	117,656
(% of high school seniors)	119.82%	71.00%	35.62%
PSU scores			
- Raw	633.71	560.02	553.53
(std.)	(79.66)	(73.62)	(79.09)
- Standardized	0.76	-0.14	-0.22
(std.)	(0.97)	(0.90)	(0.96)
% in metropolitan areas (MA)	78.80%	63.96%	54.49%
Panel B. Enrollment outcomes			
Prestige: mean	75.2	52.56	50.92
(std.)	(25.41)	(29.15)	(29.63)
University type (%)			
- CRUCH	44.71%	47.69%	52.76%
- NC: join	40.82%	13.10%	7.93%
- NC: not join	14.47%	39.20%	39.31%
Location of university: college in MA (%)	99.09%	97.78%	97.15%
- students from the MA	66.26%	28.22%	22.65%
- students outside of the MA	75.2	52.56	50.92

Source: Authors calculations using data from SIES. Note: Unit of observations is student who enrolled in a university between 2010 and 2013. Metropolitan areas include students and universities located in regions V, VIII and XIII. “NC: join” includes 7 (out of 8) non-CRUCH colleges that eventually join the coordinated assignment in 2012, while “NC: not join” includes the rest of the non-CRUCH colleges (n=23).

old admission system (i.e., pre-period). Comparing the pre and post-periods can help us understand the impact of the change in the college admission system on students and universities. In our analysis, we present two sets of results – one based on summary statistics and the other based on regression analysis. Although the results are consistent across the two sets, the former is straightforward, informing us about the overall trends, while the latter can control for various differences in characteristics among universities and college applicants.

We acknowledge that our empirical strategies do not guarantee causal inference of the policy impacts. That is, factors other than the 2012 policy change may account for some of the differences between the pre and post-period. We employ two methods to examine the severity of this concern. The first is to show that there is no time trend before the 2012 change. For this purpose, we use the rest of sample period (i.e., 2007 to 2009) and show that between the 2007-2009 and 2010 and 2011 periods, there is no systematic change in outcomes (conditional on some controls). The second method is to document that there is no other policy change that may account for our findings.

3.6 Empirical Findings

3.6.1 CRUCH's incentives for adoption and expansion of the centralized admission

First, we examine what motivated CRUCH to form a centralized admission system in the first place. At the time CRUCH universities decided to institute centralized matching, they were highly concentrated. Specifically, in 1967, there were only 8 CRUCH universities that later were split into 25 universities.[13] Among these 8 universities, 2 public universities comprised 60 percent of the student enrollees; the remaining 6 universities, which were private, were controlled by the Catholic Church in Chile.[14] The higher education sector was relatively small and mostly elites had access to it. There was a high degree of homogeneity in terms of student socio-economic and cultural background, and overall universities were comparable to one another in most respects (see Bernasconi and Rojas, 2003). Therefore, it is reasonable to assume two groups of universities, comparable to each other in terms of student share, to compete against each other.

Next, we consider the CRUCH's incentives and the timing of inviting non-CRUCH to join the centralized admission system. As most non-CRUCH universities were established by 1990, the CRUCH universities could have invited them to join their centralized matching much earlier. However, they did not do so until 2012. In our theoretical framework, we show that the net benefit of inviting non-CRUCH increases if the non-CRUCH play a bigger role when CRUCH compete for a similar student body against non-CRUCH. In this section, we present evidence

[13] The year 1967 coincides with the time when the Chilean government introduced a standardized college entrance test called "Prueba de Aptitud Académica (PAA)." The PAA is a predecessor of PSU: both were multiple choice exams.

[14] The two public universities are *Universidad de Chile and Universidad Técnica del Estado* The six private universities are *Pontifica Universidad Católica de Chile, Universidad Católica del Norte, Universidad Católica de Valparaíso Universidad Austral, Universidad Técnica Federico Santa María, Universidad de Concepción.*

supporting that this is indeed the case.[15] Figure 3.2 shows the market share of the non-CRUCH universities relative to the CRUCH. The solid line represents the average size of non-CRUCH universities measured by the number of enrollees, while the line market with triangles represents that of CRUCH universities. Overall, the number of enrollees has been increasing in both CRUCH and non-CRUCH universities because the college enrollment rate in Chile has been steadily growing[16]. However, the non-CRUCH universities show faster growth compared to CRUCH universities (i.e., steeper slope), leading to the rise in their share among college enrollees, from 15.2% percent in 1990 to 54.1% percent in 2013 (solid line in 3.1). Figure 3.3, Panel A, shows the quality of enrollees that CRUCH and non-CRUCH universities at-

[15] We obtained the minutes of meetings among CRUCH universities that took place on January 11, 2011 and April 5, 2011 (Sessions 521 and 523). The minutes of the January meeting state that the CRUCH has the mission of guaranteeing that students and their families have access to accurate information in terms of the number of vacancies and minimum scores among enrollees. They also state that college admission outcomes should be based only on merit. In Spanish, the sentences read as below: "*...los Rectores consideran que el Consejo de Rectores tiene la misión de proponer políticas al sistema universitario en su conjunto. Al mismo tiempo, que les cabe la responsabilidad de garantizar information y calidad a los estudiantes y sus familias", and "..al mismo tiempo se vota la decisión de invitar a las universidades privadas a integrarse al sistema de admisión del CRUCH, con explicitación de vacantes, puntajes de corte y admisión única según los méritos de los estudiantes.*"

[16] For example, the gross college enrollment rate, defined as "total enrollment in tertiary education (ISCED 5 to 8), regardless of age, expressed as a percentage of the total population of the five-year age group following on from secondary school leaving," was 20.9 % in 1991, 37,2% in 2000, and 78.6 percent in 2013. (The World Bank Databank)

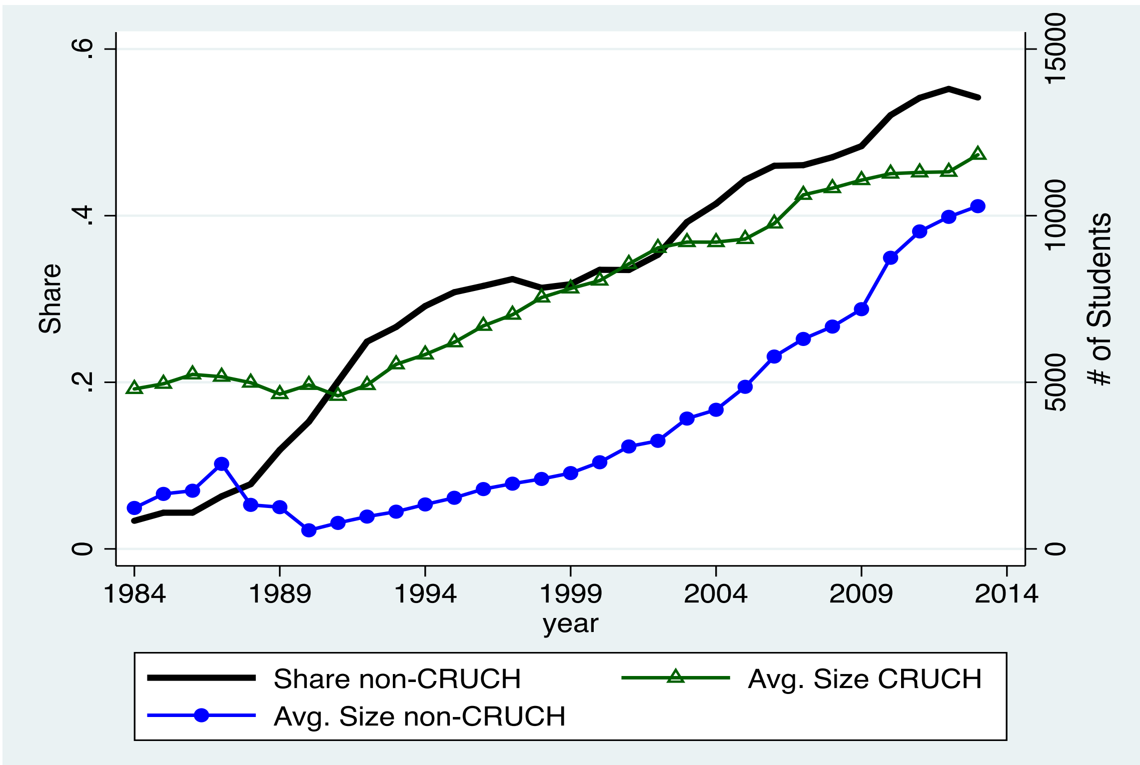
tracted over time. Specifically, we calculate the average PSU scores among enrollees in a given year and university and take the weighted average across universities among CRUCH or non-CRUCH groups, with the weights based on the number of enrollees. We also plot the 5th to 95th percentile of the average PSU scores with the line graph. Figure 3.3 shows that the CRUCH's distribution of the PSU scores overlap with those of the non-CRUCH schools, particularly with those who joined the centralized admission in 2012.

3.6.2 Non-CRUCH's incentive to participate in the centralized admission

As our theoretical model illustrates, the benefit for a non-CRUCH to join the centralized system arises when the non-CRUCH competes against CRUCH to attract students. Therefore, among non-CRUCH universities, those that are comparable to CRUCH are more likely to join the centralized matching system. Our data shows that indeed that is the case. Specifically, we compare average characteristics of universities among CRUCH, the 7 non-CRUCH that joined the centralized matching, and the remaining non-CRUCH that did not join.[17] Herein, we refer to them as Types 1 to 3, respectively. Columns 1 to 3 of Table 3.4 report the average characteristics of universities across types. The first two groups are on average comparable to each other, while the CRUCH and the non-CRUCH that decided not to

[17] One university that joined the system, "*Universidad Mayor*", did not report the information to the Ministry of Education. This is why our empirical analysis only includes 7 out of 8 non-CRUCH universities that joined the system.

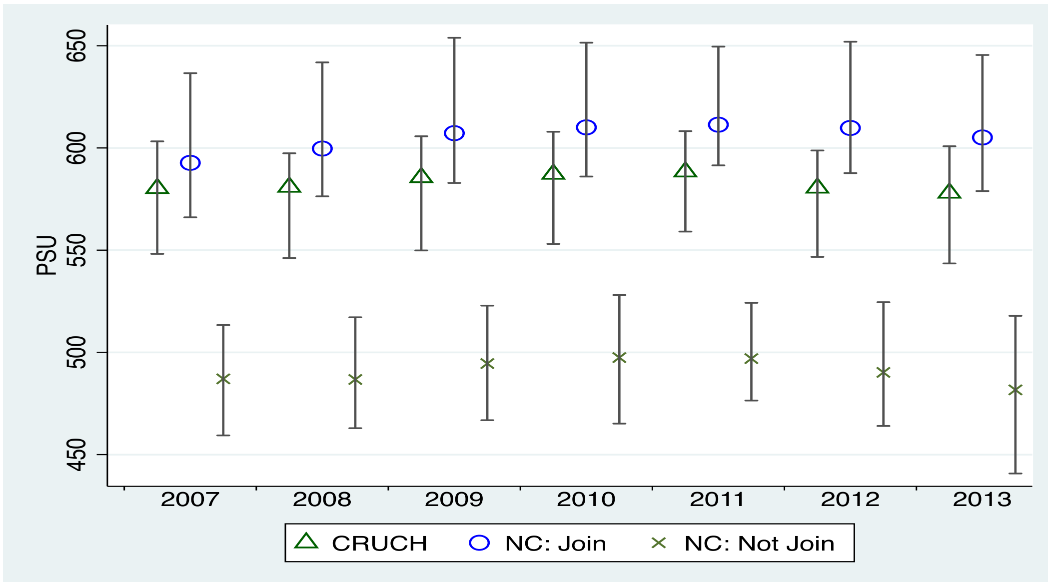
Figure 3.2: Share of Non-CRUCH Universities



Note: The solid line shows the share of non-CRUCH universities out of new university enrollees in each college admission cycle (left y-axis). The line marked with triangles (Δ) shows the average university size (total enrollees) across CRUCH universities, while the line marked with circles (O) shows the average university size across non-CRUCH universities (right y-axis).
Source: SIES, Ministry of Education of Chile.

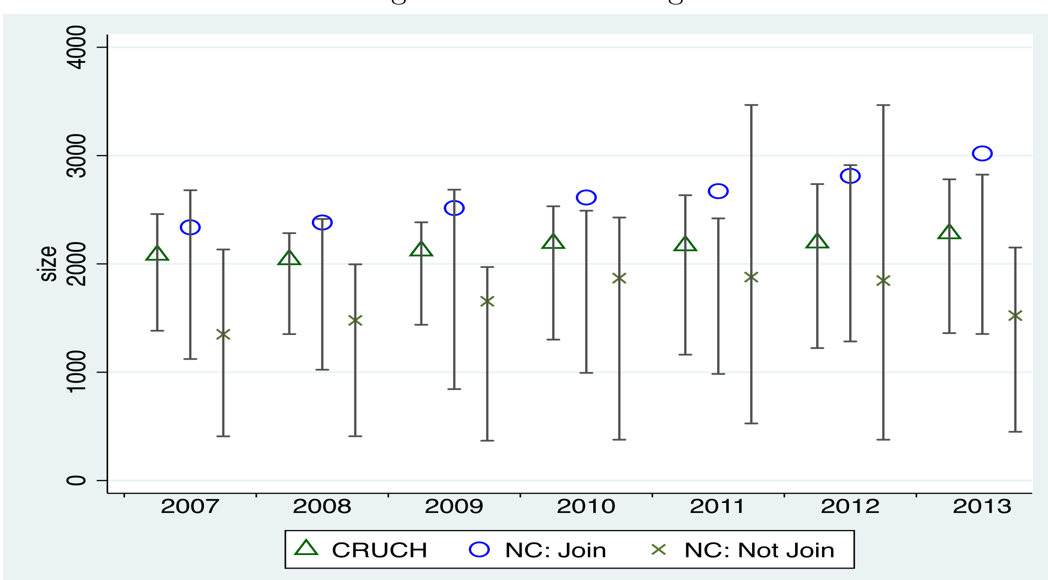
Figure 3.3: Comparison: CRUCH vs. Non-CRUCH

Panel A: Average PSU scores among New Enrollees



Note: The unit of observation is university by year. For each observation the average PSU (raw score) is calculated. This figure shows the simple average of those averages among the 25 CRUCH (Δ), 7 non-CRUCH that joined the system in 2012 (O) and 23 non-CRUCH that did not join the system (x) for different years. The 25th and 75th percentile are showed in bars.

Panel B: Average PSU scores among New Enrollees



Note: The unit of observation is university by year. For each observation the number of new enrollees is calculated (size). This figure shows the simple average of the size among the 25 CRUCH (Δ), 7 non-CRUCH that joined the system in 2012 (O) and 23 non-CRUCH that did not join the system (x) for different years. The 25th and 75th percentile are showed in bars.

join the matching are much more different from each other. The differences between the first two groups are often statistically insignificant at conventional levels, while the differences between the first and the last groups are significant at the 1 percent level, except for a few cases.

Table 3.4: Who Accepted the Invitation?

Join the system (no. of universities)	CRUCH Yes (25) (1)	Non-CRUCH Yes (7) (2)	No (23) (3)	Diff (1) vs (2) (4)	Diff (1) vs. (3) (5)
Panel A. 2010-2011					
No. majors offered	32.78	24.5	19.72	8.28**	13.06***
No. new enrollees	2179.42	2642.5	1873.63	-463.08	305.79
PSU of new enrollees*					
- Mean: Raw	587.79	610.74	497.21	-22.95*	90.58***
- Mean: Standardized	0.18	0.46	-0.92	-0.28*	1.10***
Sum of PSU					
- Raw scores (x 1000)	1,266.91	1,443.42	818.22	-176.51	448.70**
- Standardized scores	904.63	599.12	-1165.63	305.51	2,070.26***
Share of students aged over 20	24.51%	23.08%	45.54%	1.42%	-21.04% pts***
Tuition (2009 USD)	4,091.87	6,541.59	3,940.43	-2,449.72***	151.44
Panel B. 2012-2013					
No. majors offered	33.98	27.57	19.35	6.41	14.63***
No. new enrollees	2,237.08	2,916.00	1,684.52	-678.92	552.56
PSU of new enrollees*					
- Mean: Raw	579.22	607.46	486.09	-28.24**	93.13***
- Mean: Standardized	0.11	0.46	-1.04	-0.35**	1.15***
Sum of PSU					
- Raw scores (x 1000)	1,246.65	1,528.26	661.38	-281.61	585.26***
- Standardized scores	786.58	664.31	-1,057.16	122.27	1,843.74***
Share of students aged over 20	24.48%	22.16%	48.98%	2.32%	-24.50% pts***
Tuition (2009 USD)	4,320.00	6,770.44	3,955.43	-2,450.45***	364.57*

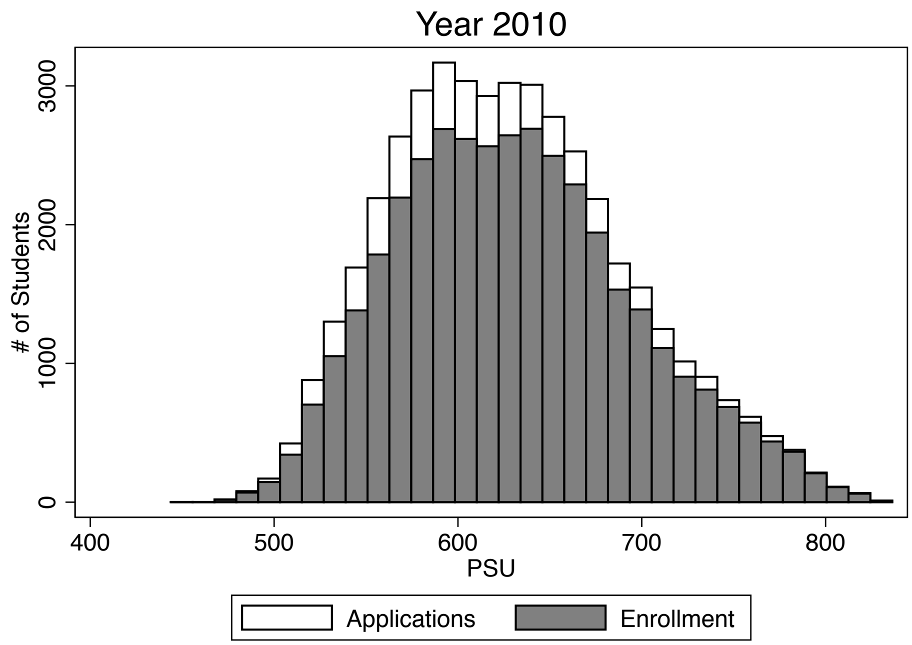
Note: The asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively

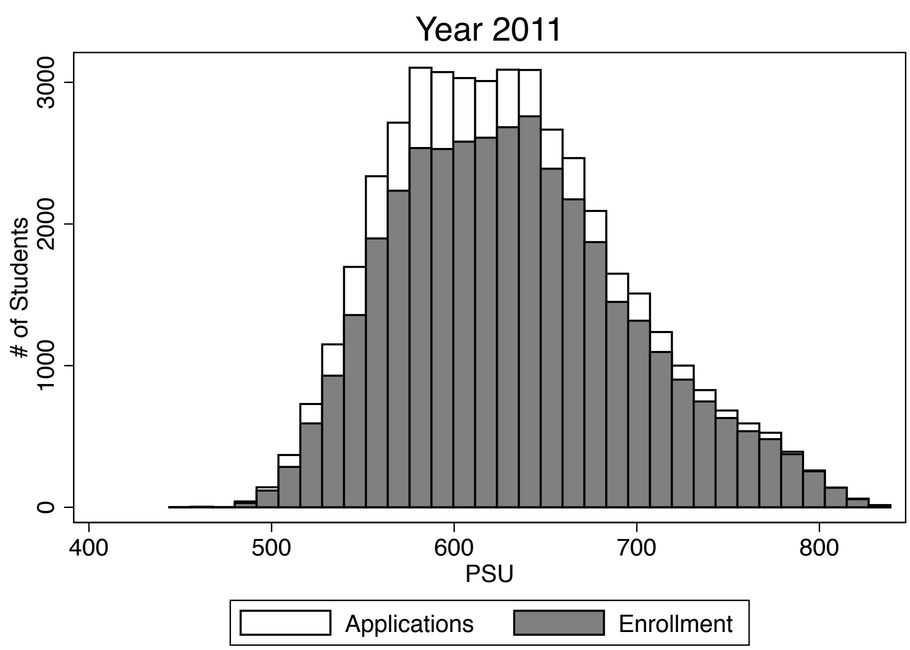
3.6.3 Payoffs of Universities

This section examines the outcomes of the CRUCH and the 7 non-CRUCH universities when they joined the centralized matching. Given that these universities voluntarily adopted the system change, the change would benefit them. First consider CRUCH universities. We calculate the prevalence of applicants who got admitted but did not enroll, implying that, from a college's point of view, those seats were wasted, lowering its payoffs. Using the application data, we calculate the list of applicants who got an admission from CRUCH using the Gale-Shapley algorithm. Figures 3.4 and 3.5 show the PSU distribution of students who applied to and got the admission from a CRUCH university (labeled "applications") and that of students who actually accepted the offer (labeled "enrollment"). The difference between the two distributions is the number of seats that could have been filled by other students but were wasted, implying the costs from a college's point of view. Figure 3.4 presents graphs for 2010 and 2011, before the change, and Figure 3.5 shows the graphs for 2012 and 2013, after the centralization expanded. These graphs illustrate that the number of unfilled seats dramatically decreased after the 2012 change. For example, in 2011, 14.8% of offers were rejected by applications (i.e., the share of white areas relative to the outer distribution in 2011). In contrast, in 2012, that share decreased by half (7.7%).

Next, we use regression analyses to measure payoffs of CRUCH as well as non-CRUCH universities. Again, consistent with our theoretical model, we measure a university's payoff by the simple sum of the enrollees' PSU scores. From 2010 to

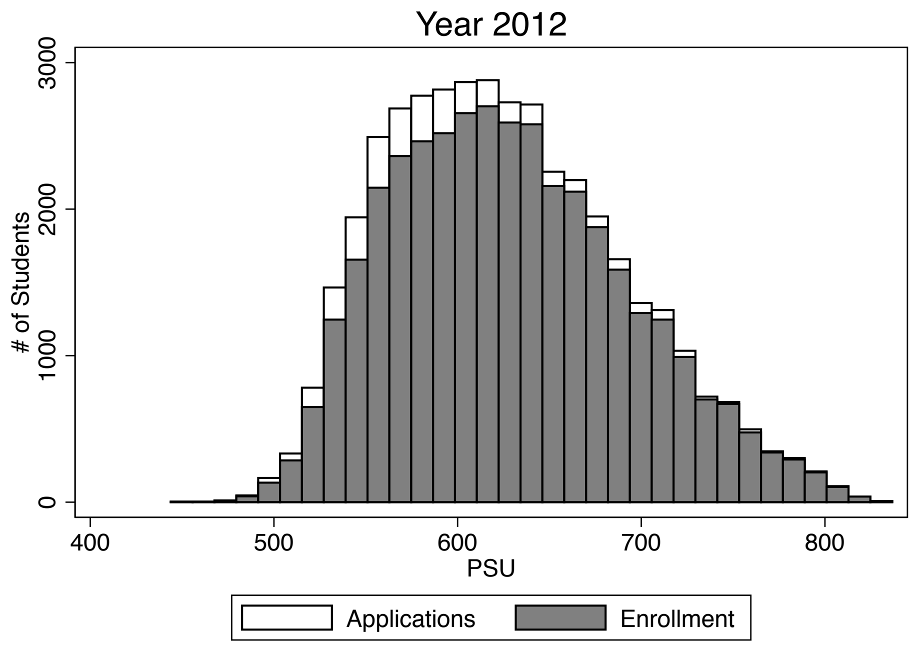
Figure 3.4: Universities' Outcomes: Before the Change

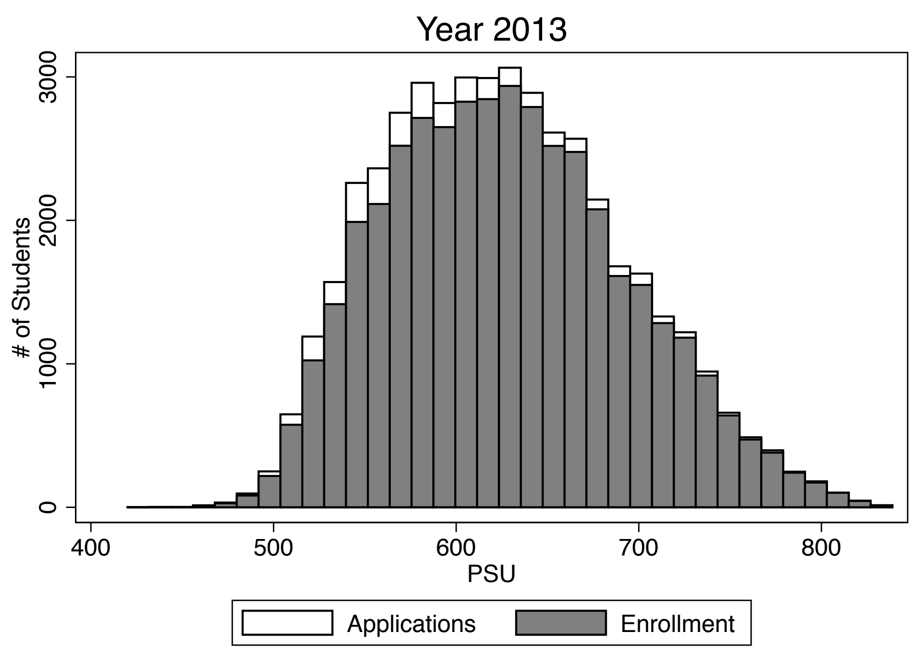




Note: PSU distribution of students who applied to and got the admission from a CRUCH university (applications) and that of students who actually accepted the offer (enrollment). The difference between the two distributions (white area) is the number of seats left empty.

Figure 3.5: Universities' Outcomes: After the Change





Note: PSU distribution of students who applied to and got the admission from a CRUCH university (applications) and that of students who actually accepted the offer (enrollment). The difference between the two distributions (white area) is the number of seats left empty.

2013, we regress the sum of the PSU scores of a college's enrollees on a college-specific dummy (i.e., college fixed effects), year dummy, and the interaction terms between whether a college admission took place after the 2012 change and the types of colleges. Specifically, we estimate the following regression model:

$$Y_{c,t} = \alpha + \beta_i \times Post_t \times 1(Type_c = i) + \theta_c + \mu_t + \varepsilon_{c,t} \tag{3.16}$$

where $Y_{c,t}$ is the payoff of college c whose type is i in year t , and $Post_t$ is a dummy equal to 1 if $t \geq 2012$ (post-change period). $Type_c$ is a categorical variable that specifies college c's type, that is, 1 if college c is CRUCH, 2 if one of the 8 non-CRUCH, and 3 for the rest of non-CRUCH and 1() is the indicator funtion. Parameter θ_c captures a college-specific effect (i.e., a college fixed effect), and μ_t is year fixed effect. The parameter of interest is β_i. If our theoretical prediction holds, then β_1 and β_2 will be positive. Parameter β_3 measures the change of payoffs among non-CRUCH that did not join the centralized admission. The difference between β_i with $i = 1, 2$ and β_3 captures the relative change in payoffs for CRUCH and the 8 non-CRUCH.

Table 3.5 presents three panels depending on the range of samples. Panel A uses the entire universities, while Panels B and C use half of them depending on the initial quality of schools. Column (1) of Panel A shows that, after the 2012 change, the average CRUCH payoff slightly increased (i.e., 5.06) but the increase is not statistically significant at conventional level, while the non-CRUCH universities that joined the centralized admission (labeled "non-CRUCH: join") on average increased their payoffs (i.e., 110.48), significant at the 10 percent level. In contrast, the non-CRUCH universities that did not join the centralized admission substantially suffer by a reduction in their average payoffs that is substantially different from zero at the 1 percent level. As this analysis does not account for the fact that there is a substantial difference in initial quality among CRUCH schools, we divide the sample into two groups and repeat the regression analysis. Panel B includes the top half of the universities based on the average PSU scores among enrollees prior to our sample period (i.e., 2007 to 2009), while Panel C includes the remaining bottom 50% of schools. The top 50% group includes only some CRUCH and the non-CRUCH that joined the centralized admission (Type 2), while the bottom 50% includes only the rest of CRUCH and the non-CRUCH that did not join the centralized admission (Type 3). Once we condition on the initial quality of schools, we can clearly see that the subset of CRUCH universities that directly compete against the Type 2 non-CRUCH increased their payoffs (column (1) of Panel B). The rest of CRUCH schools that compete againts the Type 3 non-CRUCH show a reduction in their payoffs but insignificantly.

Table 3.6 shows similar results but we control for the the time-variant number of students receiving AFI subsidy. Both sets of analyses suggest that, consistent with our theoretical model, CRUCH and the non-CRUCH that joined the centralized admission benefit from the expansion of the centralized admission.

Table 3.5: University Outcomes: Regression Analysis

Outcome (unit)	Sum of PSU (1,000 points) (1)	# of Enrollees (person) (2)	Avg PSU (1 point) (3)	# of Enrollees with AFI (4)
Panel A: All Universities				
Post x CRUCH (a)	5.06	23.24	-10.95***	1.45
	(40.12)	(75.16)	(1.36)	(15.96)
x non-CRUCH: join (b)	110.48*	239.55*	-5.68**	71.37***
	(62.05)	(130.57)	(2.65)	(26.54)
x non-CRUCH: not join (c)	-131.28***	-223.13***	-13.61***	6.05
	(38.40)	(80.80)	(1.64)	(16.43)
Test (p-val)				
(a) = (b)	0.11	0.12	0.06	0.01
(a) = (c)	0.00	0.01	0.17	0.81
(b) = (c)	$<$0.001	0.00	$<$0.001	0.02
Mean Dep. V.	1069.77	2101.49	548.32	448.90
R2	0.98	0.98	0.99	1.00
N	220.00	220.00	220.00	220.00
Panel B: Top 50% Univ.				
Post x CRUCH (a)	71.30***	138.22***	-10.88***	16.91
	(9.59)	(17.80)	(0.33)	(27.27)
x non-CRUCH: join (b)	167.59***	336.36***	-4.41**	89.41**
	(46.08)	(90.66)	(1.68)	(39.21)
x non-CRUCH: not join (c)	-	-	-	
Test (p-val)				
(a) = (b)	0.04	0.03	$<$0.001	0.08
Mean Dep. V.	1448.09	2553.45	599.31	867.50
R2	0.99	0.99	0.99	0.99
N	108.00	108.00	108.00	108.00
Panel C: Bottom 50% Univ.				
Post x CRUCH (a)	-86.56	-142.79	-7.40*	-5.65
	(70.60)	(174.90)	(2.69)	(6.43)
x non-CRUCH: join (b)	-	-	-	-
x non-CRUCH: not join (c)	-186.35***	-316.48***	-14.84***	-11.34***
	(50.55)	(111.22)	(2.33)	(3.73)
Test (p-val)				
(a) = (c)	0.26	0.37	0.07	0.76
Mean Dep. V.	704.96	1665.67	499.15	43.65
R2	0.97	0.97	0.96	0.99
N	112.00	112.00	112.00	112.00

Note: The unit of observation is university by year. As for Panels B and C, we split the colleges into two groups based on the average PSU scores among enrollees using out-of-sample data between 2007 and 2009. Panel A includes the top 50% of colleges based on the average PSU scores and the bottom 50% covers the remaining colleges. Regression models additionally include university fixed effects and year fixed effects. We also control for the time-variant number of students receiving AFI subsidy. Standard errors are clustered by year. The asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively

Table 3.6: University Outcomes: Regression Analysis

Outcome (unit)	Sum of PSU (1,000 points) (1)	# of Enrollees (person) (2)	Avg PSU (1 point) (3)	# of Enrollees with AFI (4)
Panel A: All Universities				
Post x CRUCH (a)	26.1	62.43	-9.73***	8.94
	(34.37)	(70.87)	(1.22)	(16.69)
x non-CRUCH: join (b)	95.64*	198.02*	-5.78***	69.78**
	(56.24)	(115.98)	(2.00)	(27.31)
x non-CRUCH: not join (c)	-64.18	-51.73	-8.79***	34.75
	(43.37)	(89.44)	(1.54)	(21.06)
log(AFI subsidy)	238.98***	537.48***	8.78***	60.53***
	(38)	(78)	(1)	(18)
Test (p-val)				
(a) = (b)	0.247	0.273	0.065	0.038
(a) = (c)	0.046	0.226	0.562	0.245
(b) = (c)	0.015	0.065	0.195	0.27
Mean Dep. V.	1,069.77	2,101.49	548.32	448.9
R2	0.99	0.99	1	1
N	200	200	200	200
Panel B: Top 50% Univ.				
Post x CRUCH (a)	64.63**	125.17**	-11.29***	8.83
	(30.70)	(60.44)	(1.00)	(24.60)
x non-CRUCH: join (b)	125.51***	254.01***	-7.02***	38.5
	(46.35)	(91.24)	(1.50)	(37.14)
x non-CRUCH: not join (c)	-	-	-	
	-	-	-	-
log(AFI subsidy)	241.84***	473.24***	15.03***	292.58***
	(83.44)	(164.27)	(2.71)	(66.87)
Test (p-val)				
(a) = (b)	0.208	0.169	0.007	0.435
Mean Dep. V.	1448.09	2553.45	599.31	867.5
R2	0.99	0.99	0.99	0.99
N	108	108	108	108
Panel C: Bottom 50% Univ.				
Post x CRUCH (a)	-54.75	-69.93	-4.86	-2.64
	(85.45)	(182.80)	(3.11)	(6.30)
x non-CRUCH: join (b)	-	-	-	-
	-	-	-	-
x non-CRUCH: not join (c)	-130.41*	-142.56	-9.15***	-5.13
	(65.59)	(140.32)	(2.39)	(4.83)
log(AFI subsidy)	204.49***	497.22***	7.92***	17.73***
	(51.85)	(110.93)	(1.89)	(3.82)
Test (p-val)				
(a) = (c)	0.396	0.702	0.188	0.704
Mean Dep. V.	704.96	1665.67	499.15	43.65
R2	0.97	0.97	0.97	0.99
N	92	92	92	92

Note: The unit of observation is university by year. As for Panels B and C, we split the colleges into two groups based on the average PSU scores among enrollees using out-of-sample data between 2007 and 2009. Panel A includes the top 50% of colleges based on the average PSU scores and the bottom 50% covers the remaining colleges. Regression models additionally include university fixed effects and year fixed effects. Standard errors are clustered by year. The asterisks $*$, $**$, and $***$ indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

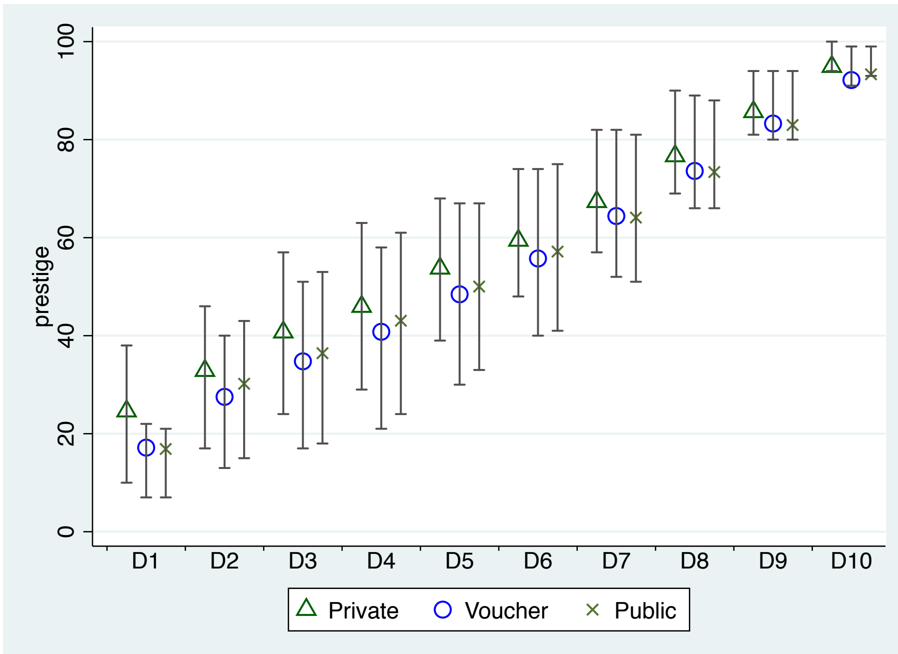
3.6.4 Student Outcomes

Our theoretical model predicts that, conditional on test scores, students facing high application costs are disadvantageous relative to their counterparts with low costs. Specifically, they are less likely to apply to colleges with separate applications, and due to the difference in application behaviors, they will be more likely to enroll in a university and major that is less prestigious than those of their counterparts. However, when the set of universities covered by the centralized matching expands, this premium decreases. In the Chilean setting, it is reasonable to assume that students whose parents are well enough off to cover the deposit fees and those who live in metropolitan areas face smaller opportunity costs. To proxy for parental background, we use high school type, expecting that private school graduates would be better off than the rest. Figure 3.6 shows the existence of the premiums. Specifically, we classify students based on their PSU scores (by decile) and high school type (private, public, and voucher). Conditional on a decile, the average PSU scores are comparable across the three high school types. Figure 3.6 shows that even if students have the same PSU scores, students from private schools were able to enroll in better-ranked options compared to those from voucher or public schools. However, the gap is reduced in 2012-13 compared to 2010-11, especially for middle-ranged students ranging from the third decile (D3) to the 8th decile (D8).

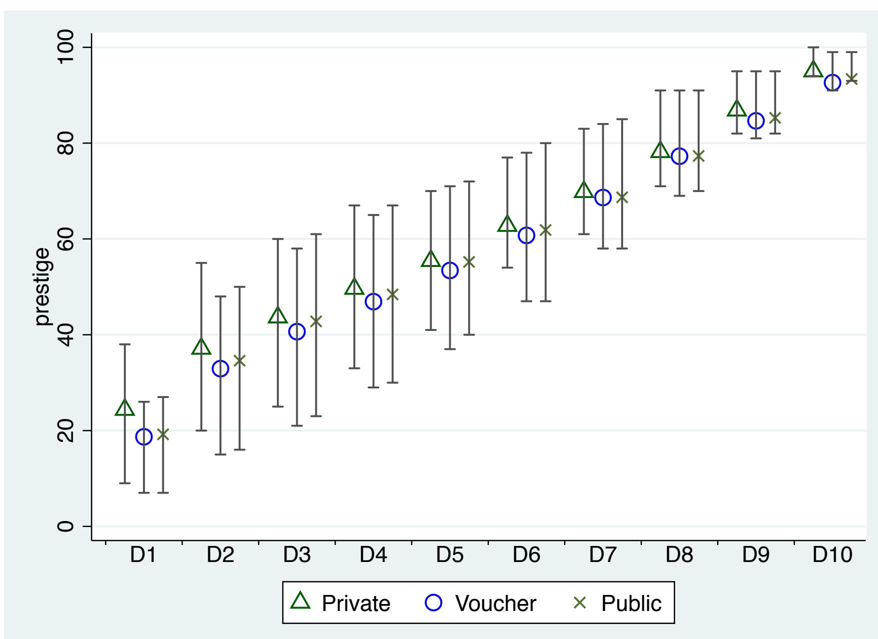
Table 3.7 presents the empirical analysis of students' outcomes before and after the change. Specifically, we regress the prestige of the option a student enrolled in

Figure 3.6: Student Outcomes: Before and After the Change

Panel A: Average "Prestige" of Enrolled Program in 2010 and 2011



Panel B: Average "Prestige" of Enrolled Program in 2012 and 2013



Note: This figure shows the simple average and 25th-75th interval of the "prestige" of options (university and major) for which new enrollees signed up, depending on the types of high schools they graduated from. The symbols Δ , O and X, indicate private, voucher, and public high schools, respectively.

as student's PSU score, high school type, and other controls as follows:

$$Y_{i,t} = \alpha + \beta \times Score_{i,t} + \gamma \times HighSchool_{i,t} + \delta \times Post_t \times HighSchool_{i,t} + \theta \times X_{i,t} + \varepsilon_{i,t} \tag{3.17}$$

where $Y_{i,t}$ is either the prestige of the program student i enrolls in year t (columns 1-3) or the probability that student i enrolls at a Type 2 college in year i. $Score_{i,t}$ is the PSU score of student i enrolls in year t, $HighSchool_i$ is a categorical variable defining her high school type (private, voucher or public), $X_{i,t}$ is a vector of student's characteristic, including gender, age, location, and finally $Post_t$ is a dummy equal to 1 if $t \geq 2012$ (post-reform period), which is interacted with the high school variable.

Table 3.7 (column (1)) shows that, after the change, students from public and voucher high schools enroll in programs with a higher prestige (4.99 and 4.81 points, respectively), roughly 2.5 points higher than students from private schools. Recall that our measure of prestige is based on relative ranking of an option, ranging from 0 to 100. Therefore, the estimated results can be interpreted as follows. After the 2012 change, a student from public high school is able to enroll in a college and major that ranked 5 percentiles higher. Note that students from private schools still benefit from the 2012 change in that the ranking of their enrolled options increases by 2.6 percentiles. This increase is due to the fact that fewer offers are wasted after the 2012 change (see Section 3.6.3). We conduct the same analysis by splitting the samples depending on whether a student resides in one of the three metropolitan areas (MA) where at least one of the 8 non-CRUCH universities are located. Columns (2) and (3) show the results. In both groups, we find comparable improvement in outcomes.

Columns (4) to (6) show the likelihood of enrolling in a non-CRUCH university that joined the centralized admission. As we showed in Section 5.3, those non-CRUCH schools increased the size of their enrollment. The purpose of these analyses is to examine whether these seats are filled by students from a certain type of high school more often or not. The estimated coefficients show that students from voucher high schools are more likely to enroll in a Type 2 non-CRUCH school relative to those from private or public schools. However, the difference is not statistically significant at conventional levels. When we study students residing in one of the three metropolitan areas (MA, column (6)), the effect becomes statistically significant at the 1 percent level but the estimate is not statistically from the effect on students from public schools (i.e., 0.009 vs. 0.007).

3.7 Discussion

In this section, we examine the sensitivity of our analysis with respect to our choice of student outcomes, namely "prestige." First, we construct our prestige ranking not based on average PSU scores among enrollees, but based on two alternative statistics: the minimum and maximum PSU scores among enrollees in a given option. Table 3.8 presents the results, consistent with the baseline results reported in columns 1 to 3 of Table 3.7. Specifically, after the 2012 change, on average all

Table 3.7: Student Outcomes: Regression Analysis

Outcome	Prestige	Prestige	Prestige	Enrolling in Type 2	Enrolling in Type 2	Enrolling in Type 2
Sample	All	In MA	Outside MA	All	In MA	Outside MA
	(1)	(2)	(3)	(4)	(5)	(6)
Post						
x Private (a)	2.559**	2.473**	2.892***	-0.009	-0.012	0
	(0.489)	(0.499)	(0.465)	(0.009)	(0.008)	(0.012)
x Voucher (b)	4.806**	5.035**	4.389**	0.018	0.023	0.009***
	(0.919)	(0.938)	(0.891)	(0.008)	(0.012)	(0.001)
x Public (c)	4.991***	5.243***	4.673**	0.011	0.016	0.007
	(0.837)	(0.625)	(1.106)	(0.006)	(0.007)	(0.004)
Test Score(PSU)	0.273***	0.276***	0.266***	-0.000**	-0.000***	0
	(0.003)	(0.002)	(0.005)	(0.000)	(0.000)	(0.000)
Voucher	-4.285***	-4.690***	-2.849***	-0.263***	-0.277***	-0.225***
	(0.206)	(0.182)	(0.380)	(0.003)	(0.004)	(0.003)
Public	-3.406***	-3.875***	-2.195**	-0.295***	-0.310***	-0.251***
	(0.196)	(0.118)	(0.442)	(0.004)	(0.004)	(0.004)
Girl	-1.711**	-1.484**	-2.127***	0.007*	0.006*	0.009**
	(0.373)	(0.390)	(0.356)	(0.002)	(0.002)	(0.003)
Age>20	-3.472***	-3.142***	-4.026***	-0.026***	-0.042***	0.002
	(0.240)	(0.286)	(0.188)	(0.002)	(0.004)	(0.002)
Test (p-val)						
(a) = (b)	0.01	0.01	0.04	0.2	0.17	0.56
(a) = (c)	0.01	0	0.07	0.25	0.17	0.72
(b) = (c)	0.27	0.61	0.29	0.04	0.19	0.59
Mean Dep. V.	55.85	58.82	51.08	0.17	0.23	0.08
R2	0.6	0.62	0.57	0.13	0.1	0.11
N	376,272	242,468	133,804	376,272	242,468	133,804

Note: We also include students' location fixed effects. Standard errors are in parentheses and clustered by year. The unit of observations is students enrolled in a university between 2010 and 2013. The asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

students are able to enroll in a better-ranked options and this positive impact is larger for students who graduated from voucher or public high schools as compared to their counterparts who graduated from private high schools. Second, we examine the extent to which our measure of prestige may reflect students' preferences. Suppose that a student's preference over options is determined by the common and idiosyncratic components of an option. We consider the average PSU scores as a proxy for the former, the value of an option that is commonly shared by college applicants. Therefore, we view our empirical results regarding student outcomes as average impacts because students' idiosyncratic values of an option may be cancelled out across individuals. However, our argument will be valid if the average PSU scores indeed well reflect the relative ranking of the value of common components. Specifically, due to application costs for non-CRUCH universities, it is possible that an option may be well-demanded by students but have a lower average PSU score than another option that is less preferred. That is, our measure of prestige will be valid if search frictions do not alter the relative ranking of an option with respect to the average PSU score. We examine this possibility using the application data as follows. Specifically, we use the 2012 application information on CRUCH and the 8 non-CRUCH universities under the centralized matching to compare students' preference ranking with our measure of prestige. Recall that the Chilean matching employs the student-proposed Deferred-Acceptance algorithm (or Gale-Shapley algorithm), under which truth-telling is a dominant strategy for participants. Therefore, if our measure of prestige well reflects students' preferences, then it will be positively correlated with students' preference ranking. To test this possibility, for each option, we calculate the fraction of applicants who rank it as their best or second-best option (i.e., rank number 1 or 2); the fraction of applicants who rank it as number 3 or 4; and 5 or above. By construction, the sum of these three variables is one within option. We then regress our measure of prestige on the former two variables. If our hypothesis is true, then the estimated coefficient of % Ranking 1-2 will be larger than that of % Ranking 3-4; and % Ranking 5-10 will be the smallest (which is out omitted category). The regression results are reported in Table 3.9. In column (1), we regress our prestige on the two regressors; we add field-fixed effects in column (2); we add university-fixed effects in column (3); and we use both field- and university- fixed effects in column (4). In all specifications, we find positive correlation of the ranking of an option in the application data with our measure of prestige. For example, in column (1), the result shows that a one percentage point increase in the share of applicants who select an option as rank number 1 or 2, while decreasing the share of those who rank it as number 5 or higher, is associated with a 0.984 increase in our measure of prestige (2.0 percent). Similarly, a one percentage point increase in the share of applicants who select an option as rank number 3 or 4, while decreasing the share of those who rank it as number 5 or higher, is associated with a 0.977 increase in our measure of prestige (1.9 percent).

Table 3.8: Alterative Measures of Prestige

Outcome Sample	Min PSU All (1)	Min PSU In MA (2)	Min PSU Outside MA (3)	Max PSU All (4)	Max PSU In MA (5)	Max PSU Outside MA (6)
Post						
x Private (a)	2.319**	2.331**	2.266**	1.722**	1.545**	2.382***
	(0.513)	(0.530)	(0.474)	(0.424)	(0.471)	(0.276)
x Voucher (b)	3.815**	3.986**	3.499**	3.457**	3.559**	3.259***
	(0.821)	(0.814)	(0.830)	(0.727)	(0.830)	(0.556)
x Public (c)	3.892**	4.361***	3.300**	3.765**	3.767***	3.745**
	(0.708)	(0.555)	(0.930)	(0.734)	(0.568)	(0.955)
Test Score (PSU)	0.268***	0.272***	0.259***	0.188***	0.193***	0.179***
	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.004)
Voucher	-0.175	-0.096	-0.359	-7.626***	-7.966***	-6.305***
	(0.306)	(0.339)	(0.269)	(0.098)	(0.154)	(0.186)
Public	1.979***	1.933***	1.690**	-7.875***	-8.064***	-7.095***
	(0.301)	(0.266)	(0.343)	(0.071)	(0.175)	(0.410)
Girl	-2.288**	-1.656**	-3.449***	-2.755***	-2.301***	-3.581***
	(0.411)	(0.422)	(0.405)	(0.199)	(0.206)	(0.196)
Age>20	-2.954***	-2.518***	-3.728***	-2.847***	-2.663***	-3.145***
	(0.313)	(0.258)	(0.425)	(0.267)	(0.320)	(0.182)
Test (p-val)						
(a) = (b)	0.052	0.043	0.057	0.011	0.014	0.089
(a) = (c)	0.021	0.002	0.142	0.007	0	0.174
(b) = (c)	0.589	0.327	0.173	0.126	0.499	0.325
Mean Dep. V.	48.3	50.67	44.49	62.53	64.85	58.79
R2	0.45	0.46	0.42	0.41	0.44	0.34
N	374,103	241,467	132,636	374,103	241,467	132,636

Note: We also include students' location fixed effects. Standard errors are in parentheses and clustered by year. The unit of observations is students enrolled in a university between 2010 and 2013. The asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

3.8 Conclusion

This paper examines schools' incentives to voluntarily form a centralized admission system and to expand the number of participants when application costs exist and a student's ability to afford these costs varies. Our theoretical analysis shows that when application costs are sufficiently large and colleges are compa-

Table 3.9: Prestige and Preference Ranking in Applications

	(1)	(2)	(3)	(4)
% Ranking 1-2 (a)	0.984***	0.994***	0.704***	0.666***
	(0.07)	(0.06)	(0.07)	(0.07)
% Ranking 3-4 (b)	0.977***	0.973***	0.367***	0.372***
	(0.13)	(0.12)	(0.12)	(0.11)
% Ranking 5-10 (omitted)				
Field Fixed-Effect	NO	YES	NO	YES
University Fixed-Effect	NO	NO	YES	YES
Test (p-val)				
(a) = (b)	0.959	0.859	0.012	0.017
Mean Dep. V.	50.46	50.46	50.46	50.46
R2	0.15	0.26	0.26	0.63
N	1,327	1,327	1,327	1,327

Note: The unit of observation is option. The asterisks *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

rable enough in terms of their qualities, colleges may voluntarily adopt a centralized admission, and also that the group of colleges using the centralized admission may expand the group by including new market participants. Using administrative datasets from Chile, we show the relevance of the theoretical model in explaining the evolution of college admission procedures. Furthermore, we empirically examine the consequences of an expansion of the centralized admission in 2012. The expansion is beneficial not only to colleges that participate in the centralized admission but also to applicants, particularly those of low socioeconomic status (SES), who are able to enroll in higher quality schools. The impact on applicants is accounted for by the efficiency improvement due to coordination among colleges, and also by the fact that applicants of low SES are less likely to be able to afford application costs in Chile. Our findings suggest that consideration of application costs, or generally speaking search costs, may be important in examining potential benefits from a market design intervention. When search costs are negligible, as in secondary school assignment problems in the US, incentives for schools to adopt a centralized admission system can be small because doing so only increases competition against other schools. In such a case, government intervention and associated compensation is necessary. In contrast, our study suggests that a centralized system can be more adoptable in a market with high search costs, such as developing countries or countries with high inequality. This paper also shows that a market design policy can play an important role in reducing inefficiency and inequality. Chile's expansion of its centralized admission system in 2012 increased the fraction of seats allocated through the centralized admission from 47 percent to 63 percent. This suggests that a student can apply to a much wider set of colleges without paying any application costs. This reduction in application costs is beneficial to students in general, but much more so to students from a low socioeconomic background. Our findings suggest that search costs affect agents' outcomes depending on the extent to which their resources cover the costs, even if two agents are of equal quality. Reducing search costs using the centralized admission diminishes the role of irrelevant characteristics, namely parental background, in determining the agents' outcomes, which could be useful to economies attempting to improve intergenerational mobility or representation of minorities in higher education.

Appendix A: Decentralized Admission Process

Figure A.1: Decentralized Admission Process

The photos shows the chaos in the decentralized application. Students line up in front of universities (top figure) the night before the scores are released to secure a slot. The bottom figure shows a typical line to enroll a university in the decentralized system.

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