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To my family, Nicolás and Gaspar, and my parents, Esperanza and Horacio. This accomplishment is also yours.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

This dissertation presents evidence about implementing a free college policy on higher education's demand and supply. This analysis includes descriptive evidence about the impact of the policy on students and programs' behavior. It also develops and estimates a demand and supply model of higher education that provides a framework to analyze the channels through which the policy operates.

The free college policy has gained traction in the US and other countries in the past years. Free college is one policy tool that affects students' behavior through multiple channels, including how they apply to college due to changes in relative prices. Free college policies can lower tuition revenue constraining the resources available to institutions. In response, they may re-optimize their capacity and price choices if they take the form of targeted subsidies. Supply responses can impact access and quality of education for groups of students. Disregarding this impact misrepresents the welfare consequences of free college.

This dissertation studies the equilibrium effects of free college. Understanding these effects allows for analyzing counterfactual scenarios such as expansions of free college or changes in the choices of institutions. I explore these questions in the context of the Chilean implementation of free college that operates as a voucher to income-eligible students, introducing differentiation between eligible and non-eligible students that matters for institutions' revenue. I characterize and measure the demand and supply reactions using a combination of descriptive results and a structural model. First, I present descriptive evidence from a difference-in-difference strategy with variation in treatment intensity at the program level. Regarding demand, applications, and enrollment increase more in programs that were relatively more expensive before free college. And in terms of supply, programs increased capacity and price more if their revenue would have decreased given the change in demand induced by the policy. Second, I estimate an empirical demand model with preference heterogeneity and a discrete choice supply model. Using the results of the estimation, I evaluate

the impact of supply responses by analyzing a decomposition counterfactual that compares the welfare of students before and after free college and also in a case when supply responses are restricted. Even though the policy is mostly welfare-enhancing for eligible students, supply responses dampen the welfare of almost half of all the students. Mainly, non-eligible students experienced a significant reduction driven by displacement to the outside option and price increases. Hence, supply responses are of the first order and need to be considered when designing financial aid policies such as free college.

CHAPTER 1

INTRODUCTION

1.1 Overview and literature review

The free college policy has gained traction in the US and other countries in the past years. There are multiple implementations of free college, from free college for all to targeted subsidies. All of them include some version of funding public education [1], and they aim to reduce education and wealth inequality. Free college is one policy tool that operates through multiple channels. It increases applications and may increase enrollment and graduation of low-income students. Also, free college decreases student debt. Finally, even without these effects, it affects how students apply due to changes in relative prices.

Nonetheless, free college policies can significantly lower tuition revenue, constraining the resources available to institutions. In response, they may re-optimize other choices such as capacity, quality, and prices in the case of targeted subsidies. Then, free college can induce further changes in supply that might not just impact access to a given set of programs but also affect the characteristics of the programs.

These supply responses are of the first order because they can impact access and quality of education. For example, due to capacity restrictions, low-income students could be crowded-out. Also, changes in product characteristics might affect quality. Then, free college generates demand and supply responses that might impact the equilibrium. Due to a combination of demand and supply responses, the new equilibrium might not achieve the gains we could have thought of, given the policy's aim.

In this context, this dissertation studies the equilibrium effects of free college. Specifically, in terms of demand, it explores the impact of free college on students' behavior and outcomes—applications and enrollment, respectively. And regarding supply, this dissertation

1. Actually, 8 OECD countries have free public education, including Mexico and Sweden.

analyzes how institutions respond regarding capacity and pricing decisions. And, more importantly, whether these decisions amplify or moderate the effects of free college on students. Understanding the impact of free college allows me to solve for and compare counterfactual scenarios such as expansions of free college or changes in the choices of institutions.

This dissertation focuses on the Chilean implementation of free college. This version of free college is a targeted subsidy that operates as a subsidy to demand. Eligible students who enroll in a set of institutions face an effective price of zero, and the institutions receive a transfer from the government that, in many cases, is lower than the sticker price. In contrast, non-eligible students have to pay the sticker price. This version of free college introduces price differentiation between two groups of students. And this happens in a centralized admission system that allows institutions to select students directly. Before free college, the sticker price was used to rationalize demand. After the implementation of free college, sticker price only affects the demand of non-eligible students but does not directly affect the demand of eligible students. This difference weakens the role of prices in rationalizing demand. Then, institutions might resort to other characteristics of their programs, such as capacity, to affect the demand of eligible students.

The second chapter presents the results from a reduced-form analysis of students' behavior and the institutions' decisions. To analyze the data, I use a difference-in-difference strategy with variations in treatment intensity at the program level. In the case of students, eligible students tend to increase applications and enrollment more in programs that were relatively more expensive before free college. This aligns with an indirect utility model in which price reduces the likelihood of choosing a program. This change in students' behavior affects programs differently, even within an institution, because the intensity of the treatment mediates its impact.

On the side of supply, programs experienced a more significant increase in capacity and price if their revenue had decreased more, given the change in demand. This implies that programs that adjusted more are those where the policy significantly impacted revenue. The effect of free college on revenue is mediated by how demand varies due to the policy. Some programs experienced a more substantial increase in the demand from eligible students. Those programs would have reduced their revenue more if not for their capacity and price changes.

The third chapter develops and estimates a demand and supply model of the higher education market. Preference heterogeneity is captured thanks to the rich observable data at the student level in the spirit of Hastings et al. [2017] and Abdulkadiroğlu et al. [2020]. The estimation uses policy variation and across-market variation to capture price sensitivity and the valuation of a set of characteristics of the programs. Students who were not eligible for financial aid before free college are more price sensitive than those who were. Also, students right below the income eligibility cutoff of the policy are less price sensitive than those right above, even though the latter have higher incomes. These results are consistent with the reduced form results suggesting that eligible students increased their applications more in those programs that were more expensive before the implementation of free college. This reflects that eligible students experienced an exogenous change in price that effectively reduced the price they paid to zero.

The supply model is a discrete choice model in which programs maximize profits by choosing price and capacity. The rationale behind this discrete choice model is two-folded. First, it solves the computational complexity of the standard approach of inverting first-order conditions. And also, the discrete actions better capture how programs choose capacity and price. These choices play a different role in rationalizing demand because of the price differentiation introduced by the free college policy. In this sense, this dissertation is related to other empirical work that considers products with more characteristics than just price, like Fan [2013], Wollmann [2018] and Allende [2019]. The results of these papers suggest that ignoring adjustments to the product characteristics that are not price causes significant differences in estimated welfare effects. The results of this dissertation indicate that the expansion or contraction of capacity might have a more substantial impact on increasing or restricting access to education at the margin of enrollment than price changes.

There is evidence in the literature that the effects of regulation in higher education are likely to be mediated by institutions' responses; this makes supply responses a central issue when evaluating the welfare implications of implementing free college. For example, Arcidiacono et al. [2014] considers the ban on using racial preferences in admissions at public colleges in California. Given this change, the institutions responded by investing more in their students or easing requirements which can explain gains in the graduation rates of students affected by the ban. This case shows how institutions adapt to changes in regulation. And more importantly, it suggests that even if a change in regulation implies a gain or a loss for a particular group of students, it is necessary to consider the responses of students and institutions to evaluate the overall effect on the targeted group.

Along this line, I analyze a decomposition counterfactual in which I compare the welfare of students before and after free college and also in a case when supply responses are restricted. This analysis allows me to understand the extent of supply responses and if they amplify or mitigate the effect of free college. The results from the decomposition counterfactual suggest that free college is mostly a welfare-enhancing policy for eligible students. This is expected as they face a price of zero after free college is implemented. However, at the same time, the welfare of almost half of the students could have been higher if it were not for supply responses. Mainly, non-eligible students experienced a significant reduction in welfare primarily driven by displacement to the outside option and price increases. Hence, supply responses are of the first order and need to be considered when designing and expanding financial aid policies such as free college.

Different free college experiences or targeted subsidies have been studied before. Murphy et al. [2019] describe the effects of the abolition of free college in England on university enrollments, equity, and proxies for institutional quality. After the abolition of free college, the British system experienced an increase in funding per student and enrollment, with no apparent widening in the access gap between advantaged and disadvantaged students. The British experience of abolishing free college suggests how financial incentives can shape institutions' strategic responses to regulatory changes and may impact students.

Even though there is no free college in the US, some examples of targeted subsidies have positively impacted the enrollment of beneficiaries. Dynarski et al. [2018] analyze a targeted subsidy aiming at high-achieving, low-income students that did not increase aid relative to what they would have qualified for after admissions. Instead, it reduced uncertainty by guaranteeing free tuition at a flagship university before application. The offer substantially increased application and enrollment. The authors suggest that this result highlights the importance of behavioral factors in understanding students' college decisions, such as uncertainty. The Chilean implementation of free college also reduces uncertainty for eligible students, and probably even more than the program studied by Dynarski et al. [2018] because it does not have an academic requirement and applies to all low-income students.

Other experiences of targeted subsidies in developing countries suggest a similar impact on enrollment. Londoño-Vélez et al. [2020] find that a high-scale scholarship targeting low-income high-achievers positively affects their enrollment in high-quality colleges in Colombia. Also, this expansion of financial aid generates a response from private colleges which increases their capacity as a response to the increase in demand. Note, however, that the policy studied by Londoño-Vélez et al. [2020] does not generate a change in institutions' revenue sources, whereas the Chilean implementation of free college does.

The effects of free college on the enrollment of eligible students have been studied before in the Chilean case. Bennett [2020] develops a generalized regression discontinuity design that expands the standard regression discontinuity analysis to a broader population further away from the cutoff. She illustrates her methodology with an application that describes the reduced form effects of free college on the enrollment and application of students. First, she finds that enrollment of eligible students around the eligibility cutoff increases after implementing the policy and that an increase in applications mainly drives this. Second, she also suggests that, although non-significant, the impact on enrollment of students farther away from the cutoff of eligibility experienced a more significant effect than those on the margin. Consistently with the author, I find a positive impact on applications and enrollment.

Also, for the Chilean case, Bucarey [2018] uses the expansion of a scholarship program to approximate the effects of free college before its actual implementation on the enrollment of beneficiaries. His results are based on a structural model and suggest that the expansion of the scholarships increased demand at selective programs, making these programs more competitive and pushing them out of reach for many low-income students who would have qualified otherwise. This crowd-out effect reflects one potential consequence of a targeted subsidy. However, this result assumes that the capacity of the institutions is fixed. Furthermore, the analyzed scholarships impose a financial stress on universities, creating an additional price differentiation different from free college. As described in this dissertation, the potential revenue impacts produced by free college induce supply responses that might not have been necessary for the context of other changes to the financial aid system.

The remainder of this chapter describes the background in which free college was implemented and the data used in the empirical analysis done in the following chapters.

1.2 Background and data

1.2.1 Brief description of the higher education market in Chile

In the last decades, Chile has experienced a dramatic increase in higher education enrollment. Thirty years ago, total enrollment was slightly above 230,000; today, it is more than 1,200,000. This significant expansion has been motivated by various reasons. On one side are government policies: increased state-funded grants and loans and lax regulation for creating and functioning higher education institutions. Conversely, there has been a strong demand for higher education due to increasing income thanks to economic growth and a vast higher education wage premium. Bordon et al. [2016] study this expansion in detail, discussing entry and quality cannibalization among universities. Even though total first-year enrollment in higher education has stabilized recently, Chile still has increased participation in tertiary education, given its income level. In 2017, 33 percent of 19-20 years old were enrolled, higher than the OECD average of 30 percent [2].

The higher education system is composed of universities and vocational institutions, and within each group, quality varies. The main focus of this paper is on universities of medium to high quality that participates in a centralized admissions system. Among these institutions are public or private universities, and private universities could be classified further as traditional or not. The difference is that the former was founded before 1980, and they form a conglomerate alongside public universities (CRUCH) that tends to act as a block. Private non-traditional universities have become a relevant group in the past decades regarding the fraction of enrollment that they represent [3]. Finally, the universities that participate in the centralized admissions system differ in quality, as mentioned before [4], and, on average, private-traditional institutions tend to have higher quality, measured by their certification in 2018 (See table B.1 on the appendix for a description of the differences between types of institutions).

The admission system to universities has two components. First, a group of universities

2. OECD, Education at a Glance

3. Around 30% of total tertiary education enrollment by 2015

4. The Ministry of Education certifies institutions and programs based on different measures of inputs and outputs, constructing an indicator of certification. This measure goes from 1 to 7 and indicates the years left for the following certification process. Universities must be accredited with a certification to access public funds linked to institutions' revenue.

is part of a centralized admissions system[5] that operates through a deferred acceptance algorithm based on Gale and Shapley [1962] (DAA). The rest of the universities use students' GPAs and standardized test scores to consider them for admission. This admission process is neither centralized nor has the same rules across institutions. Therefore, this group of universities is not regarded as eligible for free college [6] They are not the key focus of this paper.

Centralized admission system

The system has the following timing. First, students must sign up for the standardized college admission test (PSU) in December at the end of the academic calendar year. Suppose students want to receive state financial aid. In that case, they also need to complete a socioeconomic verification form.[7] All students take the PSU in December, including mandatory math and language exams and optional science and history tests. Scores for these tests are scaled to a distribution with a range of 150 to 850 and a mean and median of 500. The test results are given a few weeks after it was taken. Information from the socioeconomic verification form, their performance on the PSU, and their GPA determines students' access to state financial aid. At this point, students know whether they are eligible for financial aid and also which type. Students know state financial aid requirements before they start the application process.

The college admission process considers PSU scores, high school GPA and the student's ranking within her school [8]. All these elements are combined using known weights to create a composite score that varies at the institution-program level. After receiving their PSU scores,

5. In 2018, 39 universities participated out of 50.

6. This was true in the first year of implementation, after which only one institution outside the centralized system was considered eligible.

7. Note that since 2014 the state-guaranteed loan has not had an economic requirement due to the availability of resources.

8. See González and Johnson [2018] for a discussion on the introduction of the ranking to the system.

high-school graduates know their corresponding composite scores for all institution-program pairs, and they choose up to ten institution-program to apply for admissions. Given students' applications, GPA, rankings within the school, PSU scores, and programs' capacities, the centralized admission system assigns a seat at most at one program using an algorithm built on Gale and Shapley [1962]'s student-proposing deferred acceptance algorithm.

This process creates a cutoff for admission at each program, corresponding to the composite score of the least qualified admitted student. Rejected students are entered into the waitlist for that program. After students decide whether to take the admission offer, waitlisted students might be offered admission in a second instance of the centralized admission system. The algorithm guarantees that students are assigned to their most preferred program among those accepted.[9]. The student-proposing DAA used in the centralized admission system is strategy-proof, so applicants should report a rank-order list corresponding to their truthful preferences. In practice, students may omit programs perceived as beyond reach or irrelevant, but they are still matched with their favorite program among those they qualified for (Fack et al. [2019]).

Implementation of free college

In 2011, Chilean students led protests demanding higher education to become more affordable. The government in place reformed financing aid programs, but these did not include free college. In 2014, Chileans elected Michelle Bachelet for President, who promised in her campaign to make college free for all by 2020 (Bachelet [2013]). The discussion of free college

9. Three aspects of the system can affect this result as described by Bucarey [2018] First, the system allows students to rank up to ten options. If binding, students would need to act strategically given the possibility that they are not assigned to their most preferred option among those where they are eligible. However, just 1.5 percent of students rank ten alternatives, and only 0.02 percent are admitted to their tenth option. Second, some institutions restrict the positions where students can rank them to be considered for admission. Two of the 39 institutions will only admit students that rank them fourth or higher. However, 88 percent of students were admitted to one of their top three choices, so these restrictions are not binding to most students. Finally, the weighted score used by programs might include ties in the last admitted student, which the system solves by adjusting capacities to fit all students with identical scores. However, this does not impose violations on stability (Ríos et al. [2014])

started during the election campaign, and the details of President Bachelet's proposal were described in her proposal presented by the end of 2013. In 2015, more than a year into President Bachelet's tenure, free college was enacted and became effective for the admission process of 2016. Free college coexists with an array of financial aid instruments, including scholarships for students up to the third lower income quintile (Bucarey [2018]) and income-contingent government-backed loans with low interest rates (Aguirre [2019], Espinoza [2017], and Solis [2017]).[10] In 2017, the free college policy expanded to eligible vocational institutions, but today, the promise of free college for all has not been reached. It only covers the families in the poorest 60 percent, which implies that it effectively works as a voucher for disadvantaged students that coexists with other types of pre-existing financial aid.

Specifically, *before* the implementation of free college students pay for higher education with their resources, scholarships, or loans assigned by the government or internal scholarships from institutions. The government's financial aid was assigned based on socioeconomic and academic requirements; the particular amount that was given in terms of a scholarship or loan was set at the institution-program level according to *reference tuition*[11] which covers on average 80 to 90 percent of sticker price[12]. Through internal scholarships, students and their families or institutions paid the difference between sticker price and reference tuition. A vital element of implementing free college is that it removes this financial burden from eligible students, and the institutions lose these resources.

And *after* free college, the poorest 50 percent of families have access to free college if they enroll at a university in the centralized admissions system that chose to join the program. The participation of institutions depends on their eligibility for the program and

10. The financial aid alternatives are described in appendix A.0.1 in more detail.

11. Reference tuition is defined by the Ministry of Education of Chile using a formula that considers past levels of tuition and corrections for quality and inflation. For more details on how reference tuition is defined, see appendix A.0.1

12. In 2015, the average across universities was 84 percent. Appendix A.0.2 summarizes the main statistics of this difference and its distribution for different types of universities.

their choice to join. First, all public and private universities with four or more years of certification participate in the centralized admission system [13] is eligible to participate in free college. Given the eligibility restrictions, all traditional private institutions in the system are eligible, and approximately 40 percent of private institutions are.[14] Second, eligible institutions can decide whether or not to adhere to free college. In 2015, all public and private traditional institutions joined the program. These institutions constitute a collegiate council (CRUCH) that, since 1954, has the goal of coordinating the higher education system, and all its members tend to act as a block. It was expected that CRUCH universities decided to join and provide access to free college for low-income students. However, this was not necessarily the case for private non-traditional universities, and 8 of 13 eligible private non-traditional institutions did not join the program [15].

Free college is implemented as a voucher to demand, set at the institution-program level according to the baseline characteristics of the program. It is essential to reinforce the idea that free college implies an effective price of zero for eligible students. So institutions lose the price gap between sticker price and voucher. This introduces price differentiation between eligible and non-eligible students that only existed after free college.

Details about the definition of the voucher

The voucher v_{ij} defined by free college varies at the institution-program level based on the 2015 characteristics of the programs. It depends on the program's reference tuition and the institution's quality group in the following way. First, a regulated price r_{ij} is computed as

13. Private institutions that do not participate in the centralized admission system and meet the quality requirement can join if they have a transparent and non-discriminatory admissions system. In the time frame of this paper, only one institution joined through this channel.

14. The specific number depends on the year that these requirements are measured

15. Private institutions that abstained have the highest price gap, twice as much as those of those that joined the program. On top of this, they rely strongly on tuition as a source of revenue. Also, they enroll fewer eligible students on average. However, the variance within this group is high. Moreover, these private institutions have a similar quality to public institutions, and in terms of prices, some of them are similar to traditional private institutions

the mean of the reference tuition of all institutions in the same quality group. Then, the actual voucher is calculated using a known formula:

$$v_{ij} = p_{ij}^{15}\mathbf{1}\{r_{ij} \geq p_{ij}^{15}\} + min\{1.2r_{ij}; p_{ij}^{15}\}\mathbf{1}\{r_{ij} < p_{ij}^{15}\} \tag{1.1}$$

Where r_{ij} is the regulated price, and p_{ij}^{15} is the 2015 sticker price adjusted by inflation. If the sticker price is lower than the regulated price, the voucher is the sticker price. Otherwise, the regulated price is compensated in 20% and compared to the sticker price, and the minimum between the two defines the voucher. This formula is adjusted yearly.

As mentioned before, institutions that join free college lose the price gap between the sticker price and the voucher [16], as the policy introduces price differentiation between types of students.

$$gap_{ij} = min\{p_{ij} - v_{ij}; 0\} \tag{1.2}$$

1.2.2 Data

The Ministry of Education of Chile (MINEDUC) provides access to several data sets that follow high school graduates into higher education. Student-level data includes their application, enrollment and graduation, financial aid, and demographics. Application and enrollment data have PSU scores and the rank-order list of students participating in the centralized admission system. Enrollment information at the institution-program level is available for all students, even if they do not participate in the centralized admission system. The data also includes retention and graduation information depending on the cohort. Financial aid data specifies application and assignment and contains family income decile and quintile depending on the year.

MINEDUC also provides data at the program level. This includes sticker price, program

16. Figure B.1 on the appendix depicts the distribution of the gap for institutions that joined free college.

capacity, location, duration, accreditation, and study area. Moreover, since the implementation of free college, the data consists of the voucher defined by the policy. Finally, MINEDUC also publishes financial statements of the institutions since 2012, including revenue sources and internal scholarships at the institutional level.

The analysis time frame is from 2013 to 2017, and all the data mentioned before are available for these years. From the perspective of demand, I focus the analysis on students graduating from high school and first-time participants in the centralized admission system. And in terms of supply, I consider all the institutions that participate in the centralized admission system and all the undergraduate programs they offer.

This high-quality and finely-grained data supports my methodological approach to estimating demand and supply developed in the following chapters.

CHAPTER 2

DESCRIPTIVE EVIDENCE ON THE IMPLEMENTATION OF FREE COLLEGE

2.1 Introduction

This chapter presents descriptive evidence of the impacts of implementing free college on the higher education market. The analysis encompasses students' outcomes, such as application behavior and enrollment, and programs' outcomes, including their choice of price and capacity. To analyze the data, I use a difference-in-difference strategy with variations in treatment intensity at the program level.

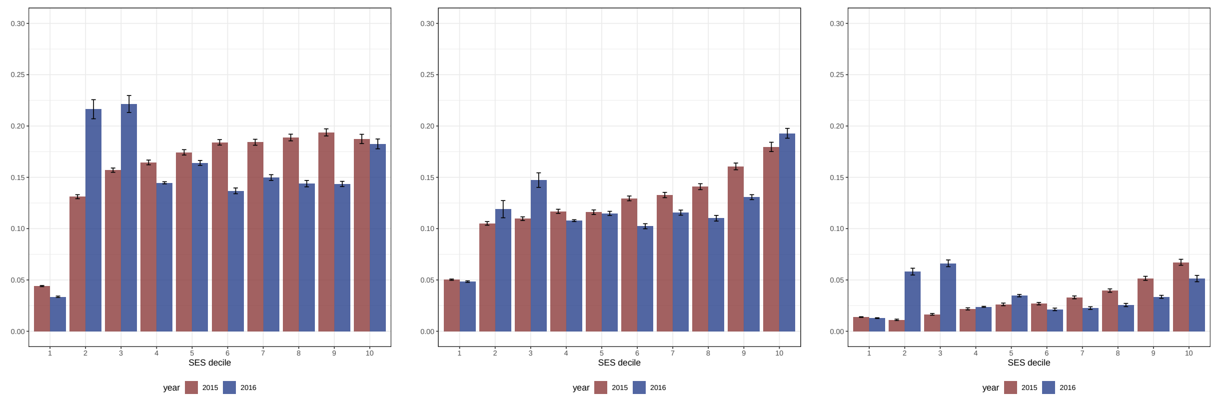
In the case of students, eligible students tend to increase applications and enrollment more in programs that were relatively more expensive before free college. On the side of supply, programs experienced a more significant increase in capacity and price if their revenue had decreased more, given the change in demand. This implies that programs that adjusted more are those where the policy significantly impacted revenue.

This evidence depicts equilibrium effects, and it only suggests potential mechanisms in which the implementation of free college could elicit responses from students and institutions. The next chapter develops and estimates a model of higher education to address the potential underlying mechanisms.

2.2 Impact on students' behavior

Implementing free college is associated with increased participation in higher education of eligible students for the policy. Particularly, the fraction of students who enrolled in different types of universities that joined free college grew, conditional on taking the college entry exam (PSU) and registering in a university. Low-income students in this group, especially those in deciles 2 and 3 of the income distribution, are more likely to enroll after the implementation of free college. They are more likely to enroll in a private university, as seen in Figure 2.1.

Figure 2.1: Enrollment in universities that joined free college, before and after implementation



(a) Public (b) Private traditional (c) Private

Notes: 95% confidence intervals
6+ students are not eligible for free college

The panels in Figure 2.1 describe the composition of students in different types of institutions that joined the policy. The change in this composition is expected because eligible students increase their participation, and this increase seems to be more pronounced in private institutions.

This increase in the participation of eligible students could be due to an increase in their applications or because they are more successful candidates after the policy. As described by Bennett [2020], the increase in enrollment of eligible students into institutions that participate in free college is mostly driven by growth in applications to these institutions. The impact on applications seems to be the consequence of a change in the preferences of students because the academic performance of eligible students did not change around the implementation of the policy [1] (Figure B.2 in the appendix). This does not imply that free college

1. Figures B.2 in the appendix present the distribution of the PSU scores around the implementation of the policy for different groups of students and years. The performance of low-income students seems to be stable in the years around the discussion and implementation of free college. Particularly, these figures depict

could not lead to an increase in the performance of eligible students in the long run, as free college reduces the cost of higher education for these students, increasing the return to higher education.

Prices are a relevant element in the application process because they impact utility negatively, all else equal. Free college affects students' preferences because it reduces the price of programs offered by eligible institutions to zero. Note that free college reduces prices for eligible students and reduces the uncertainty that eligible students face in financing higher education. Then, the effects of the policy confound these two effects. I perform a simple exercise that allows me to conclude that the price reduction might have affected preferences beyond the decrease in uncertainty.[2]

Given the increase in applications, enrollment in participating institutions should also increase but probably less than applications because the admissions process contemplates more factors, as explained in section 1.2. To explore this possibility and further describe the changes in demand, I use a difference-in-difference framework with variation in treatment intensity at the program level, similar to Finkelstein [2007] and Bucarey [2018].

$$y_{jt} = \delta_t + \delta_j + \sum_t \rho_t * e_j + \epsilon_{jt} \tag{2.1}$$

This approach compares programs with different pre-policy exposure e_j to free college

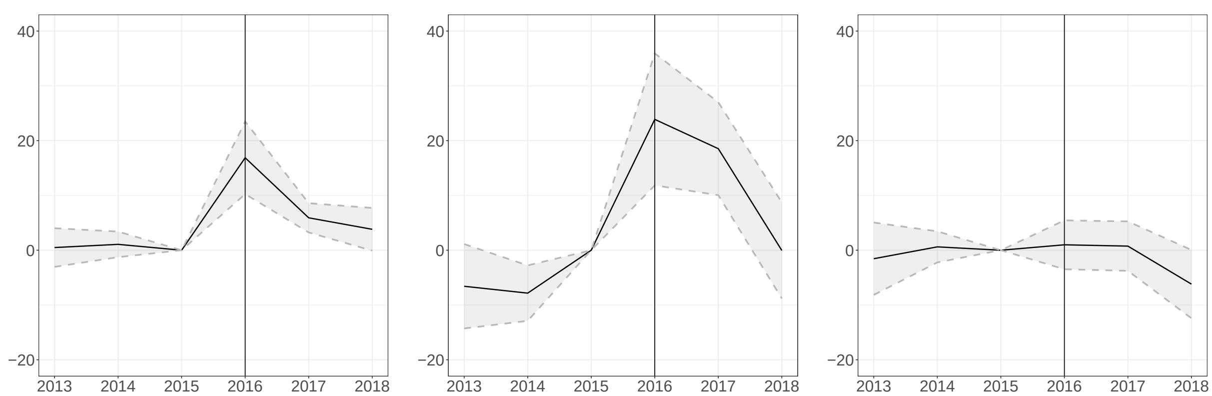
the mean of the Math and Language section of the test. These two sections are mandatory for all students taking the PSU, and all institutions in the centralized system consider these sections for program admission. Eligible students tend to have worse performance than non-eligible students. However, this disadvantage of eligible students dissipates if I compare the ranking score instead of Math and Language. The ranking score is based on the student's relative position in her cohort.

2. To separate both effects, I compare the price distribution of first-ranked programs of students from the 2015 cohort who would have been eligible for free college and were assigned a scholarship in 2015 with eligible students in 2016. Both groups secured financial aid after knowing their PSU scores, so they did not face uncertainty. However, eligible students in 2016 did not have to pay any out-of-pocket amount, whereas their 2015 counterparts might have paid the difference between the scholarship amount and tuition. Scholarships tend to cover 80 to 90 percent of sticker tuition; the remainder is paid by students out-of-pocket or institutions through internal scholarships. Figure B.3 in the appendix shows that the price distribution moved to the right after the implementation of free college, suggesting that the reduction in prices might have affected preferences beyond the decrease in uncertainty

before and after its implementation, as presented in (2.1). The outcomes of interest y_{jt} are applications and enrollment at the program level. And exposure e_j is measured as program j's relative price in the baseline year 2015.

Eligible students tend to increase applications and enrollment more in programs that were relatively more expensive before free college, which is consistent with a change in preferences due to the price reduction induced by the policy. This is consistent with the results of Castro-Zarzur et al. [2022] suggesting that eligible students moved away from teaching programs after free college was implemented, which are relatively cheap compared to other programs, to programs with higher returns.

Figure 2.2: DID: Change in applications of eligible students -
Exposure is the relative price in the baseline year 2015

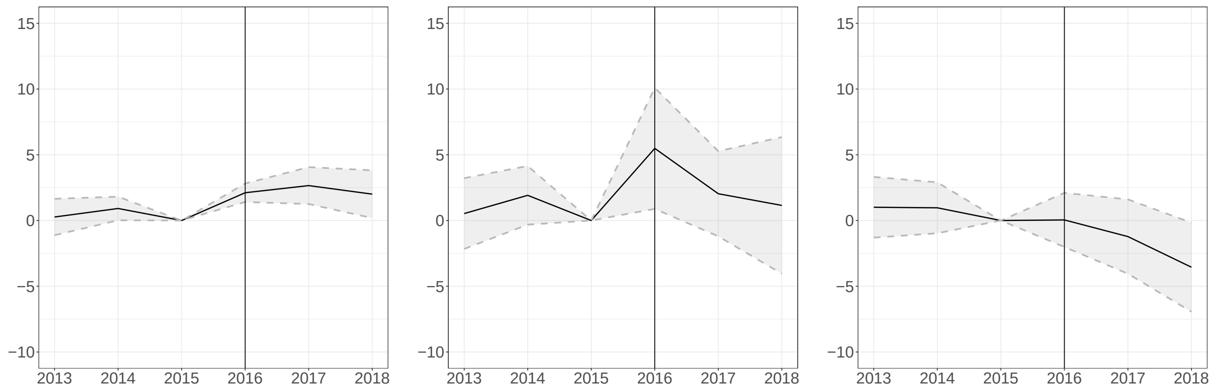


(a) CRUCH universities (b) Private in free college (c) Private outside free college

Note: 95% confidence intervals. Scaled coefficients. Regression results in the appendix (table B.2).

Figure 2.2 presents the results of (2.1) for applications. Applications in 2016 increased more in relatively more expensive programs compared to 2015; programs that are one standard deviation above the mean of the relative price increased their applications in more than 20 students in CRUCH universities and almost 40 students in private universities. However, programs from institutions that did not join free college did not change their applications significantly. Note that the increase in the application is mitigated or even reduced in 2017 onwards. This is most likely because of the 2017 expansion of free college to a group of high-quality vocational institutions, which makes the outside of eligible students more attractive.

Figure 2.3: DID: Change in enrollment of eligible students -
Exposure is the relative price in the baseline year 2015



(a) CRUCH universities (b) Private in free college (c) Private outside free college

Note: 95% confidence intervals. Scaled coefficients. Regression results are in the appendix (table B.3).

I do the same analysis to explore the changes in enrollment in the context of (2.1). Figure 2.3 shows the results. As mentioned, free college positively impacts eligible students' enrollment, but the effect is smaller than on applications. This is because enrollment is an equilibrium outcome that depends on more than preferences. Enrollment of eligible students in 2016 in programs that are one standard deviation above the mean of the relative price increased by almost two students in CRUCH universities and nearly five students in private universities. Their enrollment seems to decrease in institutions that did not join.

It is essential to mention that changes in enrollment could impact the composition of students within programs. Bucarey [2018] suggests that free college could crowd out low-income students. The mechanism of this crowd-out is through negative spillovers to students receiving financial aid before implementing free college. These spillovers capture the correlation between family income and academic performance. As the scholarship expands toward higher-income groups, it reaches more high-performance students who apply and replace beneficiaries with lower performance. This spillover effect does not directly account for responses of the institutions that could have enhanced or counteracted the crowd-out effect, which is relevant as enrollment is an outcome that confounds multiple factors, including institutions' decisions. I describe the responses of institutions in the next section.

2.3 Impact on programs' choices

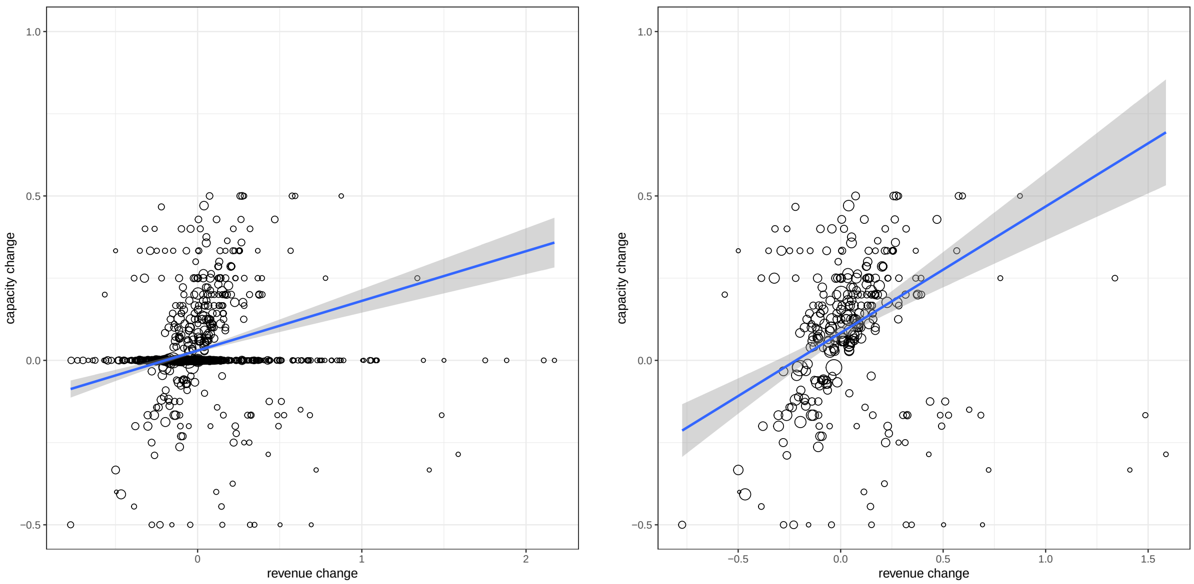
Free college is a market shock that could have impacted institutions' capacity and pricing decisions according to exposure to free college. This exposure mediates the impact of the policy and varies across institutions and programs accordingly. The policy affects institutions by reducing their revenue because it operates restricting prices for eligible students, as seen in the definition of the voucher (1.1). Then, exposure is defined as the impact on revenue that programs would have if they do not change their capacities and prices, but the preferences of eligible students do respond to free college.

Exposure is defined by comparing the revenue of the programs under two different allocations of the DAA. First, the allocation from the 2015 DAA considers the rank-order lists of students from 2015 and the actual prices and capacities from 2015. And secondly, the allocation from a counterfactual DAA without responses from institutions that uses the rank-order lists of students from 2016 but keeps capacity and price fixed at 2015 levels.

$$Exposure_j = Rev_{j,\text{DAA 2015}} - Rev_{j,\text{DAA without responses}} \tag{2.2}$$

Program j is negatively exposed if, given its 2015 capacity and prices, the change in students' preferences implies a reduction in revenue. Then, institutions may change their menu of capacity and price in response to the expected revenue change of programs induced by the implementation of free college. Figures 2.4 and 2.5 explore this possibility in the raw data.

Figure 2.4: Changes in capacity are related to exposure to the policy -
2016 change in capacity at the program level



(a) All changes

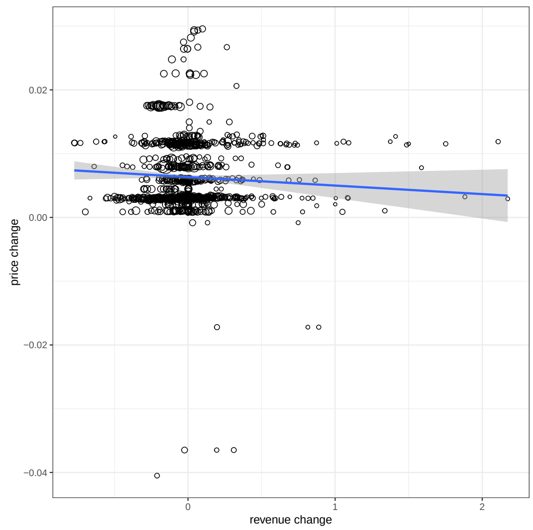
(b) Non-zero changes

Note: These figures only include capacity changes between -50 to 50 percent. Each dot and the fitted line are weighted by 2015 enrollment. 95% confidence intervals. Axis is in percentages. Panel (b) only includes non-zero changes of capacity; these represent 30 percent of cases.

Figure 2.4 shows the capacity change, at the program level, between 2015 and 2016 and its relationship with the shift in revenue measured by the exposure variable, both in percentage terms. The data features some big and small changes in capacity, but it seems like a relationship with revenue change emerges; programs for which the change in revenue is positive and significant also experienced an increase in capacity, and capacity decreases for those programs with a substantial decrease in revenue. However, note the concentration around zero capacity change. This might suggest that changing capacity is costly. As expected, the relationship becomes more robust if zero capacity changes are removed.

Figure 2.5 depicts the percentage change in real prices from 2015 to 2016 and its relationship to percentage revenue change. Price changes are primarily positive and no larger than 2 percent, equivalent to almost 60 dollars in the sample. This change might seem small, but institutions have multiple programs and enroll thousand of students [3].

Figure 2.5: Changes in price are related to exposure to the policy -
2016 change in prices at the program level



Note: Each dot and the fitted line are weighted by 2015 enrollment. 95% confidence intervals. Axis is in percentages.

I introduce more structure to the data analysis using a difference-in-difference framework with variation in treatment exposure at the program level.

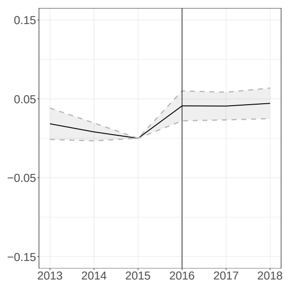
$$log(y_{jt}) = \delta_t + \delta_j + \sum_t \rho_t * e_j + \epsilon_{jt} \tag{2.3}$$

The outcomes of interest $log(y_{jt})$ are capacity and price changes at the program level, and exposure e_j is revenue change defined in (2.2) standardized at the institution level. Figures 2.6 and 2.7 show the results of the estimation of (2.3) for all institutions and particular groups of institutions.

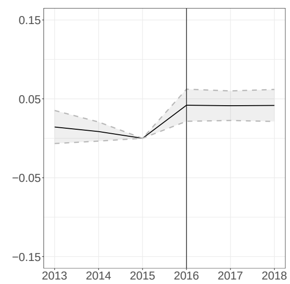
In general, programs more exposed to free college within an institution increase their capacity more after implementing the policy. This result holds across types of institutions,

3. In 2016, the average number of programs per institution was 42, and the average first-year enrollment was 59.

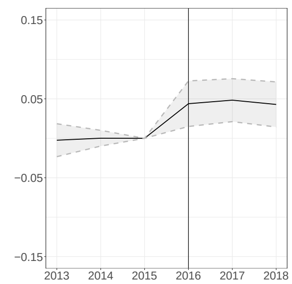
Figure 2.6: DID: Percentage change in program's capacity -
Exposure is standardized revenue change



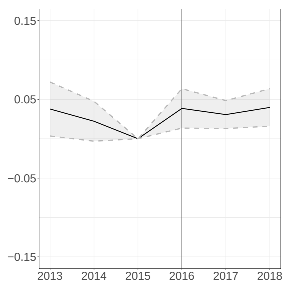
(a) All joined



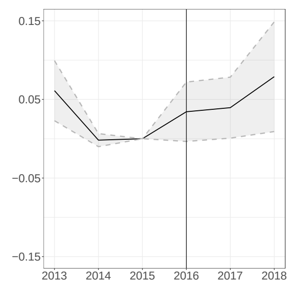
(b) Cruch



(c) Public



(d) Private traditional



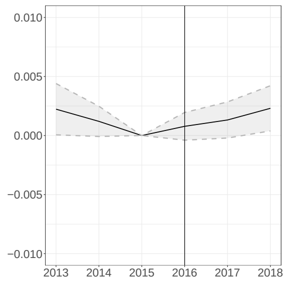
(e) Private

Note: 95% confidence intervals. Regression results are in the appendix (table B.4).

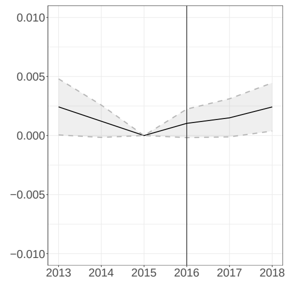
and the effect level is similar and stable over time, except for private institutions. However, these institutions represent a small part of the sample, so this group's results are noisier. The difference-in-difference analysis suggests that the relationship between revenue change and capacity change remains after controlling for a year and a program fixed effect. This implies the impact of free college on institutions' revenue might have driven changes in capacity within the institution related to how the policy operates. Programs that are favored from a revenue perspective by the shift in preferences of students tend to increase their capacity more relative to the years before the policy.

Moreover, Figure 2.7 shows the results of (2.3) for price changes. Similarly to the effects on capacity, the mechanism of revenue change seems to affect price changes after the implementation of the policy. Programs that are more exposed to free college within an institution

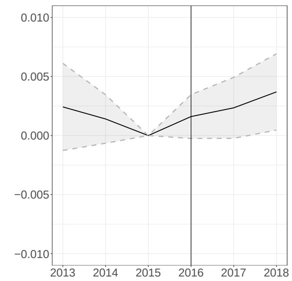
Figure 2.7: DID: Percentage change in program's price -
Exposure is standardized revenue change



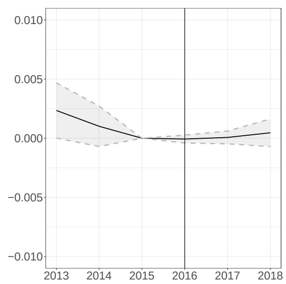
(a) All joined



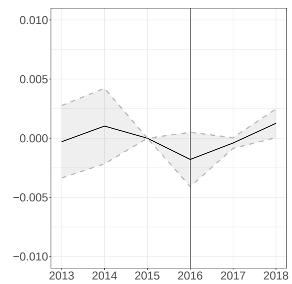
(b) Cruch



(c) Public



(d) Private traditional



(e) Private

Note: 95% confidence intervals. Regression results are in the appendix (Table B.5).

increase their prices more after implementing free college. This impact on the price change is small, but it seems consistent across all types of institutions. And as it was mentioned before, each institution has multiple programs and has enrollment in the thousands. This result in price changes is less clear for private institutions.

CHAPTER 3

AN EMPIRICAL MODEL OF HIGHER EDUCATION

3.1 Introduction

This chapter develops and estimates a demand and supply model of the higher education market. Preference heterogeneity is captured thanks to the rich observable data at the student level in the spirit of Hastings et al. [2017] and Abdulkadiroğlu et al. [2020]. The estimation of the demand model uses policy variation and across-market variation to capture price sensitivity and the valuation of a set of characteristics of the programs. The results are consistent with the evidence in chapter 2. The model predicts that students who were not eligible for financial aid before free college are more price sensitive than those who were. Also, students right below the income eligibility cutoff of the policy are less price sensitive than those right above, even though the latter have higher incomes. This is consistent with the reduced form evidence suggesting that eligible students increased their applications more in those programs that were more expensive before the implementation of free college.

The supply model is a discrete choice model in which programs maximize profits by choosing price and capacity. These choices play a different role in rationalizing demand because of the price differentiation introduced by the free college policy. The model results indicate that the expansion or contraction of capacity might substantially impact the access to education at the margin of enrollment than price changes.

The evidence from the model aims to address the potential underlying mechanisms behind the impact of free college on student welfare. This is analyzed by comparing counterfactual scenarios of the implementation of free college.

3.2 Empirical model

3.2.1 Equilibrium

The centralized admissions system is based on Gale and Shapley [1962], and so the definition of equilibrium is given by stability. Section 1.2 describes in detail the implementation of the algorithm and discusses its stability for the Chilean case.

The algorithm generates a stable match μ that allocates students to programs, given the reported preferences of students and the capacity of each program k_j. The allocation also defines a cutoff score $\underline{c}_j$ for each program that corresponds to the PSU score of the last enrolled student.

$$\underline{c}_j = \underset{n \in \mu_j^{-1}}{Min}\ e_j \tag{3.1}$$

Where n_j corresponds to students who apply to program j, and e_j is the vector of scores of these students.

The implementation of free college does not affect the definition of equilibrium. However, it does affect the allocation produced by the matching function μ because both the preferences of students and the price and capacity of the programs can be affected by the policy.

3.2.2 Preferences

The proposed demand model follows Hastings et al. [2017] and Abdulkadiroğlu et al. [2020]. Let U_{ij} denote student i's utility of enrolling in program j, and $\mathcal{J} = \{1, ..., J\}$ is the set of all available programs. The first program ranked by a student i is defined by:

$$R_{i1} = \arg\max_{j \in \mathcal{J}} U_{ij}$$

And subsequent ranks satisfy:

$$R_{ij} = \underset{j \in \mathcal{J} \ \{R_{im:m<k}\}}{\arg\max} U_{ij}, k < 1$$

Student i's rank-order list is then $R_i = \{R_{i1}, ..., R_{il(i)}\}$, where $l(i)$ is the length of the list submitted by student i. Student i's utility from enrolling in program j is:

$$U_{ij} = p_j \alpha_{c(X_i)} + X_j \beta_{c(X_i)} + \xi_j + \epsilon_{c(X_i)j} = \delta_{c(X_i)j} + \epsilon_{c(X_i)j} \tag{3.2}$$

$c(X_i)$ is the function that assigns students to covariate cells based on the variables in the vector X_i. p_j is the price of program j, X_j and ξ_j are observed and unobserved characteristics of program j, and $\epsilon_{c(X_i)j}$ is the unobserved match utility. The parameter $\delta_{c(X_i)j}$ is the mean utility of program j for covariate cell $c(X_i)$. I assume that $\epsilon_{c(X_i)j}$ follows an iid extreme value type I distribution conditional on $\delta_{c(X_i)j}$.

This utility function follows Hastings et al. [2017], where flexible preference heterogeneity is captured using observed student characteristics. Students have the exact match utility and preference parameters within each cell, and no structure is imposed on preferences within cells. This strategy allows estimating the mean utility of multiple programs leveraging rich observable data.

Therefore, equation (3.2) is a rank-ordered multinomial logit model (Hausman and Ruud [1987]). I restrict the choice set of students from all programs to CS_i. Hence, the conditional likelihood of rank-list R_i is:

$$L\left(R_{ij}, X_j\right) = \prod_{r=1}^{l(i)} \frac{exp\left(\delta_{c(X_i)_{R_{ir}}}\right)}{\sum_{j \in \mathcal{J} \setminus \{R_{im}:m<r\}} exp\left(\delta_{c(X_i)_j}\right)}$$

This specification allows for flexible preferences and heterogeneity in tastes by estimating models separately for more than 430 covariate cells defined by the intersection of the region, terciles of PSU score, free college eligibility, financial aid eligibility other than free college, elective PSU sections, and year. The definition of the cells can be adjusted to fit a counterfactual of interest. For example, I could use groups of income deciles instead of using free college eligibility. This would be relevant in the case of analyzing a counterfactual where free college expands to a particular decile and not to all that are not eligible.

Students rarely rank programs outside their zone of residence [1], also PSU scores and the elective sections of the test restrict which programs are available for students. The restriction of the choice set of students also reduces the large choice set dimensionality of the problem. In my setting, including all programs in the centralized admission system would account for more than 1300 programs. The restriction of the choice set is the product of the interaction of students' characteristics, test scores, and program cutoff scores. The choice set is defined at the cell level as it considers the actual preferences of students within each cell. But the choice set is also restricted for each student within the cell because it considers her test scores and cutoff scores. [2].

Conditional on these elements, the choice set of student i depends on the cutoff scores of the programs.

$$CS_i\left(e_i, X_i, \mathbf{c}\right) = \left\{j \in J_i | \underline{c}_j \leq e_j^i\right\}$$

Where the characteristics of students restrict the program under consideration to J_i and

1. Just like Bucarey [2018], I consider three macro zones that can represent markets because 80 to 70 percent of the programs listed in the rank-order lists of students are in their same region of residency.

2. The choice sets are determined across and within each cell. The restrictions across cells are based on cell definition and how this definition is related to the actual preferences of students. For a particular cell, the choice set is defined considering the existing rank-order list of all the students in that cell. This reduces all available programs to those considered by students in a particular cell. Then, the specific choice set of student i in cell c is restricted considering the student's test scores and the cutoff scores of the programs. All programs with a cutoff score of 50 or more points above the student's score for that program are filtered out of her choice set. Bucarey [2018] and Hastings et al. [2015] also create personalized choice sets based on students' test scores for the case of the Chilean higher education market.

PSU scores available programs to $CS_i\left(e_i, X_i, \mathbf{c}\right)$ as mentioned before.

I assume that once free college is implemented, the utility of eligible students is not affected by price. This assumption restricts the model because once controlling for other resources and characteristics of the program, as seen in equation (3.2), a price change affects program characteristics that are relevant from the perspective of students' preferences.

Maximum likelihood estimation of the preference parameter produces a list of the program mean utilities used to estimate price sensitivity and the valuation of other program characteristics. The estimation of demand is discussed in section 3.3.

3.2.3 Market shares

The equilibrium mechanism allocates students into programs given the rank-order list of students and the programs' inputs. This allocation is assumed to be pair-wise stable. Stability implies that everyone chooses their favorite program within their choice set.

The allocations induced by the assignment algorithm are translated into market shares for each program j.

$$s_j = s(\mathcal{R}, p_j, \mathbf{p_{-j}}, k_j, \mathbf{k_{-j}})$$

Total enrollment in program j depends on the vector of rank-order lists $\mathcal{R}$ of all students participating in the centralized system of admissions and of inputs of the programs such as prices $\mathbf{p}$ and capacity $\mathbf{k}$.

Enrollment can be written for particular groups of students, conditioning on their characteristics. Income is a characteristic of particular interest because the free college policy is based on it. Suppose eligible students are those with income m_i less than $\bar{m}$.

$$s_j^l = s(\mathcal{R}, p_j, \mathbf{p_{-j}}, k_j, \mathbf{k_{-j}}; m_i \leq \bar{m})$$
$$s_j^h = s(\mathcal{R}, p_j, \mathbf{p_{-j}}, k_j, \mathbf{k_{-j}}; m_i > \bar{m})$$

These definitions are used later in the objective function of the institutions offering different programs.

It is essential to highlight that these shares are affected differently by changes in price because, even though eligible students are not affected directly by prices, their share of enrollment is. Price changes affect the rank-order list of non-eligible students, which impacts the allocation from the deferred acceptance algorithm and the vector of cutoff scores. Then, the price sensitivity of s_j^l depends on the latter. If p_j increases, the utility of non-eligible students decreases, and program j is less likely to be included in their rank-order list. Then, the cutoff score of program j, $\underline{c}_j$, decreases because some non-eligible students who applied and enrolled in program j do not do it anymore once p_j increases. Therefore, the share of eligible students who enroll in program j has to increase, and $\partial s_j^l \partial p_j \geq 0$ due to the decrease in $\underline{c}_j$.

3.2.4 Supply

Programs report their price and capacity before students apply to the centralized admission system. Both choices are inputs for the final market shares. Whereas capacity is a direct input of the algorithm, price, on the other hand, is an indirect input that operates through preferences. Some programs may be oversubscribed, given the price level and capacity chosen.

Programs are not perfect substitutions, and they have different qualities. In this context, they compete with each other to attract students. The DAA allocation determines enrollment, and programs can not accept or reject students based on any student observable characteristics not included in the assignment mechanism.

In my setting, programs have to deal with price differentiation between students who are and are not eligible for free college. This price differentiation affects the program's revenue but also makes eligible students avoid facing prices. This leaves capacity as the only tool that could affect the enrollment of eligible students.

A simple pricing model illustrates how price differentiation shapes the equilibrium. In such a model, the markup is defined by the following expression,

$$\frac{p_j^* - C^{'}(s_j^*)}{p_j^*} = \underbrace{-\frac{1}{\eta_{jj}^{*h}}}_{1} - \underbrace{\frac{v_j}{p_j^*}}_{2} \underbrace{\frac{\frac{\partial s_j^l}{\partial p_j}}{\frac{\partial s_j^h}{\partial p_j}}}_{3} \tag{3.3}$$

Equation (3.3) groups the determinants of the markup under price differentiation into three. The first determinant of the markup is the price elasticity of non-eligible students. With price differentiation, program j only considers the elasticity of non-eligible students to determine its price. If non-eligible students, who have a higher income than eligible students, are less sensitive to price, then the markup would be more significant than without price differentiation.

The second determinant is the ratio between the voucher defined by the policy and the sticker price of the program j. The voucher reduces program revenue because it produces a gap between the sticker price and the transfer to the program for each eligible student who enrolls, as seen in equation (1.2). This reduction in revenue pressures the markup up. This pressure is mediated by the third determinant, which captures the fraction of eligible to non-eligible students at the margin of enrollment. Note that $\partial s_j^l \partial p_j \geq 0$ because as the price of the program goes up, the enrollment of eligible students cannot decrease because their preferences remain the same and the enrollment of non-eligible students cannot increase. Then, if there are no eligible students at the margin of enrollment, the gap between the sticker price and the voucher does not affect the markup. And on the contrary, when this fraction is large, the effect of the voucher on the markup increases.

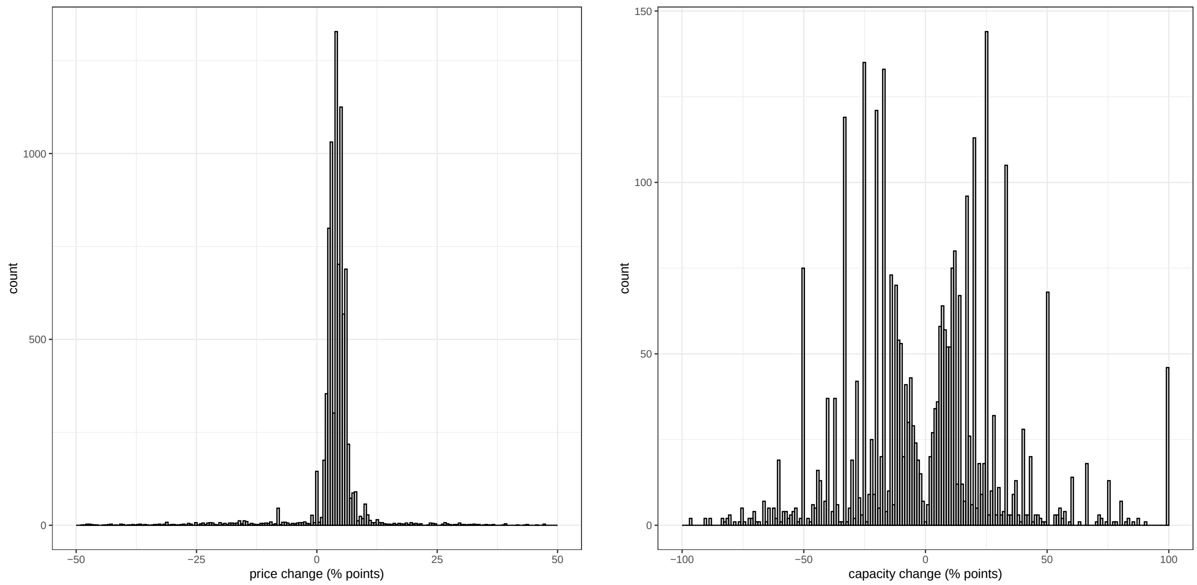
Equation (3.3) highlights that price and capacity are tools that affect the enrollment of eligible and non-eligible students differently. Mainly, capacity is a tool that could affect revenue beyond prices in the presence of students who do not respond to prices. In the appendix A.0.3, I describe two more simple models that show this role of capacity and how pricing and capacity decisions might be affected when the policy introduces differential prices.

3.2.5 An empirical model of supply

The supply model is a price and capacity discrete choice model where programs maximize profits. The reason for the simplification of the action space is two-folded. First, the standard approach supposes computing and inverting first-order conditions to recover the marginal cost. This inversion needs the price elasticity of all programs. But in this empirical setting, some programs are oversubscribed, and the elasticity would be zero for price changes that are small enough. Moreover, the DAA mediates the elasticity, and it does not have a closed form and could be discontinuous. All these make computing price elasticities computationally intensive. Then, the discretization of the action space is a solution to reduce this complexity and makes the model tractable.

Secondly, the discrete action model better captures how programs choose prices and capacity. Programs negotiate with the institution they belong to determine prices and capacity. In practice, these variables do not experience precise changes every year. The data suggest that price and capacity changes are restricted and could be modeled as a discrete variable. Figure 3.1 depicts the sample's real price and capacity changes. Ninety-five percent of price changes are nonnegative, and the mean of these changes is 3.9 percent. Regarding capacity changes, almost two-thirds of the programs in the sample do not change their capacity. The remainder of the changes is divided almost evenly between positive and negative, where the median of the former is 20 percent and of the latter is minus 20 percent.

Figure 3.1: Changes in price and capacity
All observations from 2013 to 2018



(a) Price changes (b) Capacity changes

Note: These figures include price changes between -50 to 50 percent and capacity changes between -100 to 100 percent. Panel (a) depicts changes in real prices. Panel (b) only includes non-zero changes of capacity; these represent 36 percent of cases.

In the discrete choice model, program j chooses between pairs of price and capacity actions, $\{p_{ja}, k_{ja}\}$. Price actions are defined relative to the change in reference tuition. Recall that reference tuition is the amount of financial defined by the government at the program level (see appendix A.0.2. The price and reference tuition changes are similar, with almost the same nonnegative changes and descriptive statistics. Then, the price actions are no change, same change, and more change than the change in reference tuition, or $p_j \in \{p_{j1}, p_{j2}, p_{j3}\}$ [3]. The rationale behind this particular conceptualization comes from the

3. I follow four steps to compute action prices. First, I calculate the change in reference tuition in a particular year, also known by programs. Second, I calculate this change's ratio to the sticker price shift. Third, I compute the thirds of the distribution of the ratio. These thirds are 0, 1, and 2.25, which I call

data and is related to the Bennett Hypothesis.

Capacity actions k_{ja} are increase, no change, decrease relative to the initial capacity level of the program, or $k_{ja} \in \{k_{j1}, k_{j2}, k_{j3}\}$ [4]. The specific level of change comes from the data.

Programs have different choice sets in this discrete choice model because of how price and capacity actions are defined. The choice set variation at the program level is linked to the characteristics of the programs, particularly their reference tuition and the initial capacity level. Moreover, this model presents a local profit function in that it is specified for the set of choices within the choice of the program.

Program j chooses p_{ja} and k_{ja} to maximize profits by comparing nine combinations. The profits from choosing p_ja and k_ja are,

$$\pi_j\left(p_{ja}, k_{ja}\right) = p_{ja} N s_j\left(p_{ja}, k_{ja}; p_{-j}, k_{-j}\right) - (c_0 + c_1 k_{ja}) k_{ja} + d_{Institution-Action} + \sigma \eta_a \quad (3.4)$$

Where s_j is the market share resulting from the DAA, $\{c_0, c_1\}$ are the cost parameters, $d_{Institution-Action}$ are a set of fixed effect grouping programs from the same institution, and η_{ja} is a logit error defined at the action level and not at the level of the marginal cost. This implies that the action has a dollar impact, which could be driven by the interaction with the centralized institution, as mentioned before.

It is essential to highlight that prices and capacity impact profits through the DAA, and each might do it differently. For example, if programs are oversubscribed, a price change might not change the market share, but if capacity changes, this would have a one-to-one effect on the market share.

The marginal cost is flexible enough to introduce variation in the cost parameters c_0 and c_1. These parameters might vary before and after free college and by programs' charac-

change factors. And finally, I use these change factors to express sticker price in terms of action prices.

4. A third of the sample changes its capacity from one year to next, and the median change is 20 percent. I compute the thirds of the distribution of capacity changes, and these thirds are -0.2,0,0.2, which I call change factors. Then, I use these change factors to express capacity in terms of action capacity.

teristics. However, the data variation does not allow estimating c_0 and c_1 at the program level.

As mentioned, the logit error is defined at the action level, typical for the consumer problem where utility is ordinal. In this context, profits are cardinal, and the error is measured in dollars, implying that the action impacts profits directly. Introducing this error smooths out the profit function and allows for estimation while approximating an error at the cost level. A strategy to deal with part of the interpretation of the specification is to add the fixed effects at the institution-action level. This captures a structure in the error term and introduces dependencies between programs that belong to the same institution. These dependencies allow me to measure how aligned programs are within the same institution, a summary of coordination.

3.3 Estimation and identification of the demand model

Based on the preferences of students described in section 3.2.2, maximum likelihood estimation of the preference parameter produces a list of the program mean utilities $\hat{\delta}_{jct}$ that is used to estimate price sensitivity and the valuation of other program characteristics.

$$\hat{\delta}_{jct} = p_{jtc}\alpha_c + \sum_r X_{rjt}\beta_{cr} + \gamma_j + \gamma_c + \gamma_t + \gamma_{\text{Inst-Area}} + \gamma_{\text{j is new}} + \epsilon_{jct} \tag{3.5}$$

Where p_{jtc} is the price of program j for cell c at year t, X_{rjt} includes: program j's mean PSU score, its size, the fraction of students from private HS and the fraction of students from low SES. This specification also includes a set of fixed effects: program, cell, time, institution area, and a dummy for new programs. The cell fixed effect is the cell-specific estimate of mean value and depends on the particular choice set defined at the cell level.

This specification groups all estimates $\hat{\delta}_{jc}$ across years and controls for time fixed effect to compute α_c at the cell level. This assumes that the underlying preference parameters are the same for each cell regardless of time; however, time matters because it affects the menu of available programs for students and their prices.

In principle, the challenge to estimating equation (3.5) is that the price of a program can be correlated with unobserved program quality. Then, to identify these parameters, I follow a strategy based on a policy instrument constructed using the implementation of the free college policy.

The free college policy uses an arbitrary income cutoff to separate students between eligible and non-eligible for free college. Then, eligible students face exogenous price variation introduced by the policy. In this sense, a program's price after the policy's implementation is an instrument with a perfect first stage.

For non-eligible students, price variation after free college is a choice of institutions that could be correlated with unobservable program quality. Then, I construct a price instrument for these students that uses price variation of a similar program, at the cell level, in different regions. For a particular program in the region 1, there are other similar programs [5] in regions 2 and 3, and the instrument is constructed using the prices of those programs. Notably, it considers the price of those programs for a specific cell.

This instrument is exogenous because regions are similar to different markets from the student's perspective. Moreover, this instrument is relevant because it captures price variation from other markets related to program characteristics but not student choice.

This strategy is complemented by incorporating fixed effects that alleviate the relationship between price variation and program quality. For instance, program fixed deals with across-program price variation, and cell fixed effect with across-cell variation in the quality of the outside option faced by different cells. Time fixed effects account for time variation that affects all programs. The fixed effect that combines institution and area of knowledge accounts for variation across different types of programs provided by institutions of varying

5. The definition of a similar program is based on MINEDUC's classification of the area of knowledge of the program.

quality.

The estimation of (3.5) is done by 2SLS separately for two types of students: eligible and non-eligible. The instruments for price are based on the policy and defined as described before.

3.3.1 Results

Recall that cell definition could vary depending on the counterfactual of interest. This section presents results for one particular definition of cells where free college eligibility is a binary characteristic of students. And the appendix A.0.4 shows the results for cells where free college eligibility is broken down into income deciles: 1 to 4, 5, 6, 7 to 10, and unknown [6]. The first definition is aligned with the current specification of the supply model, and it is consistent with a counterfactual of free college for all. Whereas the second definition allows analyzing counterfactual scenarios in which the expansion of free college occurs only for certain groups.

Cells defined using free college eligibility as a binary characteristic.

The results are presented separately for cells eligible and non-eligible for free college, in tables 3.1 and 3.2, respectively. The tables are organized as follows. The upper panel shows the estimation of the coefficients of (3.5) in levels, and the bottom panel contains the coefficients in dollars, in absolute value, for ease of interpretation.

The results are generally as expected. Table 3.1 presents the results of the second stage estimation by OLS for the cells with free college. As explained before, these are the cells for which the policy instrument has a perfect first stage. Note that price sensitivity is negative and more significant for students in cells that are not eligible for other financial aid before

6. Students have to apply to be eligible for financial aid, including free college. After they apply, their income is verified and classified into income deciles. Students who do not apply do not get an income decile group.

free college. This result is consistent with the fact that students who were not eligible for financial aid before free college faced a menu of prices with larger prices than the menu of prices of students who were eligible for other aid before free college.

Secondly, consider the bottom panel of table 3.1. This shows the dollar value of other characteristics of the programs. The most valuable feature is the mean PSU of the program, which measures the program's quality—I also noticed that the coefficient on the fraction of students who graduated from private schools is negative. The coefficient on the fraction of students from low SES is positive after controlling for the program's quality. This could be capturing the fact that students prefer to have similar peers. Students eligible for free college have lower SES than those who do not, and enrollment in private schools represents less than 10 percent of total enrollment.

Table 3.2 presents the second set of results. This corresponds to those cells that are not eligible for free college, and the estimation uses an instrument at the cell level, as described before. The first column is the OLS estimation, and the subsequent columns are the IV estimation for different groups of students.

Consider the upper panel of table 3.2; the OLS price is not statistically different from zero. At the same time, the IV estimate is negative and implies a higher price sensitivity than the OLS estimate. This suggests that price is positively correlated with unobservable characteristics of the programs, and if this relationship is not taken into account, the price sensitivity would be biased towards zero.

Moreover, just like table 3.1, students who are not eligible for financial aid other than free college are more sensitive to price. Furthermore, among this group, comparing students who qualify for free college with those who do not reaffirm the fact that price sensitivity depends on the menu of prices that students face because students who access free college face a price of zero in participating institutions even if they are not eligible for other aid.

And also, similar to the previous case, mean PSU is the most valuable characteristic of programs. The critical difference between the cells eligible for free college and those not is that the fraction of low SES students reduces the value of programs for the latter. This result could be explained again because students prefer peers who are similar to them, and students who are not eligible for free college have higher SES than those who are.

The results from estimating an alternative definition of cells, using income decile instead of eligibility, are presented in A.0.4. The results suggest that students right below the income eligibility cutoff of the policy are less price sensitive than those right above, even though the latter have higher incomes. This is consistent with the reduced form results suggesting that eligible students increased their applications more in those programs that were more expensive before the implementation of free college. This reflects that eligible students experienced an exogenous change in price that effectively reduced the price they paid to zero.

Finally, figure 3.2 depicts the elasticity of eligible and non-eligible students derived from the demand estimation. The figure includes observations at the student-program level and is restricted to years 2013 to 2015 because eligible students do not face prices after that. The elasticity considers different price sensitivity parameters and program menus because students have their choice sets. Then, note that non-eligible students with higher incomes are less price sensitive. In my empirical setting, where PSU scores and SES are correlated, non-eligible students have more high-quality programs in their choice set, which could also be related to less price sensitivity.

3.4 Estimation and identification of the supply model

The model described in section 3.2.5 and captured in equation (3.4) is estimated by multinomial logit using the following specification,

$$\tilde{\pi_j}\left(p_{ja}, k_{ja}\right) = \gamma rev_{ja} - (w_0 + w_1 k_{ja})k_{ja} + \tilde{d}_{X_{Inst-Action}} + \eta_a \tag{3.6}$$

Table 3.1: Second stage - Cells eligible for free college
Estimation by OLS

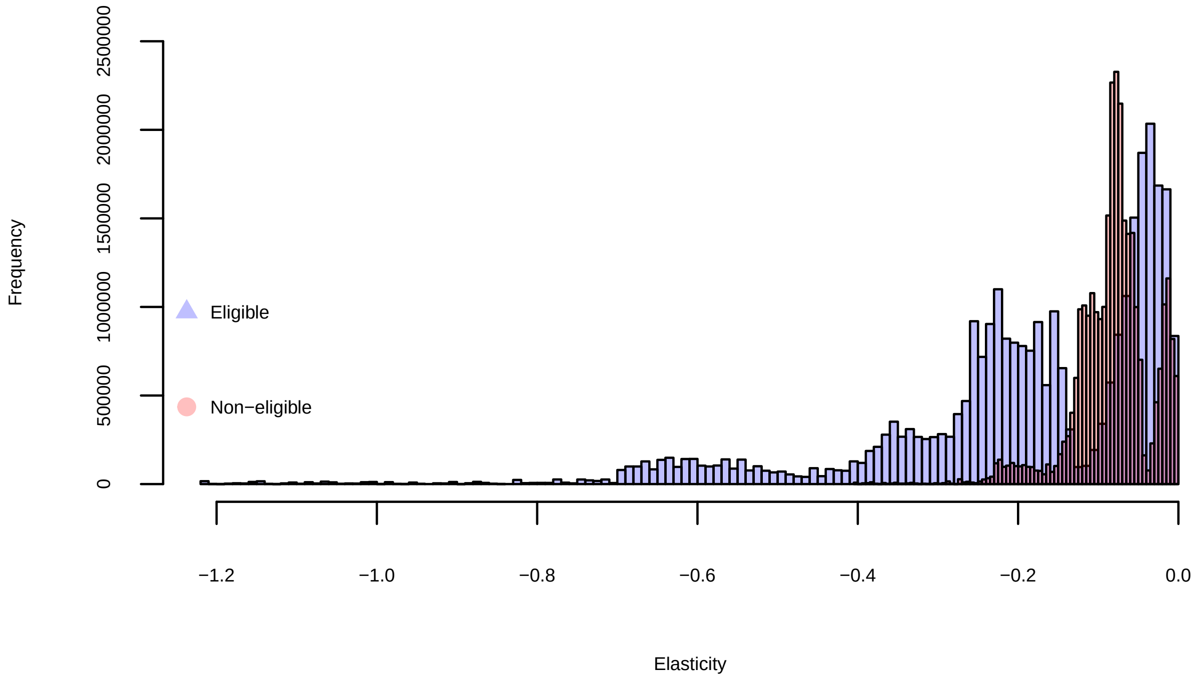
	Dependent variable: $\hat{\delta}_{jct}$		
	All	Aid Eligible	Aid Ineligible
Price (dollars)	-0.0001^{***}	-0.00003^{***}	-0.0001^{***}
	(0.000004)	(0.00001)	(0.00001)
Mean PSU (std)	1.01^{***}	0.82^{***}	1.29^{***}
	(0.03)	(0.04)	(0.05)
Number of students	0.003^{***}	0.003^{***}	0.002^{***}
	(0.0004)	(0.0005)	(0.001)
Fraction private HS	-0.46^{***}	-0.66^{***}	-0.34^{**}
	(0.11)	(0.13)	(0.17)
Fraction low SES	0.29^{***}	0.37^{***}	0.16
	(0.07)	(0.08)	(0.11)
	Fraction $\left\|\frac{\alpha}{\beta_r}\right\|$ in dollars		
Mean PSU (1 sd)	13719.64	22568.72	15566.98
Number of students	35.07	88.04	27.16
Fraction private (1%)	-63.93	-192.25	-41.30
Fraction low SES (1%)	40.78	107.06	18.83
Year FE	Yes	Yes	Yes
Program FE	Yes	Yes	Yes
Inst-Area FE	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes
Observations	60,017	36,058	23,959
Mean PSU	591.11	590.74	591.68
SD mean PSU	55.38	54.09	57.25
Note:			*p<0.1; **p<0.05; ***p<0.01

Table 3.2: Second stage - Cells ineligible for free college
Estimation by IV

	Dependent variable: δ_{jct}			
	OLS	IV: All	Aid Eligible	Aid Ineligible
Price (dollars)	-0.000004	-0.00002^{***}	-0.00003^{***}	-0.002^{***}
	(0.00001)	(0.00001)	(0.00001)	(0.0003)
Mean PSU (std)	0.90^{***}	0.90^{***}	0.61^{***}	0.94^{***}
	(0.03)	(0.03)	(0.05)	(0.04)
Number of students	0.002^{***}	0.002^{***}	0.001	0.001^{**}
	(0.0004)	(0.0004)	(0.001)	(0.0005)
Fraction private HS	-0.17^{*}	-0.19^{*}	-1.00^{***}	-0.14
	(0.09)	(0.10)	(0.17)	(0.11)
Fraction low SES	-0.22^{***}	-0.23^{***}	-0.32^{***}	-0.43^{***}
	(0.07)	(0.07)	(0.12)	(0.09)
Fraction $\left\lvert \frac{\alpha}{\beta_r} \right\rvert$ in dollars				
Mean PSU (1 sd)	222710.09	41075.28	21411.09	462.72
Number of students	479.92	87.94	19.37	0.60
Fraction private (1%)	-424.16	-84.47	-345.80	-0.70
Fraction low SES (1%)	-533.41	-102.83	-112.30	-2.11
Year FE	Yes	Yes	Yes	Yes
Program FE	Yes	Yes	Yes	Yes
Inst-Area FE	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes
FS F statistics	-	321017	79249	572
Observations	59,105	58,719	12,278	46,441
Mean PSU	602.41	602.41	602.90	602.28
SD mean PSU	57.68	57.68	57.42	57.74

Note: *p<0.1; **p<0.05; ***p<0.01

Figure 3.2: Price elasticity by student eligibility -
Student-program observations from 2013 to 2015



Note: Observations before free college because, after its implementation, eligible students do not face prices.

The coefficients of this specification are normalized by σ, and the level of the fixed effect is allowed to change considering a characteristic of the institution the programs belong to, $X_{Inst} - Action$. In principle, I would include a fixed effect at the institution-action level. This fixed effect captures the negotiation process between programs and the institution they belong to, particularly the dollar value of making a decision conditional on the particular choice set of a program. However, the institution-action fixed effect is too granular to be identified. Then, I use a characteristic of the institution that aggregates the fixed effects but still models relevant features of the relationship between programs and institutions.

Assuming that η_a follows an extreme value type-1 distribution, the probability of program j choosing the action $\{p_{jq}, k_{ja}\}$ is,

$$Pr(p_{ja}, k_{ja}) = \frac{exp\left(\tilde{\pi}_j(p_{ja}, k_{ja})\right)}{\sum_{a'=1}^{9} exp\left(\tilde{\pi}_j(p_{ja'}, k_{ja'})\right)} \tag{3.7}$$

The estimation of the parameters $\{\gamma, w_0, w_1, \tilde{d}\}$ is based on the best responses approach. I compute program j's revenue from deviating from the observed equilibrium action, keeping the actions of other programs constant at their observed level. Then, the estimation of the cost function parameters is done by maximum likelihood. These parameters are the best fit that rationalizes the observed equilibrium assuming the equilibrium is a mutual best response.

The comparison between actions allows me to recover $\{\gamma, w_0, w_1, \tilde{d}\}$. It is essential to highlight that capacity actions identify the cost parameters when programs are oversubscribed because, in those cases, price changes do not affect enrollment. Capacity changes, however, produce different revenue across actions, even for oversubscribed programs.

The identification of the parameters of the profit function also relies on the following assumptions,

Assumption 1: Distribution of $\eta \sim EVT1$

Assumption 2: Independence of η

Assumption 1 imposes restrictions on the data-generating process, obtaining a parametric model. And more importantly, assumption two states that the error term is independent of rev and k. Unlike linear models, where identification typically relies on an assumption of no correlation, nonlinear models often need to assume complete independence. The main implication of this assumption is that the cost function estimates are the same for observed capacity and changes in capacity within the choice set of programs. A threat to this assumption occurs if changes in capacity are such that the cost function also changes. However, the capacity actions are restricted to relatively small changes, which mitigate this threat but impose the local interpretation of the profit function.

The following section presents the results of the estimation equation (3.6).

3.4.1 Results

This section presents the results of the estimation of the supply model. I estimate equation (3.6) using different levels of fixed effects, $\tilde{d}_{X_{Inst}-Action}$. The results are presented in table 3.3. This table shows the results in two ways. Panel A in table 3.3 depicts the estimates from the logit estimation of equation (3.6), and panel B presents the coefficients in dollars as in equation (3.4), which eases its interpretation.

The first column presents the results of the specification without fixed effects; this specification serves as a baseline for the value of the standard deviation of the logit error. Then, in each subsequent column from (2) to (5), I add a fixed effect from less granular to more granular to the baseline specification. The ideal level of the fixed effect would be institution-action as discussed in section 3.2.5; however, the data needs more variation to implement that specification. Hence, the specifications in columns (2) to (5) increase the granularity of the fixed effect, which is defined as interacting the strategy that was chosen by the program with the a characteristic of the institution they belong to.

The estimated coefficient of the logit error $\hat{\sigma}$ standard deviation is relatively stable across specifications, and it tends to decrease as the granularity of the fixed effect increases. This tendency reflects that each strategy's impact on profits is different across programs that belong to a similar institution. The variation in profits within the institution summarizes coordination and suggests a degree of dependency between programs that belong to the same institution.

The estimate of the linear coefficient of the marginal cost $\hat{c}_0$ is positive for all specifications that include the fixed effect. In contrast, the estimate of the quadratic coefficient of the

Table 3.3: Estimation of supply model

Panel A: Variables	(1)	(2)	(3)	(4)	(5)
Revenue (US$)	9.00e-07***	8.48e-07***	8.33e-07***	1.01e-06***	1.22e-06***
	(2.59e-07)	(3.05e-07)	(3.06e-07)	(3.06e-07)	(3.15e-07)
Capacity (slots)	-0.00304**	0.0116***	0.00802***	0.000300	0.00760***
	(0.00131)	(0.00281)	(0.00288)	(0.00276)	(0.00287)
$Capacity^2$ (slots)	5.31e-06**	-9.48e-06***	-7.79e-06**	1.96e-06	-7.41e-06**
	(2.31e-06)	(3.64e-06)	(3.71e-06)	(3.76e-06)	(3.71e-06)
Panel B: In $US					
$\hat{\sigma}$	1,111,471	1,179,465	1,200,473	985,864	820,082
$\hat{c}_0$	-3,383	13,691	9,623	296	6,234
$\hat{c}_1$	6	-11	-9	-2	-6
Observations	70,902	70,902	70,902	70,902	70,902
Fixed effect	No	Capacity-Type	Capacity-Quality	Action-Type	Action-Quality

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Note: Estimation is done by multinomial logit, with strategy nine as the baseline. The difference between columns is the fixed effect included in the specification. The first column does not include FE. The others columns have fixed effects from the more aggregated to the more granular. Column (2) includes a FE at the capacity-action and institution-type level with nine categories. Then, column (3) includes a FE at the capacity-action institution-quality level with 15 levels. Column (4) includes a FE at the action institution-type level with 24 levels. Finally, column (5) includes a FE at the action institution-quality level 28 levels.

marginal cost $\hat{c}_1$ is negative and small for all specifications that include the fixed effect. Even though this coefficient is negative, the marginal cost is positive for all the capacity actions included in the strategies of the programs.

I will use the specification estimation in column (5) to analyze counterfactual scenarios. This specification includes a fixed effect at the institution-quality action level. It encompasses how institutions of the same quality negotiate with their programs. Institutions of higher quality could be more resilient to increase quality relative to institutions of less quality. A reduction in profits beyond the marginal cost captures this. The estimation of the fixed effects reflects this pattern. See appendix A.0.5 for more details.

3.5 Decomposition Counterfactual

In this section, I analyze a decomposition counterfactual to answer whether supply responses amplify or moderate the effects of free college on welfare and for which type of students. In this analysis, I compare the welfare of students derived from three different DAA allocations—first, the actual allocation of 2016, which is the first allocation with free college. Second, a counterfactual allocation is produced by only allowing demand to respond to free college. And finally, a counterfactual 2016 allocation without free college.

For each allocation, I solve the maximization problem of every program using the estimation of the marginal cost function. Then, I use the price action that maximizes profits to create the rank list of students. And finally, using students' preferences and the capacity action that maximizes profits, I compute the equilibrium allocation of the corresponding DAA. Finally, I compare the welfare of the 2016 counterfactual allocation to the actual 2016 allocation and the scenario where only demand responds to free college.

This section also describes how the programs' price and capacity choices change with free college and how the cost of the transfer paid by the government to programs due to free college varies across allocations.

3.5.1 Students

Free college is welfare enhancing for eligible students as seen in table 3.4. As expected, the utility of eligible students grows with free college, considering that they face a zero price after implementing free college. However, supply responses make 5 percent of these students worse off after free college.

For non-eligible students, free college reduces the welfare of more than 50 percent. And supply responses amplify this effect. Without free college, 80 percent of non-eligible students are better off, which drops to 52 percent when supply responses are considered. Non-eligible students are not directly impacted by free college; its impact is mediated by the assignment

Table 3.4: Fraction of students who are better off relative to a baseline without free college

	Eligible	Non-eligible
Comparison 1: demand and supply responses	94%	52%
Comparison 2: without supply responses	99%	80%
Total students	54181	58805

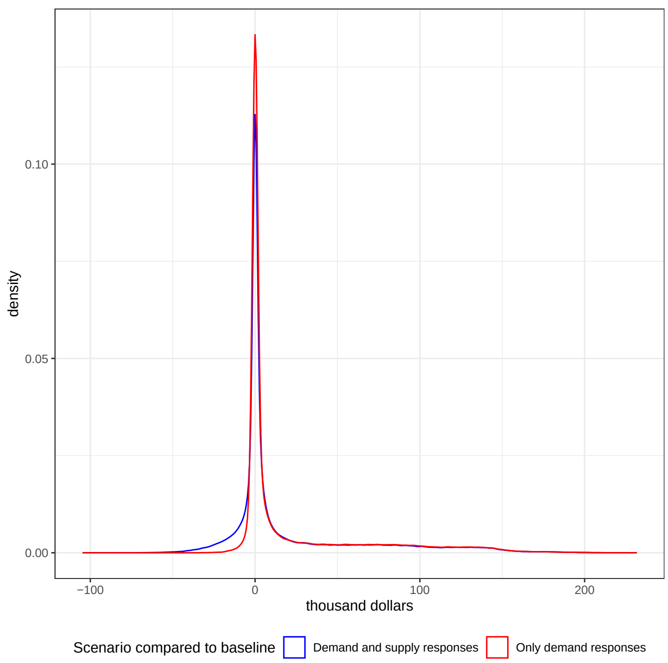
Note: This table shows the fraction of eligible and non-eligible students who are better off in each scenario relative to the baseline without free college. This fraction is the probability of being better off for one student across all simulations and then averaged across all students

mechanism and supply responses induced by free college. The comparison between scenarios 1 and 2 suggests that supply responses moderated free college's effect on non-eligible students through equilibrium effects produced by the change in the demand for eligible students.

The comparison of the welfare of eligible students presented in table 3.4 suggests that the policy increases the utility of these students through demand effects and that supply responses are relevant to understand the change in the welfare of non-eligible students. The impact of the supply responses on student outcomes operates at the margin of enrollment because of how students are selected into programs. Students are compared by their test scores, and free college, at least in the short term, does not change this characteristic of students. Free college impacts student preferences, but their test scores restrict student assignments. In contrast, the demand impact of free college is experienced directly by all eligible students who enroll in college regardless of their test scores and indirectly by non-eligible students whose enrollment changes due to the shift in the preferences of eligible students. Therefore, if supply responses amplify or moderate the effect of the free college policy, they do it mostly at the margin of enrollment. Then, this possibility needs to be studied in an analysis that goes beyond mean utility changes. Figure 3.3 presents the distribution of the change in mean utility for both comparisons.

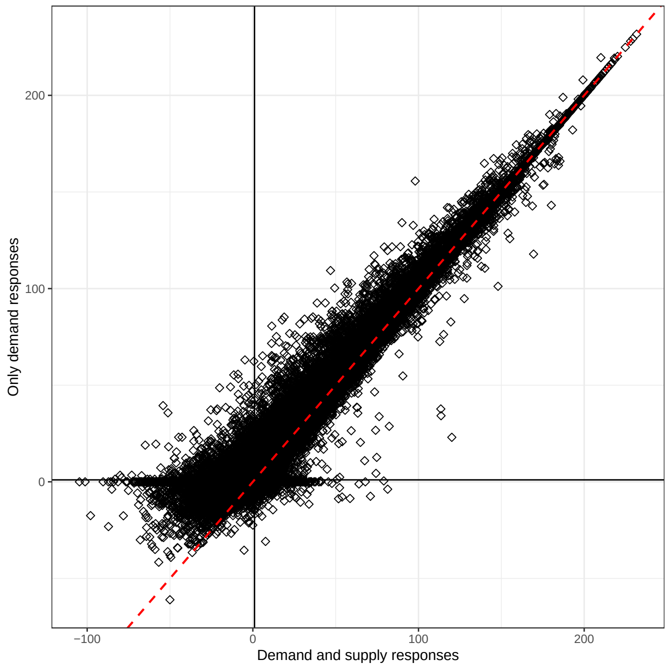
The distributions are similar. However, this does not imply that each point represents the same students. Some groups of students are worse off because of supply responses. Those students would have had a bigger utility in the 2016 counterfactual scenario (in blue

Figure 3.3: Distribution of changes in the mean utility at the student level for both comparisons



Note: This figure shows the distribution of the changes in the mean utility at the student level for two comparisons. In blue is depicted the change in mean utility using the baseline scenario of no free college compared to the actual 2016 scenario with demand and supply responses. And in red is depicted the change in mean utility considering the same baseline and compares it to a scenario where only demand is affected by the free college policy. The x-axis is measured thousand dollars and represents the dollar equivalent of the utility change.

Figure 3.4: Changes in mean utility at the student level between both comparisons



Note: This figure shows the changes in the mean utility at the student level for two comparisons. The x-axis depicts the change in mean utility using the baseline scenario of no free college compared to the actual 2016 scenario. And the y-axis shows the mean utility change using the same baseline and compares it to a scenario where only demand is affected by the free college policy. The axes are measured in thousand dollars and represent the dollar equivalent of the utility change. The 45-degree line is depicted in red.

in figure 3.3) than in the allocation with free college (in red in figure 3.3). I go deeper into the analysis of supply responses with figure 3.4, which plots the mean change in utility of both comparisons at the student level. This figure allows me to recognize and characterize which groups of students are better or worse off due to supply responses. In the x-axis, I depict the change in the utility from comparison 1, and the y-axis shows the corresponding change from comparison 2. In red is the 45-degree line.

I use figure 3.4 to classify students into four groups: win-win, win-lose, lose-lose, and lose-win. For the first group, free college is welfare-enhancing, and supply responses amplify free college's effect on their welfare. For the win-lose group, free college is also welfare-enhancing, but supply responses dampen the increase in their utility. Then, the students in the lose-lose group are those for which free college diminishes their welfare, and supply responses amplify this reduction. Finally, the group lose-win comprises students who experienced a decline in their utility due to free college, but supply responses mitigate this reduction. A large mass of students is better off after free college. However, many could have been better off without supply responses. Similarly, supply responses also amplify the reduction in utility for a group of students. To understand the composition of these four groups, I characterize them using students' characteristics conditional on the group they belong to. Table 3.5 shows the descriptive demographics of these four groups.

Table 3.5: Characteristics of students affected differently by free college

	win-win (%)	win-lose (%)	lose-lose (%)	lose-win (%)
Total	40770	20088	26933	24725
Free college eligible	67	91	11	21
Financial aid eligible	44	69	17	9
Income decile 1	0.23	0.4	0.03	0.06
Income decile 2	0.51	0.9	0.11	0.14
Income decile 3	0.78	1.52	0.14	0.2
Income decile 4	53	71	8	17
Income decile 5	12	18	2	4
Income decile 6	4	1	11	9
Income decile 7	4	1	12	10
Income decile 8	4	1	10	9
Income decile 9	7	2	17	13
Income decile 10	2	1	7	5
Income decile NA	11	3	32	33
Marginal students	17	6	13	18

Note: This table characterizes the four student groups affected by free college differently. Total is the number of students; all other characteristics are in percentages. Financial aid eligibility is different from free college eligibility because the former includes academic requirements and not only financial requirements. The regulator defines the student's income decile for all students who apply for financial aid, comparing the verified self-reported income to the national income distribution. So the variable income decile NA corresponds to students who do not apply for financial aid. Finally, I define marginal students as those accepted in the bottom 20 percent of the total program enrollment they registered for in the baseline allocation.

Table 3.5 shows that more than 50 percent of students are better off after implementing free college. However, almost a third of them would have been even better without supply responses.

Unsurprisingly, students eligible for free college represent a more significant fraction of students whose welfare is enhanced by the policy relative to those who experienced a decrease, i.e., win-win and win-lose groups. Conversely, non-eligible students represent a larger mass of those groups harmed by free college, i.e., lose-lose and lose-win. And this tendency seems stable across income deciles. Moreover, marginal students are overrepresented among the lose groups. Marginal students are more likely to be displaced from a program that experienced increased demand from students with higher test scores or from a program that shrank their capacity. Students in the lose-lose group probably suffered from both changes.

Table 3.6: Composition of student groups by students' characteristics

	Total	win-win (%)	win-lose (%)	lose-lose (%)	lose-win (%)
Free college eligible	53848	51	34	5	10
Financial aid eligible	38591	46	36	12	6
Income decile 1	197	47	41	5	8
Income decile 2	453	46	40	7	8
Income decile 3	709	45	43	5	7
Income decile 4	42548	51	34	5	10
Income decile 5	9941	49	35	6	9
Income decile 6	6978	23	3	41	32
Income decile 7	7845	23	3	43	31
Income decile 8	6814	25	4	40	31
Income decile 9	11105	25	3	42	29
Income decile 10	4209	24	3	44	30
Income decile NA	21717	21	3	39	37
Marginal students	15801	43	7	22	27

Note: This table describes the composition of each group of students considering a set of characteristics. Total is the number of students; all other characteristics are in percentages. Financial aid eligibility is different from free college eligibility because the former includes academic requirements and not only financial requirements. The regulator defines the student's income decile for all students who apply for financial aid, comparing the verified self-reported income to the national income distribution. So the variable income decile NA corresponds to students who do not apply for financial aid. Finally, I define marginal students as those accepted in the bottom 20 percent of the total program enrollment they registered for in the baseline allocation.

Table 3.6 complements the previous analysis and presents the likelihood of different student subgroups being part of one of the four groups affected by free college. Table 3.6 reinforces the idea that eligible students are better off because of free college. However, almost 40 percent are worse off because of supply responses. And the opposite happens with non-eligible students. Even if nearly a third of them are better off because of free college, the majority are worse off, and around 40 percent could have been better off without supply responses to free college.

To understand what causes the change in welfare, I explore the mechanisms related to the change in the welfare of different types of students in the case with and without supply responses. Table 3.7 shows the potential channels for the comparison without supply responses. Without supply responses, the possible mechanisms that change welfare are enrolling in a different program, being displaced to the outside option, or, particularly for eligible students, facing a price of zero.

Table 3.7: Mechanisms that explained the change in welfare between baseline and counterfactual with only demand responses

	Eligible				Noneligible			
	win-win	win-lose	lose-lose	lose-win	win-win	win-lose	lose-lose	lose-win
Welfare change (US$)	49,605	60,574	3,355	19	671	4,438	-430	-571
Same program (%)	95	94.2	97.6	99.8	96.6	92.8	98.2	98.2
Displaced to o.o. (%)	0.86	0.82	1.92	0.41	0.5	0.33	0.66	0.63
Policy transfer (US$)	3,526	3,394	3,766	3,922	-	-	-	-
Price reduction (%)	-	-	-	-	1.09	3.68	1.94	0.78
Price increase (%)	-	-	-	-	2.22	5.2	1.9	1.03

Note: This table presents the channels that explain the average change in welfare for different types of students. Welfare change is the average dollar equivalent change in utility. The variable same program is the percentage of students in the same program in the baseline scenario and the case with only demand responses. Displacement to the outside option measures the percentage of students ending up in the outside option after implementing free college. Policy transfer is the average value of the voucher paid by the government to the institution. Finally, price reduction and price increase are the percentages of students who enroll in programs that reduce and increase their prices. Note that some lose-lose and lose-win groups depict a positive change in utility. This happens because this table compares the utility change between the counterfactual with only demand responses to the baseline without free college. The groups of students are defined considering the scenario with supply responses.

The increase in the welfare of eligible students is mainly driven by the policy subsidy that makes them face a price of zero. More than 95 percent of them are enrolled in the same program. Among the lose-lose groups, displacement to the outside option is a relevant factor relative to other groups, even considering including non-eligible students. From the perspective of non-eligible students, the policy has a lower impact on welfare because, without supply responses, free college only affects them indirectly through the equilibrium effects due to the change in preferences of eligible students. In any case, the welfare change of non-eligible students is related to enrolling in a different program in the counterfactual scenario with other characteristics and, in some cases, a higher price.

Table 3.8: Mechanisms that explained the change in welfare between baseline and counterfactual with demand and supply responses

	Eligible				Noneligible			
	win-win	win-lose	lose-lose	lose-win	win-win	win-lose	lose-lose	lose-win
Welfare change (US$)	50,781	55,786	-2,752	-58	2,933	2,857	-9,971	-481
Same program (%)	93.7	90	94.6	99.8	94.1	91.1	95.1	98.4
Displaced to o.o. (%)	1.04	4.73	18.15	0.42	1.02	2.35	7.61	0.56
Policy transfer (US$)	3,515	3,438	3,963	3,928	-	-	-	-
Same price (%)	-	-	-	-	95.94	94.83	94.94	98.42
Price reduction (%)	-	-	-	-	6.05	5.62	8	1.35
Price increase (%)	-	-	-	-	5.35	9.89	15.88	1.53
Same capacity (%)	83.49	68.61	21.94	57.24	81.17	75.98	53.58	83.74
Capacity reduction (%)	8.52	16.29	35.01	17.2	8.88	9.04	24.67	8.02
Capacity increase (%)	7.99	15.1	43.05	25.55	9.94	14.98	21.75	8.24

Note: This table presents the channels that explain the average change in welfare for different types of students. Welfare change is the average dollar equivalent change in utility. The variable same program is the percentage of students in the same program in the baseline scenario and the case with only demand responses. Displacement to the outside option measures the percentage of students ending up in the outside option after implementing free college. Policy transfer is the average value of the voucher paid by the government to the institution. Finally, price reduction and price increase are the percentages of students who enroll in programs that reduce and increase their prices.

Table 3.8 expands the analysis of mechanisms to the case with supply responses. Supply responses add to the previous channels the possibility of programs changing capacity and prices, which impacts enrollment and program characteristics. Supply responses produce more changes in the program eligible students enroll in and considerably increase displacement. Eligible students in the lose-lose groups are much more likely to be displaced because of supply responses. Besides this group, the price channel seems to be the main driver of the welfare change of eligible students. Regarding non-eligible students who experienced reduced welfare, supply responses make them worse off due to a combination of increased displacement and price increases.

3.5.2 Programs

Free college induces changes in supply that have an impact on students' welfare. This impact was summarized in the previous section. In this section, I describe the price and capacity changes induced by free college by comparing the optimal choices between the scenario with free college, including demand and supply responses, and the baseline without free college.

Table 3.9: Change in price and capacity actions in the case with free college relative to the baseline without free college

	All programs	Increase revenue	Decrease revenue
Total	1,387	607	716
Same price (%)	92	92	92
Increase price (%)	4	5	3
Decrease price (%)	4	2	5
Same capacity (%)	81	80	83
Increase capacity (%)	9	10	8
Decrease capacity (%)	10	10	9

Note: This table shows the fraction of programs making price and capacity choices. The percentage of each choice comes from comparing the case with free college, including demand and supply responses, to the baseline scenario without free college. Increase revenue are those programs that increase their revenue with free college, and Decrease revenue are the programs that decrease their revenue with free college.

Table 3.9 describes the changes in price and capacity for different groups of programs. In general, programs are more likely to adjust capacity than prices. Price increases are more likely across programs that increase their revenue after free college than those that experienced a reduction in revenue. This could be driven by many programs being oversubscribed in equilibrium. Regarding capacity changes, they are evenly distributed across increases and decreases and do not seem to be correlated with increases or decreases in programs' revenue. The price changes most likely mediate their impact.

More details on the characteristics of programs that increase or decrease their revenue with free college are in table B.6.

3.5.3 Government

Finally, supply responses also have an impact from the government's perspective, as seen in table 3.10. Overall, they reduce the welfare of implementing free college. Moreover, supply responses increase the cost of the transfers paid by the government to the programs.

Table 3.10: Cost and benefit of policy

	Transfer cost	Welfare change
Comparison 1: demand and supply responses	128,266,114	2,199,252,961
Comparison 2: without supply responses	128,132,960	2,505,079,685

Note: This table shows the direct cost of the policy measured as the total transfer from the government to the programs. And the benefit of the policy is measured as the sum of the dollar equivalent of the mean change in utility of students.

CHAPTER 4

CONCLUSION

The free college policy has gained traction in the US and other countries. Free college can be implemented in different forms, and all of them expand financial aid in a more or less targeted way. A less targeted subsidy might benefit low-income students. Still, less targeted financial aid will likely change how eligible students apply for college, potentially displacing students who enrolled before the financial aid was available. This effect is driven by the impact that free college has on demand. But free college also affects programs because it might lower their revenue, and programs could decide to adjust their price or capacity. These responses are relevant because they can affect access to college for a group of students and also change program characteristics. Then, the free college policy produces demand and supply responses that impact the equilibrium. This paper studies the extent of these responses in the context of the Chilean implementation of free college and, particularly, analyses whether supply responses amplify or moderate the effects of the policy.

Evidence from a difference-in-difference strategy with variation in treatment intensity at the program level suggests that students eligible for free college are more likely to apply and enroll in relatively more expensive programs before free college. This evidence points towards a change in students' behavior after free college is implemented. Also, a similar difference-in-difference strategy concludes that programs whose revenue would have decreased more, given the shift in demand, are more exposed to free college and increase their capacity and price more after its implementation. This reduced form evidence shows that free college impacts demand and supply decisions.

I model and estimate flexible preference heterogeneity using rich observable data on student characteristics. And I identify price elasticity using the arbitrary income cutoff of the free college policy and across market price variation. Non-eligible students are less price sensitive than eligible students. The parameter of price sensitivity is critical to analyzing counterfactual scenarios. Moreover, I model and estimate a supply model of discrete choice in which programs maximize profits by choosing price and capacity. The rationale behind this discrete choice model is two-folded. First, it solves the computational complexity of the standard approach of inverting first-order conditions. And also, the discrete actions better capture how programs choose capacity and price. The model suggests that expanding or contracting capacity might substantially impact increasing or restricting access to education at the margin of enrollment than price changes.

Finally, I analyze a decomposition counterfactual in which I compare the welfare of students before and after free college and also in a case when supply responses are restricted. The main conclusion of this analysis is that supply responses have an impact depending on student characteristics. Free college is mostly a welfare-enhancing policy for eligible students due to the reduction in price implied by the policy. But, the welfare of almost half of the students could have been higher if it were not for supply responses. Non-eligible students experienced a significant reduction in welfare because of supply responses. Driven mainly by displacement to the outside option and price increases. Hence, supply responses are of the first order and need to be considered when designing and expanding financial aid policies such as free college.

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APPENDIX A

APPENDIX

A.0.1 Other financial aid programs

Free college coexists with other types of financial aid created before 2016. The financing mechanisms include loans and scholarships. Notably, a substantial state-guaranteed loan (CAE) that expanded in 2012 by reducing its interest rate from 5.8 to 2 percent. Free college also coexists with scholarships considering academic and socioeconomic requirements. The eligibility for these scholarships expanded between 2011 and 2015, increasing and diversifying the potential student body.

CAE is a massive state-guaranteed loan program created in 2006, under which private banks provide college tuition loans to eligible students who enroll in accredited institutions.[1] Students decide the amount to request to meet their financial needs up to the reference tuition[2] and pay a rate of 5.8%. The interest rate was cut down to 2% in 2012. Access to the loan depends on socioeconomic need and a test score cutoff[3] if the student wants to apply to a university, or a GPA or PSU cutoff if the application is for vocational education. By 2015, the program could be used by students of all income levels who meet the academic requirement.

The CAE loan has been widely studied in the literature. Based on a regression discontinuity design on CAE's requirements, Solis [2017] presents evidence of credit constraint in Chile's higher education. Notably, the author finds that the gap between high-income and low-income students closes after creating CAE. Aguirre [2019] also analyzes the effects of CAE using an RD design. However, she considers its long-term outcomes by comparing stu-

1. Institutions are certified by the *Comision Nacional de Acreditacion* (CNA) that aims to secure and promote quality of HEIs. Accredited institutions can receive public funds through different mechanisms, such as CAE.

2. Reference tuition is also defined by the Ministry of Education using a formula.

3. The cutoff is defined using the college admission exam PSU.

dents who qualified to use the loan in universities and vocational education. The results show that loans for universities induce low-performing students away from technical schools and towards higher-quality university alternatives, where they have little chance of succeeding.

Scholarships were available for students before the creation of CAE. The scholarships[4] are assigned to students who enroll in accredited institutions using cutoff rules for family income quintile and admission test scores. Scholarship eligibility expanded between 2011 and 2015, increasing and diversifying the potential student body.

Bucarey [2018] analyze this expansion and concludes that it might have crowded-out students at the bottom of the income distribution that is less competitive for the scholarships once it expands to students who are relatively less poor and that might have better academic credentials.

A.0.2 Reference tuition 2015

Reference tuition defines a student's maximum from CAE or a scholarship. In 2015, reference tuition covered, on average, 84 percent of the real price. This number varies year by year and across institution-program pairs. One year before the implementation, reference tuition covered 30 to 100 percent of full tuition. On average, reference tuition covers a higher fraction of full tuition in public universities and less in private universities.

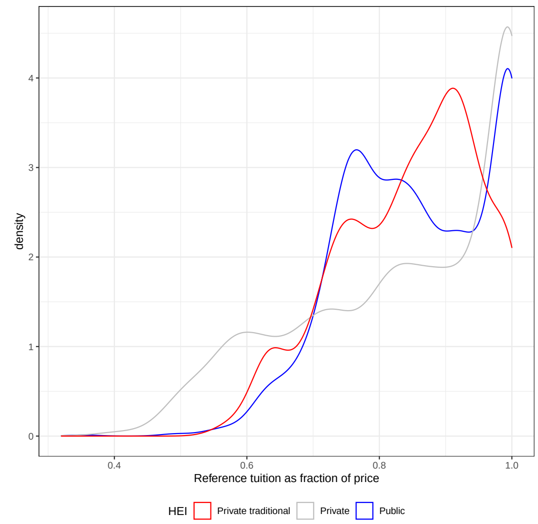
Table A.1: Reference tuition as a fraction of full tuition in 2015

HEI	Mean	P10	P25	P75	P90
Public universities	0.86	0.72	0.77	1.00	0.11
Private universities	0.83	0.59	0.72	1.00	0.16
Private traditional universities	0.85	0.70	0.76	0.99	0.11

Figure A.2 depicts the change in reference tuition in the sample. This distribution mimics the distribution of price changes. Ninety-six percent of changes are non-negative, and the

4. These scholarships are for accredited institutions and have requirements, as mentioned before. Mainly, Beca Bicenteraio is for CRUCH universities, Beca Juan Gomez Millas for all those universities founded after 1980, and Beca Nuevo Milenio for vocational education.

Figure A.1: Distribution of reference tuition as a fraction of full tuition in 2015 by type of university



mean of the change is 3.8 percent.

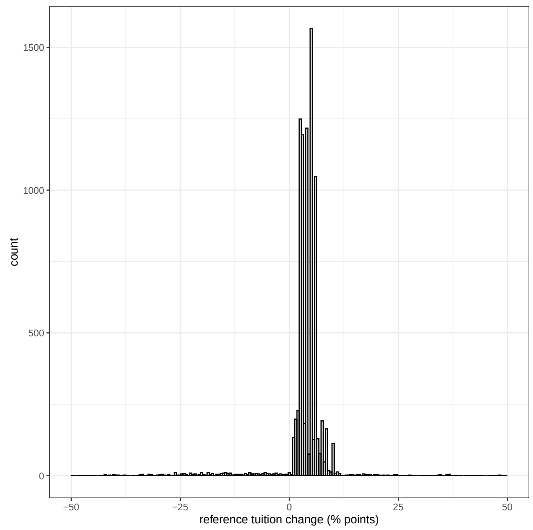
A.0.3 Illustration of the effect on price differentiation in the choices of programs

This section briefly illustrates how pricing and capacity decisions might be affected when the policy introduces differential prices. I consider two simple cases to describe how capacity choices can increase revenue in the presence of differential prices. The conclusions drawn from this section provide insights into the mechanism behind how capacity choices are a tool for institutions beyond prices that could increase revenue in the presence of students who do not respond to price.

Perfect substitutes

Consider the case of two firms that are perfect substitutes and, in the first stage, commit to a level of capacity and then, in the second stage, compete in prices. Kreps and Scheinkman [1983] shows that the Cournot outcome holds as a unique equilibrium of this two-stage game

Figure A.2: Change in reference tuition from 2013 to 2018



Note: This figure only includes price changes between -50 to 50 percent.

under some circumstances. Then, using the Cournot outcome, I will argue that the price differentiation introduced by free college could induce prices to increase and capacity to decrease due to using capacity as a commitment device.

The traditional Cournot analysis, as presented in Tirole [1988], concludes that the Lerner index is proportional to the firm's market share and inversely proportional to the elasticity of demand.

$$L_j = \frac{P\left(Q\right) - C_j^{'}\left(q_j\right)}{P\left(Q\right)} = \frac{q_j}{Q} \times -\frac{P^{'}\left(Q\right)}{P\left(Q\right)} Q$$

Now consider that demand is differentiated between those consumers who pay full price Q^p and those who do not pay but for which firm j receives a transfer equal to v_j, Q^v. Notice that if firm j changes capacity, the effect on q_j^p and q_j^v depends on how these types of consumers are ordered in terms of willingness to pay. The allocation of the goods is done considering willingness to pay. Then, it is not hard to derive the Lerner index for firm j:

$$L_j = \frac{P\left(Q^p + Q^v\right) \times \frac{\partial q_j^p}{\partial q_j} + v_j \times \frac{\partial q_j^v}{\partial q_j} - C_j^{'}\left(q_j^p + q_j^v\right)}{P\left(Q^p + Q^v\right)} = \frac{q_j^p}{Q^p + Q^v} \times - \frac{P^{'}\left(Q^p + Q^v\right)}{P\left(Q^p + Q^v\right)}\left(Q^p + Q^v\right)$$

Relative to the standard case, the revenue produced by increasing q_j depends on the type of consumer assigned the extra units and the value of those units for the institution. Also, the Lerner index is proportional to the firm's market share of consumers type p and inversely proportional to the elasticity of demand of these consumers. Regarding differential prices, capacity q_j could decrease if the elasticity of consumer type p is higher than the standard case. If these consumers are more willing to pay because these conditions imply a higher price, a smaller capacity is needed for market clearing.

Vertical differentiation

Consider the case of two firms of a different quality that commit to a capacity level in the first stage and then in the second stage compete in prices. All consumers agree on which level of quality is best, but they all have a different willingness to pay for quality. Now consider that demand is differentiated between those consumers who pay full price Q^p and those who do not pay but for which firm j receives a transfer equal to v_j, Q^v. Notice that if firm j changes capacity, the effect on q_j^p and q_j^v depends on how these types of consumers are ordered in terms of willingness to pay. If capacity is costly, the level chosen in the first stage should bind in equilibrium. Then, there is an equilibrium in which capacities are binding; prices maximize revenue given capacity such that the marginal consumer is indifferent between both firms.

Now consider that demand is differentiated between consumers type p who pay full price and consumers of type v who do not pay but for which firm j receives a transfer equal to v_j. Notice that if the firm of high-quality changes capacity, the effect on profits depends on how many consumers of type p and v are around the margin of the marginal consumer, which depends on their willingness to pay for quality.

In this case of vertical differentiation, the new equilibrium might feature a larger capacity of the high-quality firm to increase profits. This could happen if there are more type p consumers relative to type v at the margin of the original capacity, which implies that an increase in capacity captures more consumers of type p if the price is low enough.

In my application, programs are not perfect substitutes, and they display different levels of quality, particularly when comparing the same program across institutions. Also, students are sorted into programs according to their preferences and PSU scores. Then, an institution cannot reject a particular student based on any observable characteristics, including their eligibility for free college, besides their PSU scores. In this context, the insights from the previous analyses suggest that program capacity could decrease or increase in the new equilibrium with differential prices depending, in part, on the ratio of eligible (or type l) and non-eligible students (or type h) at the score cutoff, the elasticity of non-eligible students and the relationship between the voucher and the price.

A.0.4 Results of demand estimation using income deciles to define cells

Cells defined using groups of deciles: 1 to 4, 5, 6, 7 to 10, and unknown.

I extend the previous results of the demand estimation by introducing an alternative definition of cells that uses the income to define income decile groups instead of grouping them into a binary category, like free college eligibility. This alternative definition aims to introduce income heterogeneity in the analysis. This type of heterogeneity is relevant if the counterfactual of interest is expanding free college to a specific income group, as mentioned before. Tables A.2 and A.3 present the results of estimating (3.5) defining c using income decile groups and the same identification strategy described before.

To compare the different income decile groups, I consider students with similar price menus considering two dimensions. Then, tables A.2 and A.3 separate students according to their eligibility for aid other than free college and their income decile group. Both dimensions are relevant to define the menu of prices. First, consider students eligible for free college; all of them face a zero price after implementing the policy. However, before the policy, those students eligible for other aid observed a price menu with lower prices than those who were not. The other dimension is the income decile; in principle, students from higher income deciles could be less sensitive to price. Moreover, both dimensions interact. Students from a higher income decile are less likely to be classified for financial aid because of how this aid is assigned. Then, students from a higher income decile tend to face larger prices. It is also important to mention that institutions could provide financial aid directly to students and are more likely to give this aid to low SES students. This data is not observable, implying that the price menus observed by low-income decile students could have lower prices than in the observed data.

Table A.2 shows that students from income deciles 1 to 4 are more sensitive to price if they are not eligible for aid other than free college when comparing columns 1 and 2. This is consistent with those students facing a price menu with higher prices. It isn't easy to make the same comparison for income decile group 2 because the specification in column 4 produces a statistically zero coefficient. However, I can compare students from columns 1 and 3. This comparison keeps aid eligibility constant and presumably price menus, but income varies across these columns. Students with lower income (column 1) are less sensitive to price than students with higher income (column 3). This result is not as expected but could be related to the fact that these two groups do not face the same price.

Furthermore, table A.3 presents the results for students who are not eligible for free college. Students not eligible for free college are less likely to qualify for other aid because these two subsidies are assigned based on income. From the group of students who are not

Table A.2: Second stage: Cells eligible for free college by decile group - Estimation by OLS

	Dependent variable: δ_{jct}			
	Group 1 Aid Eligible	Group 1 Aid Ineligible	Group 2 Aid Eligible	Group 2 Aid Ineligible
Price (dollars)	-0.00002^{**}	-0.00004^{***}	-0.00003^{***}	0.00003
	(0.00001)	(0.00001)	(0.00001)	(0.00002)
Mean PSU	1.43^{***}	1.76^{***}	1.17^{***}	1.93^{***}
	(0.05)	(0.06)	(0.05)	(0.14)
Number of students	0.003^{***}	0.003^{***}	0.002^{***}	0.002
	(0.001)	(0.001)	(0.001)	(0.002)
Fraction private HS	-0.91^{***}	-0.69^{***}	-0.97^{***}	-0.01
	(0.20)	(0.21)	(0.19)	(0.50)
Fraction low SES	0.63^{***}	0.36^{***}	-0.03	0.08
	(0.12)	(0.13)	(0.12)	(0.32)
Year FE	Yes	Yes	Yes	Yes
Program FE	Yes	Yes	Yes	Yes
Inst-Area FE	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes
Observations	33,782	20,812	11,735	8,255

Note: Group 1 contains income deciles 1 to 4, and group 2 only decile 5.
*p<0.1; **p<0.05; ***p<0.01

eligible for free college, group 3, which corresponds to those students from income decile 6, is of utmost interest because this group is the natural group to which the policy could expand (and expanded a few years after its implementation).

Table A.3 shows that students from income decile 6 (group 3) eligible for aid other than free college are more sensitive to price than students from higher income groups. This is also the case when comparing within group 3 and across aid eligibility (columns 1 and 2). However, as seen in column 2, the price coefficient is not statistically significant from zero for students from income decile 6 who are not eligible for aid other than free college. This could be because of the sample size.

Now consider group 4 in columns 3 and 4. In this case, the comparison is complicated

Table A.3: Second stage: Cells ineligible for free college by decile group - Estimation by IV

	Dependent variable: δ_{jct}				
	Group 3 Aid Eligible	Group 3 Aid Ineligible	Group 4 Aid Eligible	Group 4 Aid Ineligible	Group 5 Aid Ineligible
Price (dollars)	-0.00003^{***}	-0.001	-0.00002	-0.003^{***}	-0.003^{***}
	(0.00001)	(0.001)	(0.00003)	(0.001)	(0.001)
Mean PSU	1.11^{***}	1.69^{***}	1.08^{***}	1.44^{***}	1.56^{***}
	(0.05)	(0.11)	(0.19)	(0.05)	(0.08)
Number of students	0.002^{**}	0.004^{***}	-0.001	-0.001	0.0005
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Fraction private HS	-1.13^{***}	-1.24^{***}	-1.11^{*}	-0.16	-0.04
	(0.19)	(0.40)	(0.59)	(0.18)	(0.23)
Fraction low SES	0.08	-0.31	-0.76^{*}	-0.86^{***}	-0.16
	(0.13)	(0.27)	(0.40)	(0.14)	(0.24)
Year FE	Yes	Yes	Yes	Yes	Yes
Program FE	Yes	Yes	Yes	Yes	Yes
Inst-Area FE	Yes	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes	Yes
FS F statistics	62409	106	54846	467	222
Observations	10,407	7,852	8,269	36,907	23,791

Note: Group 3 contains income decile 6, group 2 deciles 7 to 10, and group 5 is for unknown decile.

*p<0.1; **p<0.05; ***p<0.01

as the price coefficient in column 3 is not statistically different from zero. This implies that aid-eligible students, hence observing a menu of lower prices, are less sensitive to price than those who do not qualify for other aid. However, this conclusion reverses if I consider the level of the price coefficients.

Finally, students from group 5 are more sensitive to price than other groups from lower income deciles. This result is similar to what was described in table A.2; it is possible that students from lower-income groups receive direct aid from institutions, affecting the interpretation of price sensitivity.

A.0.5 Marginal cost function: fixed effects estimates

The following table presents the value of the fixed effects of model estimation (3.6) using institution-quality and action fixed effect. The strategy is shown in pairs (p, k) that indicate the price and capacity action. Price actions are $0, 1$ and 2.24 and denote if the price does not change, if it changes in the same proportion as the change in reference tuition, and if the prices increase proportionally more than the change in reference tuition (2.24 times more). And capacity actions are $0, 1$ and -1 and indicate if the capacity does not change, if it increases 20 percent, or if it decreases 20 percent.

Increasing capacity is generally less profitable for higher-quality institutions, conditional on their price action. And conversely, decreasing capacity is more profitable for this type of institution conditional on action price.

Table A.4: Estimation of fixed effects from the marginal cost function

Specification	(5)
Quality A; Strategy (0,-1)	0.439**
Quality B; Strategy (0,-1)	-0.474***
Quality C-D-NA; Strategy (0,-1)	-0.711***
Quality A; Strategy (0,0)	2.265***
Quality B; Strategy (0,0)	1.288***
Quality C-D-NA; Strategy (0,0)	-0.147
Quality A; Strategy (0,1)	0.498**
Quality B; Strategy (0,1)	-0.683***
Quality C-D-NA; Strategy (0,1)	2.395***
Quality A; Strategy (1,-1)	1.932***
Quality B; Strategy (1,-1)	1.596***
Quality C; Strategy (1,-1)	0.315**
Quality D; Strategy (1,-1)	1.091***
Quality NA; Strategy (1,-1)	3.229***
Quality A; Strategy (1,0)	3.875***
Quality B; Strategy (1,0)	2.944***
Quality C; Strategy (1,0)	1.887***
Quality D; Strategy (1,0)	1.999***
Quality NA; Strategy (1,0)	3.256***
Quality A; Strategy (1,1)	2.270***
Quality B; Strategy (1,1)	1.969***
Quality C; Strategy (1,1)	1.140***
Quality D-NA; Strategy (1,1)	0.671***
Quality All; Strategy (2.24, -1)	-1.055***
Quality A; Strategy (2.24, 0)	1.372***
Quality B; Strategy (2.24, 0)	0.456***
Quality C-D-NA; Strategy (2.24, 0)	0.152
Baseline strategy (2.24,1)	-
Fixed effect	Action-Quality
Observations	70,902

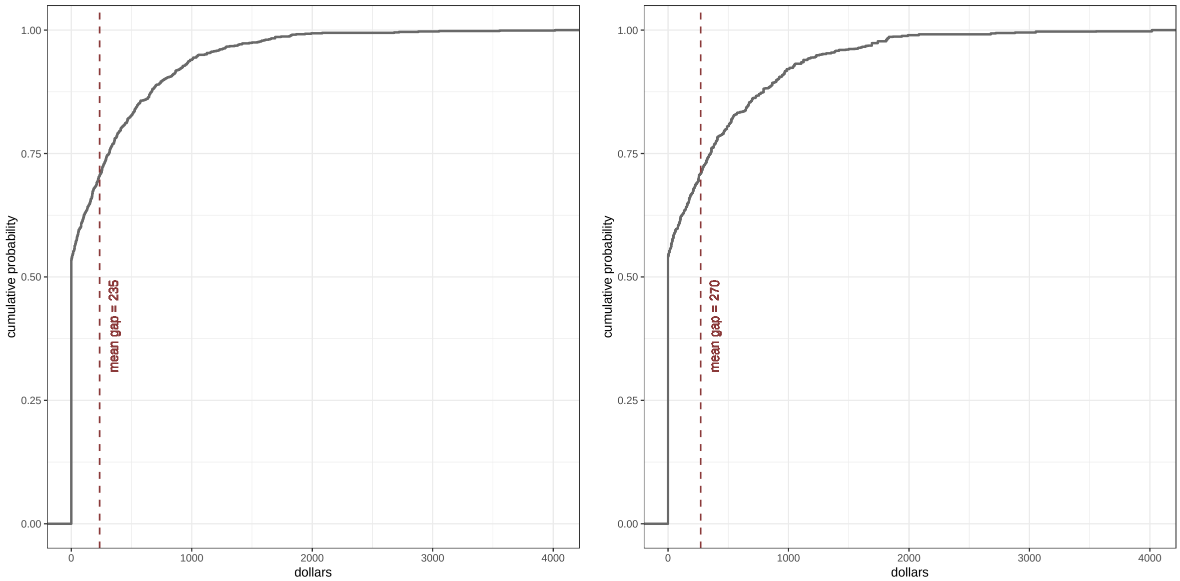
Standard errors are omitted for ease of presentation.
*** p<0.01, ** p<0.05, * p<0.1

APPENDIX B

FIGURES AND TABLES

B.1 Figures

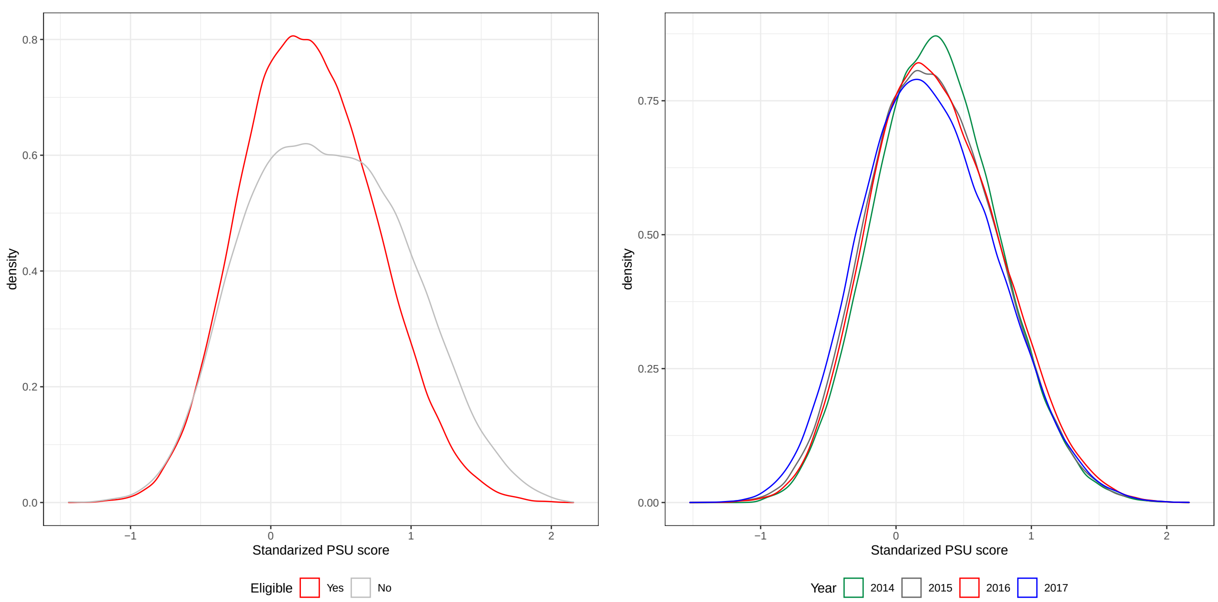
Figure B.1: Price gap induced by free college impacts revenue



(a) Programs (b) Eligible students

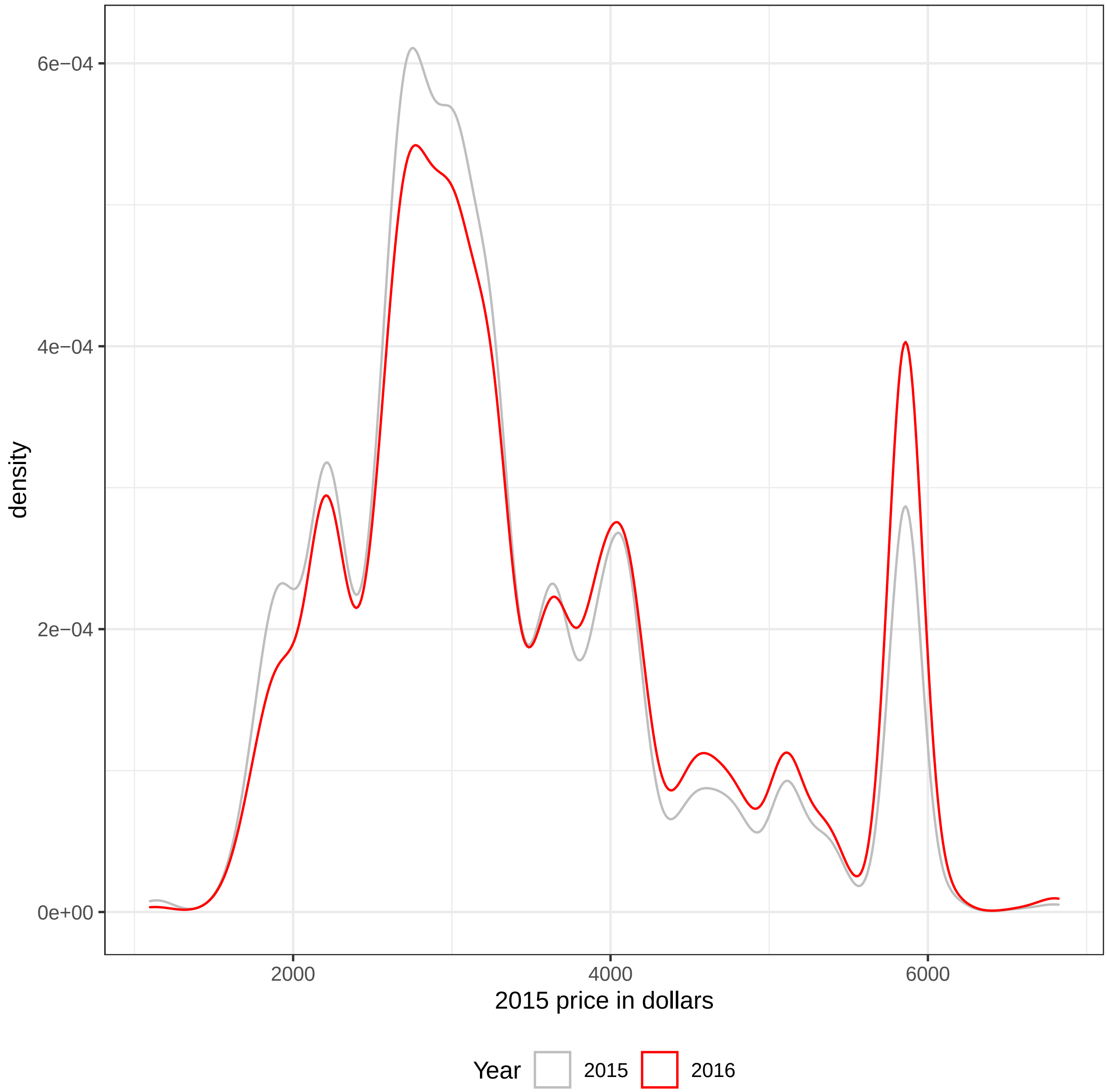
Note: Cumulative distribution of annual price gap. Only programs from institutions with free college. Institutions lose revenue from the gap between price and voucher

Figure B.2: PSU results are stable around policy change - Math and Language PSU mean score



(a) By eligibility on 2015 (b) Eligible students by year

Figure B.3: Distribution of prices of eligible students' first ranked program before and after free college



Notes: Considers institutions that joined and students with the minimum score to participate in the centralized admissions system. The 2015 cohort considers students who would have been eligible for free college and received a scholarship. Real prices in 2015. Each observation is a student.

B.2 Tables

Table B.1: Description of universities in 2018

	Public	Private-traditional	Private
Observations	18	9	33
Total enrollment	178,482	142,618	328,792
Certified status	0.89	1	0.67
Years certified	4.62	5.67	3.77
SD years certified	1.02	1.12	1.11
Max years certified	7	7	5
Min years certified	3	4	2
Gratuidad eligibility status	1	1	0.42
First-year enroll 50 percentile	0.53	0.5	0.29

Notes: Made by the author with Mineduc 2018 data. Total enrollment corresponds to all students enrolled by type of institution.

Table B.2: DID: Change in applications of eligible students -
Exposure is the relative price in the baseline year

	Dependent variable: applications (1st ranked)		
	Cruch	Private joined	Private not joined
Relative price 2015 x			
Pre 2013	1.600	−14.547*	−3.069
	(5.071)	(8.690)	(6.669)
Pre 2014	2.680	−17.161***	1.191
	(3.321)	(5.661)	(2.830)
Pre 2015	-	-	-
	-	-	-
Post 2016	45.579***	51.597***	1.919
	(9.117)	(13.293)	(4.429)
Post 2017	16.087***	40.038***	1.455
	(3.684)	(9.359)	(4.478)
Post 2018	9.895*	−0.100	−12.161*
	(5.402)	(9.695)	(6.262)
Year FE	Yes	Yes	Yes
Program FE	Yes	Yes	Yes
Institution FE	Yes	Yes	Yes
Observations	6,033	488	1,352
R^2	0.954	0.878	0.908
Mean eligible applicants	62	62	57
Scaled coefficient 2016	16.41	23.88	1

Note: Clustered at program level *p<0.1; **p<0.05; ***p<0.01

Table B.3: DID: Change in enrollment of eligible students -
Exposure is the relative price in the baseline year 2015

	Dependent variable: eligible enrollment		
	Cruch	Private-Grat	Private-NonGrat
Relative price 2015			
Pre 2013	0.929	1.170	1.990
	(1.946)	(3.036)	(2.328)
Pre 2014	2.413*	4.196*	1.888
	(1.259)	(2.497)	(1.932)
Pre 2015	-	-	-
	-	-	-
Post 2016	5.546***	11.855**	0.087
	(0.949)	(5.077)	(2.037)
Post 2017	7.015***	4.400	−2.372
	(1.967)	(3.573)	(2.806)
Post 2018	5.244**	2.487	−6.991**
	(2.515)	(5.739)	(3.405)
Year FE	Yes	Yes	Yes
Program FE	Yes	Yes	Yes
Institution FE	Yes	Yes	Yes
Observations	6,008	488	1,346
R^2	0.957	0.936	0.947
Mean eligible applicants	35	43	41
Scaled coefficient 2016	2	5.5	0.04
Note: Clustered at program level		*p<0.1; **p<0.05; ***p<0.01	

Table B.4: DID: Change in capacity -
Exposure: $Rev_{\text{DAA 2015}} - Rev_{\text{DAA without responses}}$

	Dependent variable: log capacity				
	All joined	Cruch	Public	Private Traditional	Private
Revenue change (std institution level) x					
Pre 2013	0.018*	0.014	−0.002	0.038*	0.061*
	(0.010)	(0.011)	(0.011)	(0.017)	(0.020)
Pre 2014	0.008	0.009	0.0001	0.022	−0.002
	(0.006)	(0.006)	(0.005)	(0.013)	(0.004)
Post 2016	0.041***	0.042***	0.044***	0.039**	0.034
	(0.010)	(0.010)	(0.015)	(0.013)	(0.019)
Post 2017	0.041***	0.041***	0.048***	0.031***	0.040
	(0.009)	(0.010)	(0.014)	(0.009)	(0.020)
Post 2018	0.044***	0.042***	0.043**	0.040**	0.079
	(0.010)	(0.010)	(0.015)	(0.012)	(0.036)
Year FE	Yes	Yes	Yes	Yes	Yes
Program FE	Yes	Yes	Yes	Yes	Yes
Mean capacity	69	67	63	74	89
Observations	6,124	5,673	3,369	2,304	451
R^2	0.945	0.945	0.954	0.930	0.950

Note: Clustered at institution level. *p<0.1; **p<0.05; ***p<0.01

Table B.5: DID: Change in prices -
Exposure: $Rev_{\text{DAA 2015}} - Rev_{\text{DAA without responses}}$

	Dependent variable: log(price)				
	All joined	Cruch	Public	Private Traditional	Private
Revenue change (std institution level) x					
Pre 2013	0.002*	0.002*	0.002	0.002*	−0.0003
	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)
Pre 2014	0.001*	0.001*	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Post 2016	0.001	0.001	0.002	−0.0001	−0.002
	(0.001)	(0.001)	(0.001)	(0.0002)	(0.001)
Post 2017	0.001	0.002*	0.002*	0.0001	−0.0004
	(0.001)	(0.001)	(0.001)	(0.0003)	(0.0002)
Post 2018	0.002**	0.002**	0.004**	0.0005	0.001
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)
Year FE	Yes	Yes	Yes	Yes	Yes
Program FE	Yes	Yes	Yes	Yes	Yes
Mean price	2918	2852	2753	2995	3749
Observations	6,077	5,628	3,330	2,298	449
R^2	0.991	0.990	0.980	0.998	0.994

Note: Clustered at institution level. *p<0.1; **p<0.05; ***p<0.01

Table B.6: Composition of programs that increase and decrease its revenue due to supply responses

	Increase revenue	Decrease revenue
Total	607	716
Joined free college (%)	86	82
Traditional university (%)	31	40
Public university (%)	50	42
Private university (%)	24	27
Northern region (%)	27	36
Capital region (%)	41	26
Southern region (%)	32	38
Quality A (%)	43	41
Quality B (%)	40	42
Quality C (%)	14	15
Quality D (%)	4	5

Note: This table describes programs that increase and decrease its revenue due to supply responses induced by free college. The description includes a series of characteristics of the programs, including the type of institution, its location, and quality.