Strategic Adoption in a Two-Sided Market: A Study of College Applications in Brazil*

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Abstract

This paper measures the importance of indirect network effects in the adoption by colleges and students of ENEM, a standardized exam for high-school students in Brazil that can be used in college application processes. We estimate network effects and find that they are economically significant. Students are more likely to take ENEM the larger the number of colleges adopting it. Similarly, colleges are more likely to adopt it the larger the number of students taking the exam. Moreover, we find evidence that colleges play strategically and that heterogeneity determines their decisions. A college is less likely to adopt ENEM the larger the number of competitors adopting it. Colleges' characteristics such as ownership and organization affect adoption decisions. In a counterfactual exercise we compare colleges' adoption decisions under competition and under joint colleges' payoffs maximization. Adoption rates are significantly reduced when colleges internalize the competitive effect, i.e., the effect of their decisions on other colleges' payoffs. On the other hand, they increase when indirect network effects - the effect of students' response to their decisions on other colleges' payoffs - are also internalized. Competitive adoption rates are found to exceed joint optimum rates by a small difference. These results suggest that, without considering students' welfare, adoption rates are excessive, but close to the joint optimum.

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1 Introduction

Indirect network effects exist when the adoption decisions of agents in one side of the market affect the adoption value for agents in another one. Typical examples are the adoption of credit cards by consumers and retailers and the adoption of video game standards by consumers and game publishers. Consumers value a credit card the larger the number of retailers that accept it, and retailers value it the larger the number of consumers who use it, while the same is true for video game consumers and publishers. In many markets agents in at least one of its sides consider the effect of their decisions on other agents' decisions. In the case of video games, where game publishers are relatively concentrated, they consider the effect of releasing games for a console on the decisions of consumers and other publishers. Thus, when measuring network effects we must consider strategic effects among agents.

This paper measures network effects in a market taking into account strategic interactions among agents in one of its sides. We study the adoption by colleges and students of ENEM, a standardized exam for high-school students in Brazil that can be used in college application processes. College applicants value ENEM if it is considered in college admission processes, while colleges in their turn value it as a way to select applicants. Indirect network effects arise here because applicant usage of ENEM leads to more college usage, which in its turn leads to more applicant usage. Colleges play strategically because they consider the effect of their adoption decisions on the decisions of competing colleges and of applicants.

Such study requires data that allow us to estimate network effects between the two sides while taking into account strategic interactions among heterogeneous players. Data on adoption decisions for both sides of the market are necessary to estimate those network effects. Individual-level data on adoption decisions are necessary to control for the interdependence among decisions of those who play strategically, as we assume that colleges do. Moreover, individual-level data allow the researcher to take into account the heterogeneity among those players and to better identify the parameters of interest. We meet these requirements using a novel data set that includes municipality-level data for applicants and individual-level data for colleges over time.

An important characteristic of the college market in Brazil is the low mobility of college applicants. Students typically go to a college close or even in the same municipality where they graduated from high-school. For this reason, we divide markets by microregions. Microregions contain adjacent municipalities and their boundaries are determined by IBGE, the governmental institute responsible for census statistics in Brazil.

In order to measure network effects, we estimate a utility function for students and a payoff function for colleges. Students' utility from taking ENEM relative to not taking it depends both on the odds and the benefits of being admitted to a college if they take or do not take ENEM. Since these odds depend on the competition for college admission, the utility of taking ENEM depends on the number of colleges that adopt it as well as on the share of students in the market who take the exam. However, students are assumed to play nonstrategically in the sense that they do not consider the effect of their individual choices on colleges' and other students' decisions. On the other hand, colleges play strategically and the payoff from adopting ENEM also depends on the college market competition. More specifically, it depends both on the number of students who take it and on the number of competing colleges that adopt it. When deciding whether or not to adopt it a college takes into account the consequences of its decision on the decisions of the other players in both sides of the market.

The supply of ENEM to students and colleges is such that the estimation of the utility and payoff functions is sufficient to measure network effects. ENEM is offered by the federal government. Students are charged the same fee across the whole country for taking ENEM and colleges are not charged for using it to select applicants.[1] Thus, the supply to both sides is perfectly elastic in each given market and, disregarding changes in the fees paid by students over time, constant across markets. Therefore, variations in students' and colleges' decisions across markets must be due to differences in their demand for ENEM. This implies that, conditional on having the exam offered in a given market and taking into account the fees paid by students, we do not need to estimate a supply function for this market in order to measure network effects. This feature greatly simplifies the empirical framework and eliminates one potential source of mismeasurement of those effects.[2]

We find that indirect network effects are significant in both ways. Students' utility from taking ENEM is strongly affected by colleges' decisions to adopt it. The decision of one college to adopt ENEM increases the fraction of students in a market taking it by as much as 24%. The effect of the number of students taking the exam on colleges' payoffs is also found to be large. A 10% increase

[1] Evans (2003a, b) and Evans and Schmalensee (2005) observe that in two-sided markets it is a common practice to charge prices for one side that are negative or below marginal cost. Such evidence is consistent with theoretical results from Rochet and Tirole (2003) and Armstrong (2005). Indeed, Rochet and Tirole (2004) give the following definition to two-sided markets: "A market is two-sided if the platform can affect the volume of transactions by charging more to one side of the market and reducing the price paid by the other side by an equal amount; in other words, the price structure matters, and platforms must design it so as to bring both sides on board."

[2] This feature however prevents us from analysing the welfare consequences of competition among networks, as studied for example in Berry and Waldfogel (1999) and Rysman (2004a).

in the number of students taking it increases the average number of adopters by market by 5%.

We also find that colleges' characteristics and strategic interaction among colleges affect their decisions. Older colleges are more likely to adopt ENEM. Ownership and academic organization also affect those decisions. A university is 25% more likely to adopt ENEM than a regular college. Also, an additional adopter in a market decreases the probability of adoption by other colleges by 16%. These results confirm our claim that firm-level data are important to estimate network effects in two-sided markets.

Given the estimates of network effects, we can determine whether adoption rates are above or below joint colleges' payoffs maximizing level. We use a counterfactual exercise to compare adoption decisions under competition and under joint payoffs maximization. The competitive outcome differs from the joint payoffs maximizer one for two reasons. First, under the former regime each college does not consider the competitive effect its adoption decision has on other colleges' payoffs. This is the negative effect due to competition among adopters for students who take ENEM. Second, under the competitive regime each college does not consider how the students' response to its decision affects other colleges' payoffs. This is a positive effect because the value students attribute to ENEM increases with the number of colleges that adopt it. Thus, an additional adopter causes an increase in the pool of students taking ENEM benefiting all the adopters in the market. The latter source of inefficiency is caused by indirect network effects.

We find that adoption rates are significantly reduced when colleges internalize the competitive effect. On the other hand, internalizing indirect network effects increases the adoption rates, but not enough to outweigh the competitive effect. Competitive adoption rates are found to exceed joint optimum rates by a small difference. These results suggest that, without considering students' welfare, adoption rates are excessive, but close to the joint optimum.

The literature on direct network effects - which studies network effects among agents facing the same adoption decision, or the same supply curve - presents evidence on the importance of considering heterogeneity and strategic interactions among players when measuring those effects. For example, Goolsbee and Klenow (2002) use household level data to study network effects in the diffusion of home computers. They find evidence of positive network effects and, in particular, that they are originated from the more experienced and intensive computer users. Gowrisankaran and Stavins (2004) and Ackerberg and Gowrisankaran (2005) use firm level data to analyze the network effects in the adoption of an electronic payment system by banks. For an electronic transaction to be processed both the sender and the receiver banks must have adopted the system. However, there is a single adoption decision because if a bank adopts the system it is able to both send and receive

electronic payments. They find evidence that banks' individual decisions are positively affected by the adoption decisions of other banks in the same market.

This paper contributes to the literature that measures network effects between two distinct sides of a market being the first to measure the two-sided feedback while taking into account heterogeneity and strategic interactions among players. Berry and Waldfogel (1999) analyze the efficiency of entry of radio stations, which face listeners and advertisers on each side of the market. They also estimate the demand curves for both sides, but assume that listener demand is not affected by advertisement. Gandal, Kende and Rob (2000) study the feedback loop between compact disc player sales and compact disc availability, finding evidence of a positive feedback. Rysman (2004a) analyses the welfare effects of competition among yellow pages directories. These directories face consumers and advertisers on the two sides of the market. He also finds evidence of positive network effects between these two sides. Clements and Ohashi (2004) study the competition among video game consoles, which face consumers and software publishers on each side of the market. They find that indirect network effects affect the product cycle of video games. However, all these papers use aggregate data for both sides, being unable to consider heterogeneity and strategic interactions among players.

Two exceptions are Rysman (2004b) and Nair, Chintagunta and Dubé (2004). Rysman (2004b) studies network effects in the credit card market using data at the consumer and merchant level. He shows a positive correlation between consumer usage and merchant acceptance, but does not establish a causal relationship between those decisions. Nair, Chintagunta and Dubé (2004) measure network effects between personal digital assistants (PDAs) sales and PDA software availability. They use SKU-level sales and prices data for PDA models and individual-level data for software availability, and find evidence of significant network effects. Both of these papers consider heterogeneity among players. However, they are applied to markets with a large number of players on both sides. Presumably for this reason, in these papers it is assumed that players on neither of the two sides consider the effect of their decisions on other players' decisions. Our paper therefore is the first to consider strategic interactions among adopters when measuring network effects between two distinct sides of a market.

This paper also contributes to the economics of education literature concerning standardized exams. As far as we know, this is the first paper to analyze network effects in the adoption of these exams. On the other hand, the use of standardized exams by colleges is a common topic in the education literature (e.g., Schaffner, 1985), but again no attempt has been made to measure network effects in these markets yet.

The paper is organized as follows. Section 2 describes the Brazilian college market, ENEM and the data. Section 3 describes the estimation methods employed and section 4 discusses the results. Section 5 compares the outcome under competition and joint payoffs maximization by colleges and evaluates the importance of indirect network effects. Section 6 concludes.

2 Market Characteristics, ENEM and Data

2.1 The College Market and ENEM

The market studied in this paper is the college market in Brazil.[3] In the period analyzed, from 1999 to 2002, this market has experienced significant growth. Annual college enrollment has jumped from 2.3 millions in 1999 to 3.5 in 2002, where most of this increase has taken place in private institutions (see Figure 1). The number of institutions also jumped significantly from 1,097 in 1999 to 1,637 in 2002 (see Figure 2).[4]

The most common process to select applicants is through college-specific entrance exams, in which colleges offer exams covering high-school material and select applicants based on their scores. These exams may vary from the most simple ones to five hours, three days exams in case of demanding institutions. Such process distorts the material covered in high-school, since schools and students have an incentive to drive their efforts towards a good performance in exams, leaving other important skills aside.[5] Moreover, since each college typically requires its own and exclusive exam, it is extremely costly for applicants to apply to a large number of colleges, due to the number of different exams an applicant would need to take.

The low mobility of college applicants is indeed an important characteristic of this market in Brazil. Students typically go to a college close or even in the same municipality where they graduated from high-school. Different reasons contribute to it. First, as already mentioned, students cannot apply to a large number of colleges since these institutions typically require students to take their exclusive entrance exams. Second, colleges typically offer their entrance exams only in their own campuses. Mobility is also reduced for reasons not related to the application process. For example, student housing is expensive, and the large majority of institutions do not even have

[3] The data used in this subsection was taken from the INEP website (www.inep.gov.br) and from the book authored by the former Minister of Education Paulo Renato Souza (2005) about his administration from 1995 to 2002.

[4] This expansion can be potentially explained both by deregulation of the market, which lowered barriers to entry, and by the expansion of secondary schooling, where the number of students concluding high-school per year jumped from 0.9 millions in 1994 to 1.8 millions in 2002.

[5] See Holmström and Milgrom (1991) for such theoretical result.

dormitories.

ENEM was created in 1998 by the Ministry of Education of Brazil and has three objectives: (i) to serve as a reference for students when making their decisions related to the job market or college education, (ii) to provide employers with information about prospective employees and, following the discussion above, (iii) to provide colleges with information about prospective students, where such information might complement or serve as an alternative to the entrance exams discussed above.[6] The exam consists of 63 multiple-choice questions and one essay covering the material of secondary school. It lasts for 5 hours and is offered once a year, in August[7]. The exam fee in 2005 was R$ 35.00 (around US$ 15.00), but students from public high-schools or who prove to be unable to pay such fee are exempt of it.

Figures 3 to 5 summarize the diffusion of ENEM exam centers in Brazil and its adoption by colleges and students. Figure 3 shows an increase in the number of municipalities with exam centers from 184 in 1998 - the first year of ENEM - to 600 in 2002. Figure 4 shows that the number of colleges adopting it jumps from a single one in 1998 to 338 in 2002. Figure 5 shows that this increase was followed by the number of students taking it: from 116 thousand in 1998 to 1,328 thousand in 2002.

2.2 Data

The novel data set used in this paper combines 2003 state-level data with annual data ranging from 1999 to 2002 collected both at the municipality level and at the college level.[8] They were obtained from INEP, which is an institute affiliated to the Ministry of Education, and thus constitute official data. We aggregated the data by microregion-year pairs, which is the definition of a market used in this paper. Microregions contain different municipalities and their boundaries are determined by IBGE, the governmental institute responsible for census statistics in Brazil. The division of markets by microregions is reasonable considering the low mobility of students discussed in the previous subsection.

The state-level data contains information on the average number of courses and the average number of faculty members with B.A., specialization, M.A., and Ph.D. degrees for institutions in each state. Those numbers are discriminated by the ownership and the academic organization of

[6] Souza (2005) also identifies ENEM as an instrument to be used by the government to signal to high-schools the skills that it considered that students should develop in their pre-college education.

[7] Exceptionally, in 2005 the exam was offered in September.

[8] Our analysis was constrained to this period due to restrictions on data availability.

those institutions. We then matched each college in our data to these state-level data according to the state where it is located, its ownership and its academic organization.

The municipality-level data contains annual observations on market structure, number of high-school students, and ENEM availability and attendance. Information on market structure includes the number of colleges per ownership type and its academic classification according to the Ministry of Education. The division of colleges according to their ownership separates them among non-philanthropic private, philanthropic private, federal, state, and municipal colleges. The distinction between nonphilanthropic and philanthropic private institutions is particularly relevant because the latter receive tax exemptions in exchange for devoting a fraction of their revenues to philanthropic activities. The academic classification divides them according to the complexity of their organization. From the most complex to the most simple, they can be classified as universities, universitarian centers, integrated colleges, colleges, and institutes. The data on high-school students graduating per year is divided between gender, and two categories of high-school ownership: public and private. Our initial sample contains information on 7445 municipality-year pairs. However, information on market structure and high-school students was missing for a significant number of those pairs.

The municipality-level data also contains annual observations on whether at least one ENEM exam center was located in that municipality. We have a total of 1,221 municipality-year pairs with exam centers. For these municipalities we also have information on the number of students registered to take ENEM. We matched these data with the two other data sets describe above and aggregated them in 680 microregion-year pairs. Table 1 summarizes the data.

The college-level data contains annual observations from colleges. A few issues must be discussed about the collection and selection of the data. First, following the discussion above, our sample was restricted to markets for which we were able to obtain data on market structure and the number of high-school students graduating per year. Second, the data was collected in 2004 and the INEP website contains college-level information from active colleges only. Thus, we potentially lost information from colleges which were active in at least one of the years from 1999 to 2002 but left the market afterwards. However, a comparison between the number of colleges for which we obtained college-level information and the market structure data discussed above - which does not have this censoring problem - suggests that differences in the number of observations are very rare and are small when they exist. Third, following our assumption that different microregion-year pairs constitute separate markets, we restricted attention to college-year observations corresponding to microregion-year pairs with ENEM exam centers. Fourth, we do not have information on the

year a college selected applicants for the first time, which is the first year when it may have decided whether or not to adopt ENEM. However, we do know the date in which each college was opened. Therefore, since the academic year in Brazil usually starts in March, we assumed that colleges start selecting applicants in the first year after they are opened. After this assumption, our sample consists of 1,668 colleges distributed across municipalities which had ENEM exam centers for at least one year, giving us a total of 3,995 college-year pairs.

Each college-year observation includes information on whether or not it uses ENEM in its application process in that year, the year the college was opened, its ownership type, academic classification, and the municipality where its headquarters - usually its main campus - is located. This last variable is used to match colleges to microregions. Tables 2 and 3 summarize the data.

3 Estimation

In this section we present the empirical model to be estimated. Since colleges are not charged for adopting ENEM and students are charged the same fee across the country for each year in the sample, the model does not need to include a supply function for the exam. This characteristic of the market simplifies the model and rules out the possibility that any potential mismeasurement of that supply function would also affect the network effects estimates. Therefore, we only need to estimate a utility function for students, which determines whether or not they take ENEM, and a payoff function for colleges, which determines whether or not they adopt it. We discuss the estimation of these two functions with special attention to the Method of Simulated Moments estimator (McFadden, 1989; Pakes and Pollard, 1989) employed to estimate the parameters of the colleges' payoff function. We discuss the results of the estimation in section 4.

As discussed in section 2, in our estimations we assume that observations from different microregion-year pairs are independent. This assumption also allows us to save on notation; thus, we refer to some microregion-year pair simply as some market l.

3.1 Students

There are M students in the market. A student is a college applicant who must decide whether or not to take ENEM. A student values ENEM because the colleges she is applying to may use it in their decision processes on whom to accept as an undergraduate student. We do not explicitly describe the decision problem of students on which colleges to apply to. Instead, for simplicity, we focus only on the decision of whether or not to take ENEM. The utility from taking ENEM relative

to not taking it should depend both on the odds and the benefits of being admitted to a college if she takes or if she does not take ENEM. With respect to the odds, we assume that students value more ENEM if it is adopted by a larger number of colleges. We also allow students to care about the choices of other students. A student may consider it for example because a larger share of students taking ENEM implies more competition to be admitted in those colleges that adopt it. We assume however that, even though students understand that a college is more likely to adopt ENEM if it expects a larger number of students to take it and that students also care about the decisions of other students, they do not consider the effect of their individual choices on colleges' and other students' decisions. This assumption is reasonable considering the size of a single student compared to the whole market and it greatly simplifies the problem. Since students do not behave strategically, we can restrict attention to the strategic interaction among colleges when solving for the equilibrium of the game.

The utility of student j from market l if she takes ENEM is assumed to be given by the function

$$U_{jl}(n_l) = \mathbf{x}_l^U \boldsymbol{\beta} + \alpha \ln(n_l + 1) + \kappa \left[\ln(s_{El}) - \ln(s_{0l})\right] + \xi_l + \epsilon_{Ejl}$$

where $\mathbf{x}_l^U$ is a vector of market-level characteristics that affect students' demand for ENEM, n_l is the number of colleges that adopt ENEM, s_{El} and s_{0l} are the fractions of students who take and who do not take ENEM, respectively, ξ_l an unobservable term specific to the option of taking ENEM, and ϵ_{Ejl} an individual-specific unobservable term. Student j attributes a value equal to ϵ_{0jl} to the option of not taking ENEM. ϵ_{Ejl} and ϵ_{0jl} are assumed to be identically and independently distributed across options, students and markets with a type 1 extreme value distribution. These errors, respectively, represent individuals' and markets' characteristics observable to the students but not to the econometrician. The variables $\ln(n_l + 1)$ and $\ln(s_{El}) - \ln(s_{0l})$ together with the number of colleges in the market, which is contained in $\mathbf{x}_l^U$, represent the effect of the odds of being admitted in a college, while $\mathbf{x}_l^U$ and the error terms represent its benefits.

A student j chooses to take ENEM if and only if $U_{jl}(n_l, \mathbf{x}_l^U, \epsilon_{Ejl}) \geq \epsilon_{0jl}$. The mean utility across students of the outside option is therefore normalized to zero, while the mean utility of ENEM is given by

$$\delta_E \equiv \mathbf{x}_l^U \boldsymbol{\beta} + \alpha \ln(n_l + 1) + \kappa \left[\ln(s_{El}) - \ln(s_{0l})\right] + \xi_l$$

Let $\boldsymbol{\beta}' \equiv \frac{1}{1-\kappa} \cdot \boldsymbol{\beta}$, $\alpha' \equiv \frac{\alpha}{1-\kappa}$, and $\xi' \equiv \frac{\xi}{1-\kappa}$. Assuming that $\kappa < 0$, $\boldsymbol{\beta}'$, α' and ξ' will have the same sign as $\boldsymbol{\beta}$, α and ξ, respectively. Under the assumptions imposed above, $\boldsymbol{\beta}'$ and α' can be estimated by

$$\ln(s_{El}) - \ln(s_{0l}) = \mathbf{x}_l^U \boldsymbol{\beta}' + \alpha' \ln(n_l + 1) + \xi'_l \tag{1}$$

Following our discussion, we expect α' to be positive because students value ENEM more the larger the number of colleges that adopt it.

3.2 Colleges

There are N colleges denoted by $i \in \{1, ..., N\}$. A college must decide whether or not to accept ENEM as a criterion in its application process. A college may value ENEM for different reasons. For instance, a student's score in ENEM provides information about her skills. Colleges may value this additional information because their payoff usually depend on the quality of their student body. Another reason to value ENEM is that a college may use it to substitute some of its own entrance exams it requires from applicants, therefore saving the preparation, organization and grading costs of those exams. Also, since ENEM is adopted by many colleges, it reduces the average cost of applications faced by students. Therefore, when a college adopts it it may also face a larger pool of applicants. On the other hand, a college that adopts ENEM may also incur in some costs. For example, as discussed before, ENEM is a simple, standardized exam. Thus, a college that replaces one of its own exams with ENEM may now have less information about the quality of its applicants than it had before. Also, a college that substitutes ENEM for its own entrance exams abdicates the revenues from the fees it may charge applicants who take those exams. In any case, it is reasonable to expect that the more students take ENEM, the more valuable it is for a college to adopt it.

However, we also expect that conditional on a number of students taking ENEM, a college values it less the more colleges also adopt it. One reason is that students are constrained on the number of entrance exams they can take. Those exams are usually concentrated in the end of the senior high-school year and require at least one day, usually on weekends. Students therefore cannot apply to many colleges that require their own exams since they are typically time constrained. Therefore, the more colleges substitute ENEM for their entrance exams, the more a college will be willing to require its own one. A second reason is that adoption by competitors increases the competition for students who take ENEM. Holding the number of those students fixed, adoption by competitors decreases the ratio of students who take ENEM to colleges, therefore making adoption less attractive.

We do not describe colleges' decision problems on whom to accept. However, analogously to the students' utility, we assume that colleges' payoffs depend on the college market tightness as well as on market and college-specific characteristics that might affect the relative benefits from admitting students when adopting ENEM. We expect colleges to value ENEM more if a large number of

students take it, and to value it less if a large number of colleges adopt it.

Colleges are assumed to maximize a payoff function. College i's adoption payoff is a function of the number of colleges and students adopting the exam, i.e., $\pi_i = \pi_i(n, m)$. The adoption payoff of college i in market l is assumed to be determined by the following parametric form:

$$\pi_i(n_l, m_l) = \gamma + \mathbf{x}_{0l}\boldsymbol{\eta} + \mathbf{x}_{il}\boldsymbol{\lambda} + \phi \ln(n_l + 1) + \varphi \ln(m_l) + \varepsilon_{il} \tag{2}$$

where $\mathbf{x}_{0l}$ and $\mathbf{x}_{il}$, respectively, are vectors of market specific and college specific variables that affect a college's benefit from adoption. ε_{il} is a term that is observed by the colleges, but not by the econometrician. It is assumed to be uncorrelated across markets but may be correlated across firms within a market. Indeed, we follow Berry (1992) choosing a specification for ε_{il} that allows for such correlation:

$$\varepsilon_{il} = \sqrt{1 - \rho^2} u_{il} + \rho u_{0l}$$

where u_{il} and u_{0l} represent firm specific and market specific shocks on relative profitability, respectively. u_{il} and u_{0l} are independent and identically distributed according to a standard normal. ρ is assumed to lie in the interval $[-1, 1]$.

The variables $\ln(n_l + 1)$ and $\ln(m_l)$ together with the total number of colleges and students in the market contained in the vector $\mathbf{x}_{0l}$ represent the effect of the college market tightness on the adoption payoff. The vectors $\mathbf{x}_{0l}$ and $\mathbf{x}_{il}$ represent the benefits from admitting students when adopting ENEM.

We assume that if a college does not adopt ENEM it gets a payoff equal to zero. Therefore, college i chooses to adopt ENEM if and only if $\pi_i(n_l, m_l) \geq 0$.

Following our discussion, we expect ϕ - the coefficient representing the number of adopters on a college's payoff - to be negative. We expect φ to be positive because a larger number of students taking ENEM implies higher demand for colleges adopting it.

3.3 Equilibrium

We need an equilibrium concept that allows us to determine the identities of the colleges that adopt ENEM. We are interested in determining their identities both because heterogeneity across colleges is significant and because, as it will be shown later, colleges' characteristics do affect their adoption decisions. In order to identify the adopters, we follow Berry (1992) and we impose an order of adoption decisions in each period. We use the fact that in a setting such as the one described

above, a specific order of adoption decisions implies a unique subgame perfect equilibrium.[9]

We use a rule for the order of adoption decisions that is economically reasonable and helps us overcome computational difficulties in the estimation of colleges' payoff function. We assume that colleges move according to their academic classification from the most complex (universities) to the most simple (single career colleges). In case of ties, we assume that they move according to their age, with older colleges moving first. This rule can be justified if the largest and most complex institutions act as leaders in their local markets. It helps us compute the parameter estimates because it implies that the order of decisions is independent of them. Therefore it avoids discontinuities in the function to be minimized in the estimation, improving the quality of the estimates. We return to this issue in Appendix C.[10]

In Appendix A we show that in this case a pure strategy Nash equilibrium (PSNE) always exists in the model and the number of adopters is constant across different equilibria, independently of the order of decisions.[11] However, even though the equilibrium number of firms is the same for all PSNE, the identities of adopters and nonadopters may be indeterminate.

3.4 Identification

Here we discuss the identification of the parameters in equations (1) and (2). Some of the explanatory variables in these equations are endogenously determined in the model, and we address the identification problems using instrumental variables.

First, we discuss the identification of parameters in (1), the equation corresponding to the students' decision problem. Since colleges' adoption payoffs depend on students' decisions, we should expect $\ln(n_l)$ to be correlated with ξ_l. We use as an instrument for colleges' decisions to adopt ENEM the number of disciplines offered by each college. The reason why this is an appropriate instrument is as follows. When applying to a college in Brazil, a student must choose the discipline she is applying to. Therefore, it is reasonable to assume that students do not care about the number

[9] See Ciliberto and Tamer (2004) for an entry model with weaker assumptions. They do not impose any order of entry and allow for heterogeneity in the effect each entrant has on the other. Under those weaker assumptions they obtain bounds for parameter estimates.

[10] As an alternative, we could follow Berry (1992) and Schmidt-Dengler (2005) imposing that, in a given period, the college that can profit the most from adoption moves first, followed by the second one, and so on. This order can be justified if the colleges which can profit the most from adoption prepare themselves faster to be in position to adopt ENEM. However, in this case the order of actions depends on the parameters. Since colleges' decisions in their turn depend on the order of moves, it causes the function to be minimized to become discontinuous.

[11] Similarly to Bresnahan and Reiss (1991) and Berry (1992), this result relies on the assumption of no heterogeneity in the effect of each adopter on the other.

of disciplines that a college offers, but only to the characteristics of the chosen discipline-college pair. We do understand that the number of disciplines offered by a college main contain information about its quality. For this reason we control extensively for colleges' characteristics using our data on year of foundation, ownership, academic organization and faculty education. We assume that controlling for all these characteristics is enough to eliminate the quality information content of the number of disciplines. Thus, we assume that students' decisions are independent of the number of disciplines offered by colleges. On the other hand, we argue that colleges' decisions to adopt ENEM is positively affected by the number of disciplines they offer. The reason is that since students' application is divided by disciplines, colleges usually require (partially or completely) different entrance exams for different disciplines. However, the larger the number of disciplines offered by a college, the larger its savings from adopting a standardized exam as ENEM, because otherwise it will have to prepare, grade and process the information of a larger variety of entrance exams. Also, a college specialized in only one or a few disciplines usually has an entrance exam designed to evaluate the skills related to those disciplines. In these cases specially, an exam intended to measure general skills such as ENEM may not be a good substitute. Therefore, we consider the number of disciplines offered by a college an instrument appropriate for our empirical framework.

The parameters of the colleges' payoff function (2) are estimated using the Method of Simulated Moments. Since in this method there is no "first stage" for the Two Stage Least Squares, in order to assess the explanatory power of the instrument discussed above, we present in Table 4 Logit estimates of colleges' decisions on the exogenous variables. The first specification measures market structure using the number of colleges in the market only. The second specification also includes the number of colleges distinguished by ownership and academic organization. For both specifications the excluded variable seems to affect significantly colleges' decisions. Interestingly, in both specifications the coefficients on the academic organization dummies increases (although nonmonotonicaly) from the least to the most complex organization, consistent with the demand for student information increasing in college quality. Also consistent with this are the negative coefficients on the year of foundation, which is negatively correlated with quality, and the fraction of public high-school students, which are on average less skilled than private high-school students.

In order to identify the effect of the number of students taking ENEM on colleges' decisions, we use a variable that might affect the students' decisions to take ENEM or to go to college, but is not correlated with colleges' decisions. We use the number of municipalities in a microregion. The number of municipalities is a measure of both the urbanization and the importance of local governments in the microregion which both affect students' decisions to take ENEM or to go to college.

This is particularly important since public schools usually serve as ENEM exam centers. Thus, the larger the number of municipalities, the larger the number of public schools and, consequently, the lower the cost of taking ENEM. On the other hand, conditional on students' decisions as well as on markets and its students' characteristics, that number should not affect colleges' decisions. We show that the number of municipalities is a relevant explanatory variable when we present the estimation results of the students' utility function.

3.5 Estimator

This subsection presents the Method of Simulated Moments employed to estimate the parameters of the colleges' payoff function. The application of the MSM estimator is similar to the one made by Berry (1992).

I start by taking K independent draws of the structural errors $(u_{0l}, u_{1l}, ..., u_{Nl})$ for market l. Let $\hat{\mathbf{u}}_l$ denote of such draw of a $N+1$-vector of standard normals. For each college i in market l the simulated payoffs are found by substituting in (2) the actual errors by the simulated ones:

$$\hat{\pi}_i(n_l, m_l) = \gamma + \mathbf{x}_{0l}\boldsymbol{\eta} + \mathbf{x}_{il}\boldsymbol{\lambda} + \phi \ln(n_l + 1) + \varphi \ln(m_l) + \sqrt{1-\rho^2}\hat{u}_{il} + \rho\hat{u}_{0l}$$

In order to simplify our notation, define $\mathbf{x}_l \equiv (\mathbf{x}_{0l}, \mathbf{x}_{1l}, ..., \mathbf{x}_{Nl})$ and $\boldsymbol{\theta} \equiv (\gamma, \boldsymbol{\eta}, \boldsymbol{\lambda}, \phi, \varphi, \rho)$ as the vectors containing the parameters and the exogenous variables of $\hat{\pi}_i(n_l, m_l)$, respectively. An unbiased estimate of the number of adopters is given by

$$\hat{n}(\mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_l) = \max_{n \in [0,N]} \left(n : \#\{i : \hat{\pi}_i(n_l, m_l) \geq 0\} \geq n\right) \tag{3}$$

which corresponds to the largest number of colleges that receive positive payoffs from adoption for a given vector $\hat{\mathbf{u}}_l$. We use those K draws of $\hat{u}_l$ to average the estimates in (3). The errors

$$\hat{\nu}_{0l} = n_l - \frac{1}{K}\sum_{k=1}^{K} \hat{n}_k(\mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk})$$

are used to construct moment restrictions for our estimator.

As already discussed, we assume that colleges make their adoption decisions following the order described in subsection 3.3. Let the function $\hat{n}cum(i, \mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk})$ define the number of colleges that decide to adopt ENEM until college i's turn to decide, given the exogenous variables, the parameters of the model, and one draw of simulated unobservables. If, given $\hat{\mathbf{u}}_{lk}$, $\hat{n}$ colleges are predicted to adopt ENEM, then college i will adopt ENEM if and only if $\hat{n}cum(i, \mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk}) \leq \hat{n}$. If colleges are indexed according to the order of decisions, we have $\hat{n}cum(i, \mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk}) = 0$. Then,

we can compute an unbiased estimate of the probability of adoption by any college i

$$\hat{p}_i(\mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk}) = \begin{cases} 1 \text{ if } \hat{n}(\mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk}) > \hat{n}cum(i, \mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk}) \\ 0 \text{ otherwise} \end{cases} \tag{4}$$

iterating it together with

$$\hat{n}cum(i+1, \mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk}) = \hat{n}cum(i, \mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk}) + \hat{p}_i(\mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk})$$

from colleges 1 to N_l.

For any order of adoption decisions - including the one we use - it must always hold that any college such that $\hat{\pi}(\hat{n}+1, \hat{\mathbf{u}}_{lk}) \geq 0$ will adopt ENEM. If there are such L colleges and if $L < \hat{n}$, then the remaining $\hat{n} - L$ slots will be filled by other colleges such that $\hat{\pi}(\hat{n}+1, \hat{\mathbf{u}}_{lk}) < 0$ but $\hat{\pi}(\hat{n}, \hat{\mathbf{u}}_{lk}) \geq 0$ according to the assumed order of decisions.

Now, define the indicator function I_{il} such that it equals 1 if college i adopts ENEM and 0 otherwise. Then, a new set of moment conditions can be constructed from the errors

$$\hat{\nu}_{il} = I_{il} - \frac{1}{K}\sum_{k=1}^{K} \hat{p}_i(\mathbf{x}_l, m_l, \boldsymbol{\theta}, \hat{\mathbf{u}}_{lk})$$

for $l \in \{1, .., L\}$. Again, the variance of the simulated probabilities is reduced by averaging across the K draws. Since the number of colleges varies across markets, the number of such simulated errors also varies. Therefore, a selection rule must be established in order to choose which errors to use from each market. Any rule is appropriate as long as it does not depend on the parameters. We pick the two highest and the two lowest colleges according to the rank of academic classification also used to determine the order of adoption decisions. Again, in case of ties, they are chosen according to their age, with older colleges being ranked first. Such rule is attractive because is provides variation in colleges' characteristics. This rule can be justified since universities and older institutions are more likely to adopt ENEM. Such rule is clearly exogenous to the model. Relabeling these four colleges as $i = 1, 2, 3, 4$, we have a total of five prediction errors $\hat{\nu}_{il}$, $i \in \{0, 1, 2, 3, 4\}$. By construction, these errors are mean independent of the exogenous variables when evaluated at the true parameter values $\boldsymbol{\theta}^*$, i.e. $E[\hat{\nu}_{il}(\boldsymbol{\theta}^*) \mid \mathbf{x}_l)] = 0$ for $i \in \{0, 1, 2, 3, 4\}$.[12]

Define a function $\bar{g}(.)$ of the parameters of the model and the observations across the L independent market observations as

$$\bar{g}(\boldsymbol{\theta}) = \frac{1}{L}\sum_{l=1}^{L} \hat{\boldsymbol{\nu}}_l(\boldsymbol{\theta}) \otimes \mathbf{z}_l \equiv \frac{1}{L}\sum_{l=1}^{L} g_l(\boldsymbol{\theta})$$

[12] Notice that in the case of small markets the decision of one college can be used to construct two residuals. For example, in a duopoly market we have $\hat{\nu}_{1l} \equiv \hat{\nu}_{4l}$ and $\hat{\nu}_{2l} \equiv \hat{\nu}_{3l}$.

where $\mathbf{z}_l$ is a subset of the exogenous data uncorrelated with $\hat{\boldsymbol{\nu}}_l$. Following our discussion in subsection 3.4, $\mathbf{z}_l$ is such that the $\hat{\nu}_{0l}$ errors are interacted with market level exogenous variables in $\mathbf{x}_l$ and the number of municipalities in each microregion. Also, the $\hat{\nu}_{il}$ errors for $i \in \{1,2,3,4\}$ are interacted with the same variables as $\hat{\nu}_{0l}$ and also with college-level exogenous variables.

An $\hat{\boldsymbol{\theta}}$ estimate is chosen in order to minimize the quadratic distance measure below:

$$G(\boldsymbol{\theta}) = \bar{g}(\boldsymbol{\theta})' A \bar{g}(\boldsymbol{\theta}),$$

where A is a positive definite matrix.

The optimal weight matrix A is computed in the following way. First, a consistent estimate of $\boldsymbol{\theta}$ is obtained by minimizing $\bar{g}(\boldsymbol{\theta})\bar{g}(\boldsymbol{\theta})'$. Denote this preliminary estimate by $\hat{\boldsymbol{\theta}}_p$. The matrix A is then calculated as $\bar{g}(\hat{\boldsymbol{\theta}}_p)\bar{g}(\hat{\boldsymbol{\theta}}_p)'^{-1}$. The asymptotic distribution of $\sqrt{L}\left(\hat{\boldsymbol{\theta}} - \boldsymbol{\theta}_0\right)$ is equal to $\left(1+\frac{1}{K}\right)\left(E\left[\frac{\partial g(\boldsymbol{\theta})}{\partial \theta}\right]' A E\left[\frac{\partial g(\boldsymbol{\theta})}{\partial \theta}\right]\right)^{-1}$. Standard errors are computed replacing $E\left[\frac{\partial g(\boldsymbol{\theta})}{\partial \theta}\right]$ with the consistent estimate $\frac{\partial \bar{g}(\hat{\boldsymbol{\theta}})}{\partial \hat{\boldsymbol{\theta}}}$.

4 Results

In this section we present parameter estimates of our model and discuss their fit to the data.

4.1 Parameter Estimates for the Students' Utility Function

Table 5 presents the estimated parameters from the students' utility function (1). The dependent variable for the four specifications is $\ln(s_{El}) - \ln(s_{0l})$ where s_{El} and s_{0l} are the fraction of students who take and who do not take ENEM in market l, respectively. The number of students who take it is measured by the number of students registered to take the exam. The total number of students however does not have such a simple counterpart in the data. The natural candidate is the number of students graduating from high-school in the market. However, for more than half of the observations the number of registered students exceeds this number. The most likely reasons are that (i) many people apply to college years after finishing high-school, (ii) people use ENEM for reasons other than college applications, and (iii) data on the number of high-school students graduating in each market is not properly collected. In order to overcome this problem we assume that the total number of students is a multiple of the number of high-school students graduating, and we assess the robustness of this measure by varying this multiple. Table 5 reports the results assuming the multiple is equal to two. In Appendix B we show that the results are robust to changes in the multiple.

The first specification in Table 5 corresponds to OLS estimates. The coefficient on the number of colleges that adopt ENEM is positive and significant, suggesting that there is an indirect network effect of college adoption on the decision of students indeed. This specification considers the supply of the exam by the federal government as constant across markets, as we assume throughout the paper. Indeed, the fees students are charged are the same across the whole country in any given year. Any changes in the fees across years should be captured by the year dummies, which are included in every specification. Therefore, differences in the supply across markets may only occur through differences in the availability of exam centers. In order to test our assumption, in the second specification we add as a regressor the number of municipalities with exam centers in the market. The results are roughly the same, indicating that our assumption is correct. We also show in Appendix B that this result is robust to different measures of exam center availability.

The third specification corresponds to IV estimates. The instruments we use are based on the number of disciplines offered by each college. This is a college specific variable and we need build market-level variables based on it in order to use it as instruments for the number of adopters. We use the average number of disciplines offered by colleges in a market and the largest number of disciplines offered by a college in a market. The motivation for this second instrument is that, as shown in Table 4, colleges with a large number of disciplines are more likely to adopt ENEM. As discussed in subsection 3.4, the validity of these instruments relies on the assumption that, conditional on colleges' characteristics, students do not consider the number of disciplines offered by colleges when deciding whether or not to take ENEM. Once again, the coefficient on college adoption is positive and significant, but five times larger than its OLS counterpart, possibly due to omitted variables bias. The fourth specification shows that the IV results are also roughly unaffected by the inclusion of a control for exam center availability.

In order to examine the economic significance of these estimates, we consider the marginal effect of the adoption by a college on the share of students taking the exam. Using as a benchmark the medians of the number of adopters (0) and of the share of students registered for ENEM (0.44), when a college adopts ENEM, this share increases to 0.49 or 0.68, depending on whether we use the OLS or the IV coefficient estimate, respectively.

4.2 Parameter Estimates for the Colleges' Payoff Function

Table 6 presents the estimated parameters from the colleges' payoff equation (2) using the MSM framework described previously. The sample is restricted to markets with at least two colleges in

order to increase the number of moments we might use in the estimations. The sample consists of 539 markets with a total of 3835 college-year pairs. We draw 100 exogenous shocks vectors for our estimations. We present the results for two different specifications. The first assumes no correlation between shocks within markets, while in the second the correlation coefficient ρ is estimated. Both specifications include dummies for each of the five regions in which the country is divided. We include among the explanatory variables the number of colleges in the market, the number of colleges adopting ENEM, the number of high-school students graduating in the market, and the number of students registered to take ENEM. Colleges' characteristics are distinguished through the log of the year of foundation, number of courses, ownership and academic organization. The estimation also includes dummies for the four years covered in the sample.

The coefficient on the number of students taking ENEM shows that indirect network effects from students to colleges are significant. A 10% increase in the number of students taking it increases the average number of adopters by market by 5%. The coefficients on the number of adopters and on measures of colleges' characteristics show, respectively, that strategic effects and college heterogeneity determine adoption decisions. The coefficient on colleges' adoption is negative and large. An additional adopter in a market decreases the probability of adoption by other colleges by 16%. The coefficient on year of foundation is negative and statistically significant, but its economic importance is low: a one standard deviation increase in the year of foundation of a college (16 years) reduces its probability of adoption by less than 1%. On the other hand, the coefficients on number of courses and academic organization dummies are large and significant. For example, an university is 25% more likely to adopt ENEM than a regular college. These results confirm those from Table 4, with older institutions being more likely to adopt ENEM and with the likelihood of adoption increasing with the number of courses and the complexity of the organization, although not uniformly as in that table. On the other hand, coefficients on ownership dummies are significantly different when compared to that table. In particular, the signs for the private nonphilanthropic and federal are different from those in Table 4. As a whole these results provide strong support to our claim that firm-level data are important to estimate network effects in two-sided markets.

In order to evaluate the fit of the model, Figure 7 compares average observed and simulated probabilities of adoption for markets with 2 to 15 competitors. The lower bound of 2 colleges is again due to the restriction we imposed to the sample used for the estimation of colleges' payoff function. The upper bound of 15 is justified because markets with up to 15 colleges constitute more than 90% of our observations. We used 100 simulations for each market. The graph indicates that the model slightly underpredicts the number of adopters for markets with few colleges, but fits the

data reasonably well through the whole range of number of colleges.

5 Application: Joint Payoffs Maximization

In this section we conduct a counterfactual exercise. We compare colleges' adoption decisions under competition and under joint colleges' payoffs maximization. A comparison with a social optimum in which we also consider government's expenses with ENEM and students' utility is not possible because government's, students' and colleges' payoffs are measured in different units. Also, an evaluation of colleges' payoffs under competition and joint payoffs maximization is not informative in our framework since colleges' payoff for not adopting ENEM is normalized to zero.

The competitive outcome differs from the joint payoff maximizer one for two reasons. First, under the former regime each college does not consider the direct effect its adoption decision has on other colleges' payoffs. This is the negative effect discussed in subsection 3.2. It is independent of students' decisions to take ENEM as a response to colleges' decisions. Second, under the competitive regime each college does not consider how the students' response to its decision affect other colleges' payoffs. This is a positive effect because the value students attribute to ENEM increases with the number of colleges that adopt it. Thus, an additional adopter causes an increase in the pool of students taking ENEM benefiting all the adopters in the market. The latter source of inefficiency is caused by indirect network effects.

The exercise is therefore composed of three steps. First, we compute the average number of adopters across 100 simulated competitive equilibria as the benchmark. These equilibria are computed using the data on exogenous variables, the estimated parameters and the corresponding 100 draws of vectors of simulated structural errors. As in our MSM estimator, colleges follow the order of decisions described in subsection 3.3. Each college adopts if its adoption payoff from equation (2) is greater than 0. The number of adopters is updated according to the decisions of colleges that already played in the game. In the second step we compute the average number of adopters when each college also internalizes the direct effect its adoption decision has on other colleges' decisions. The equilibria are computed in the same way as before, but now the colleges' payoffs equation also includes a term corresponding to the (negative) effect of a college's adoption on the payoffs of all the other colleges that already decided to adopt. Naturally, under this regime change, the equilibrium number of adopters should decrease. In the third step we compare the two previous regimes with a third one in which each college internalizes both this direct effect and the indirect network effect. Once again, the payoffs equation is added with a term that corresponds

to the positive effect of additional students taking ENEM that the new adopter brings on the payoffs of all the colleges that already adopted ENEM. Adoption should be more frequent under this third regime compared to the second one. However, compared to the competitive benchmark the difference between average probabilities of adoption is uncertain. There is no theoretical result indicating whether the direct competitive effect or the indirect network effect should dominate. Such question is then answered by this counterfactual exercise.

Figure 8 and Table 7 present the results. Adoption rates are significantly reduced when colleges internalize the competitive effect. Internalizing indirect network effects increase the adoption rates, but not enough to outweigh the competitive effect. However, using a 95% confidence interval, we cannot reject the hypothesis that the outcomes under competition and joint payoffs maximization are equivalent. These results suggest that without any consideration on students' welfare and governments' expenses, adoption of ENEM by colleges is excessive, but close to the joint optimum.

6 Conclusions

This paper measures the importance of indirect network effects in the adoption of an exam by colleges and students. We found that network effects are significant in both directions. Moreover, we found evidence that colleges play strategically and that their characteristics also determine whether or not they adopt the exam. Having estimated the parameters of the structural model, we were able to compare colleges' payoffs and adoption decisions under competition and under joint payoffs maximization. We found that adoption rates are significantly reduced when colleges internalize the competitive effect. On the other hand, internalizing indirect network effects increases the adoption rates, but not enough to outweigh the competitive effect. We concluded that without considering students' welfare, adoption of ENEM by colleges is excessive, but close to the joint optimum.

The framework we used could be extended in many different ways in order to provide a more accurate description of the market. We used a static model, even though in reality the players in the market may be optimizing a dynamic problem. For example, a college may anticipate the adoption of ENEM in order to preempt adoption by competitors. Our option for a static model has two main reasons. First, the sunk costs from adoption in this market are extremely low. They are simply the costs faced by colleges of considering for the first time one more piece of information - namely the ENEM score - from college applicants. With low sunk costs such dynamic problem collapses into a static one. Second, introducing dynamics into the model would require us to simplify it in

other dimensions. As far as we know, there is no dynamic entry or adoption paper that allows for strategic interactions and player heterogeneity using a data set as rich as ours. Moreover, our model would become even more complex than those since it includes two different sides of a market.[13]

As another extension we could relax the assumptions made in order to pin down a unique equilibrium, as discussed in subsection 3.3. Those assumptions allow us to obtain point estimates of parameters. It might be interesting to know how sensitive our estimates are to those assumptions, even though it certainly requires a more complex empirical framework.[14]

A Appendix A: A Simple Adoption Model

In this appendix we present a static model describing the decision problems of students and colleges. The model is more general than the one presented in the main body of the paper. We show that, under the assumption that colleges' adoption payoffs are negatively affected by adoption by competing colleges, a pure strategy Nash equilibrium (PSNE) always exists in the model and that the number of adopters is the same across different equilibria. The model and its results and demonstrations are adapted from Berry (1992).

A.1 Students

There are M students in the market. Since students do not behave strategically, we can restrict attention to the strategic interaction among colleges when solving for the equilibrium of the game. Therefore, we simply assume that the number of students m taking the exam is a function of n; $m = m(n)$, which is increasing in n:

Assumption A1 $m(n+1) \geq m(n) \forall m, n \geq 0$.

A.2 Colleges

Colleges are assumed to maximize a payoff function that we generally term as payoffs. College i's payoffs are a function of the number of colleges and students adopting the exam, i.e., $\pi_i = \pi_i(n, m)$.

We impose the following assumptions on the profit functions and on $n(.)$:

Assumption A2 $\pi_i(n, m(n)) \geq \pi_i(n+1, m(n+1))$ for all $n \geq 0$ and $i \in \{1, ..., N\}$.

[13] See for example Schmidt-Dengler (2005) for an empirical study of adoption decisions with strategic interactions with a dynamic framework. In the market he studies however there are no indirect network effects.

[14] As already mentioned, see Ciliberto and Tamer (2004).

Assumption A3 $\pi_i(n, m(n)) \geq \pi_j(n, m(n))$ if and only if $\pi_i(n+1, m(n+1)) \geq \pi_j(n+1, m(n+1))$ for all $\forall n \geq 0$ and $i, j \in \{1, ..., N\}$.

Assumption A2 states that the adoption payoffs are declining in the number of adopters even considering the fact that adoption by colleges fosters adoption by students. Assumption A3 imposes that if a college gains more from adoption than another one for a given number of adopters, this relation is maintained for any number of adopters.

A.3 Equilibrium

Let σ_i denote college i's adoption decision. We say that $\sigma_i = 1$ if it adopts ENEM, and that $\sigma_i = 0$ otherwise. Thus, the strategy space of any college is given by $\{0, 1\}$. A strategy profile σ in this game is a N-vector of zeros and ones. Let $\hat{\pi}_i(.,.)$ denote college i's adoption profits as a function of σ. We say that college i receives $\hat{\pi}_i(\sigma_i, \sigma_{-i})$ if it adopts ENEM and 0 otherwise, where σ_{-i} is the vector of strategies of college i's competitors.

A PSNE is a strategy profile σ^* such that, conditional on on the strategies of all other colleges σ^*_{-i}, college i adopts ENEM if it has a nonnegative payoff from adoption, and does not adopt otherwise. Formally

$$\sigma^*_i \in \arg\max_{\sigma_i \in \{0,1\}} \sigma_i \hat{\pi}_i(\sigma_i, \sigma^*_{-i}) \text{ for all } i \in \{1, ..., N\}$$

The assumptions made so far assure the existence of a PSNE. To see this, we can order colleges in a decreasing ranking of profitability and suppose that they adopt in this very order until the next adoption would be unprofitable. By construction, all the adopters have nonnegative payoffs, while nonadopters would have negative adoption payoffs, and this constitutes a PSNE.

In order to draw conclusions on the number of adopters, we need to impose additional structure on the payoff functions that guarantee that, in case an equilibrium is not unique, all PSNE have the same number of adopters.[15] We assume that a payoff function has the following separable form:

$$\pi_i(n, m) = v(n, m) + \psi_i \tag{5}$$

The function above implies that competitor's characteristics do not affect a college's profits directly. They affect profits indirectly, through competitor's decisions. Competitor's decisions affect

[15] The PSNE presented above may not be unique. For example, suppose that in that equilibrium n^* colleges adopt ENEM and that $\pi_{n^*}(n+1, m(n+1)) < 0$ and $\pi_{n^*+1}(n, m(n)) \geq 0$. Then, there would be another PSNE identical to the one described above, but with colleges n^* and $n^* + 1$ switching positions.

college i's profits through the term $v(.,.)$. According to A2, $v(.,.)$ must be such that $\frac{dv(n,m(n))}{dn} \equiv \frac{\partial v(n,m(n))}{\partial n} + \frac{\partial v(n,m(n))}{\partial m}\frac{\partial m(n)}{\partial n} < 0$. The payoff function above also embeds the assumption that college characteristics affect only a fixed part of profits, ψ_i, which is independent of the number of competitors adopting ENEM.

Under A1-A3, if adoption profits are given by (5), then the equilibrium number of adopters is the same for all PSNE, although the identities of adopters and nonadopters may be indeterminate. To see this, let n^* be the number of adopters in one equilibrium and assume that there is another equilibrium with a number of adopters $n > n^*$. Since adopters have nonnegative payoffs, it implies that $v(n, m(n)) + \psi_i \geq 0$ for all adopters, contradicting the definition of n^*. The same argument can be made for $n < n^*$, concluding our demonstration.

B Appendix B: Robustness Results

In this appendix we discuss the robustness of the estimation of the students' utility function to different measures of the number of college applicants and of the supply of ENEM exam centers in microregions.

Table A1 shows that the results from Table 5 are robust to changes in the measurement of the number of potential applicants. Recall that for the estimates presented in Table 5 we used the number of students graduating from high-school multiplied by two as a proxy for the number of college applicants. In Table A1 we show that the main results are robust to changes in that multiple. To save space we present only regressions that include among the regressors the number of municipalities with exam centers in the microregion. Columns 1 and 2 report OLS results setting the multiple to one and three, respectively. The coefficient we are mainly interested, which corresponds to the number of adopters, is equal to 0.09 and 0.23 respectively. The latter is very close to the 0.26 presented in Table 5 while both estimates imply positive and substantial network effects. The coefficient is precisely estimated in the second specification but not in the first. A potential reason for this is that when we set the multiple to one, we automatically dropped all the observations in which the number of students registered for ENEM exceeded the number of students graduating from high-school, otherwise we would calculate the log of a negative number. As a consequence, the number of observations was decreased by almost one half. Columns 3 and 4 report IV results for the same multiples, respectively. Again, the coefficient of interest is more precisely estimated in the second specification than in the first. The estimated coefficient decreases with the multiple, but once again implies a significant network effect for both specifications.

Table A2 shows that the results from Table 5 also robust to changes in the measurement of exam centers availability. Recall that in Table 5 we used for this purpose the number of municipalities with exam centers. In Table A2 we substitute it for a weighted fraction of municipalities with exam centers where the weights are given by the number of students graduating from high-school in each municipality. This measure however has a shortcoming because for some municipalities we could not obtain data on the number of students graduating. Thus, these municipalities were assigned no weight. For this reason we prefer the estimates presented in Table 5.

The estimates presented in Table 8 are approximately the same as those in Table 5. This is true for both the OLS estimates in columns 1 and 2 and the IV estimates in columns 3 and 4. In columns 2 and 4 we also added a dummy for availability in the largest municipality in the microregion as a regressor. The dummy was found to be not statistically significant, while the parameters of interest are basically unchanged.

C Appendix C: Computational Issues

The fact that all the residuals used to construct moments for the colleges' payoff function correspond to discrete dependent variables, namely adoption decisions, makes the MSM function difficult to be minimized. The indicator function (4) which enters the MSM function is composed of flat parts and discontinuous jumps. In the flat parts changes in the parameters do not cause any change in the MSM function, while minimal changes in the neighborhood of a discontinuity may cause the MSM function to change significantly. In order to deal with this problem we smoothed the MSM function replacing the indicator function with a Logit specification. The smoothing turns the MSM function into a continuous one but does not prevent it from having different local minima. Thus, we minimized the MSM function using a Nelder-Mead downhill simplex algorithm, which does not require function derivatives and performed better when compared to other algorithms that require derivatives.

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Figure 1
Annual College Enrolment (millions of students)

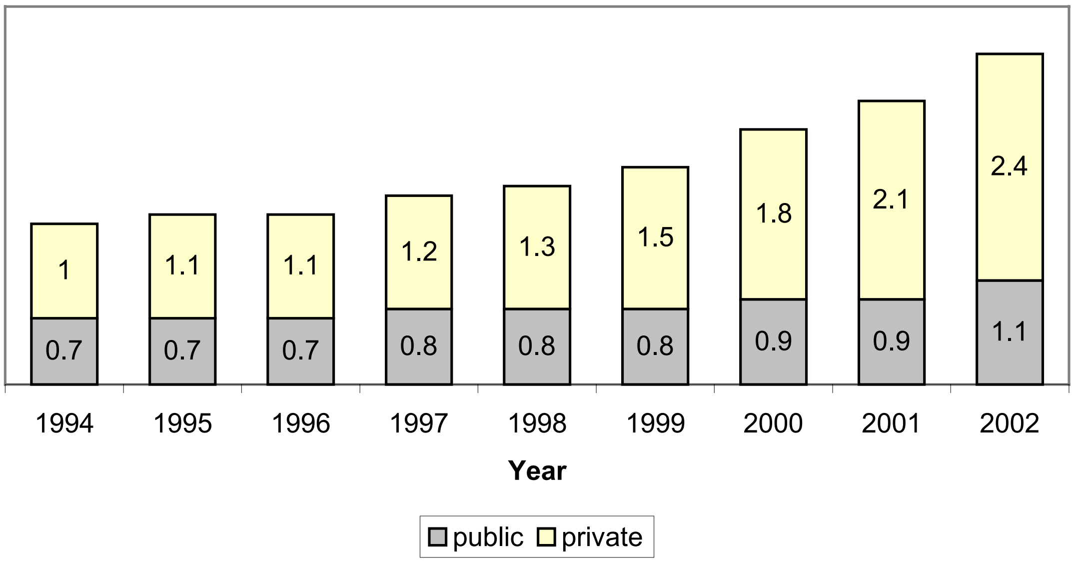


Figure 2
Number of Colleges

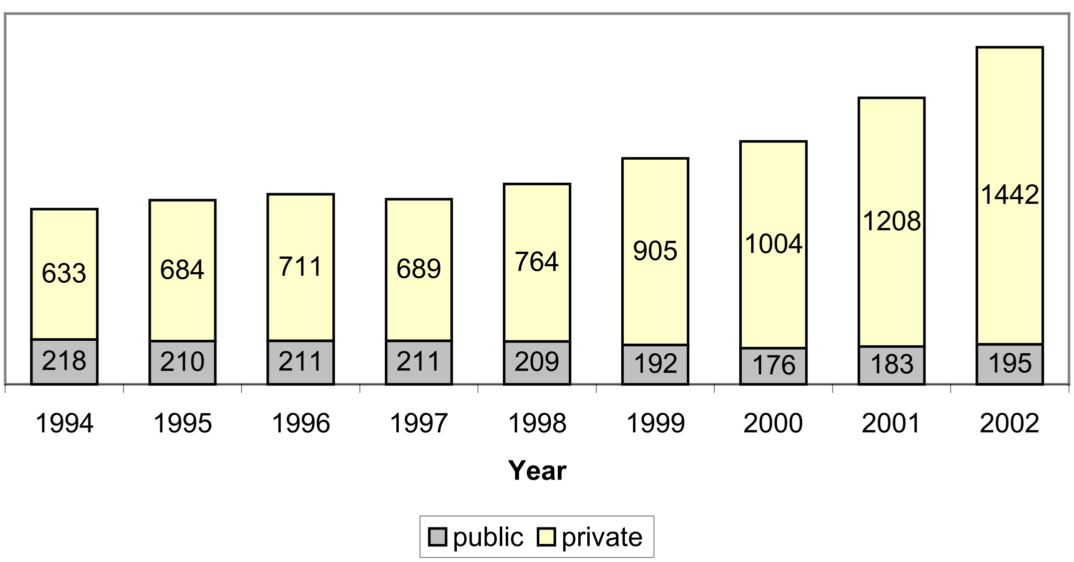


Figure 3
Number of Municipalities with ENEM Exam Centers

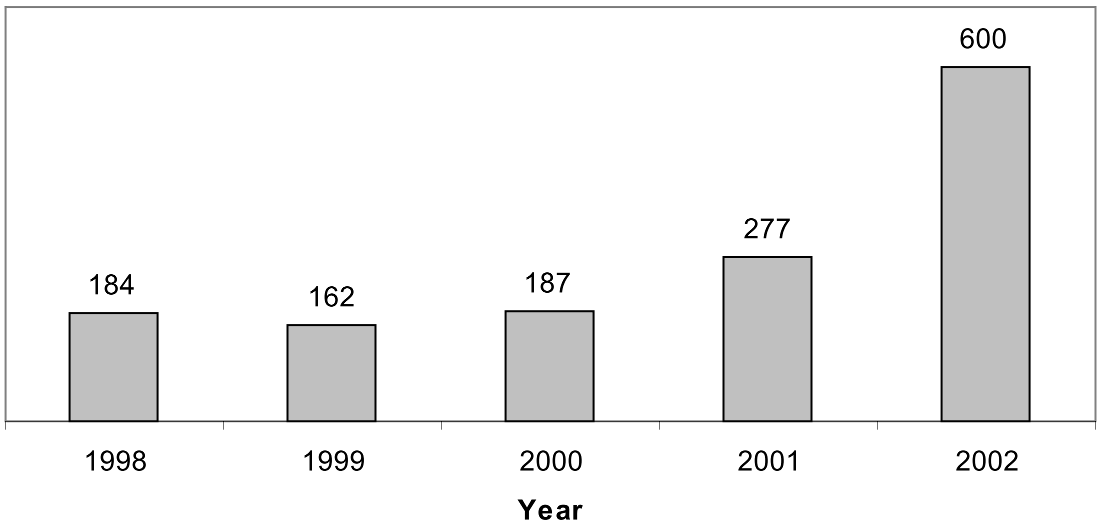


Figure 4
Number of Colleges that Adopt ENEM

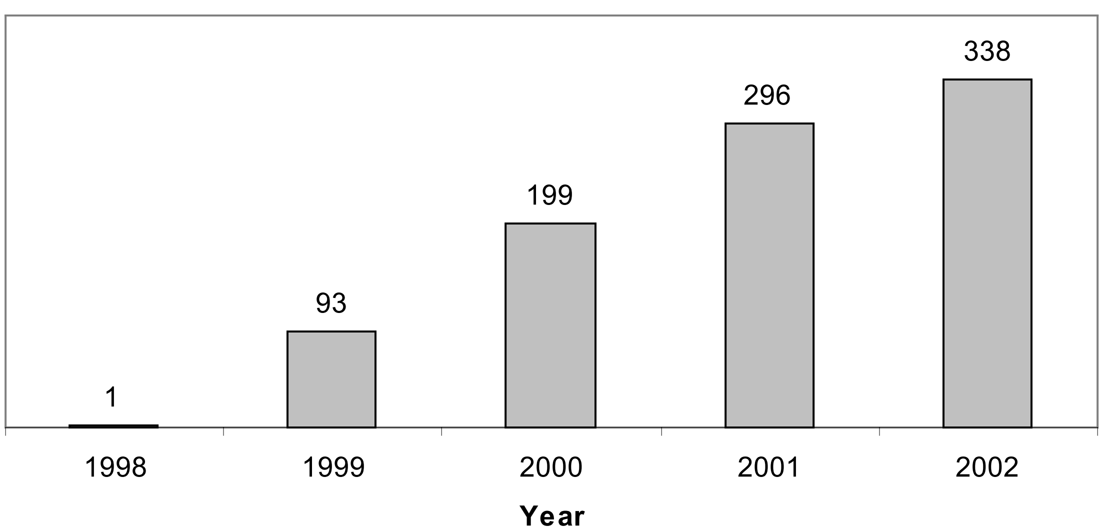


Figure 5
Number of Exam Takers (thousands of students)

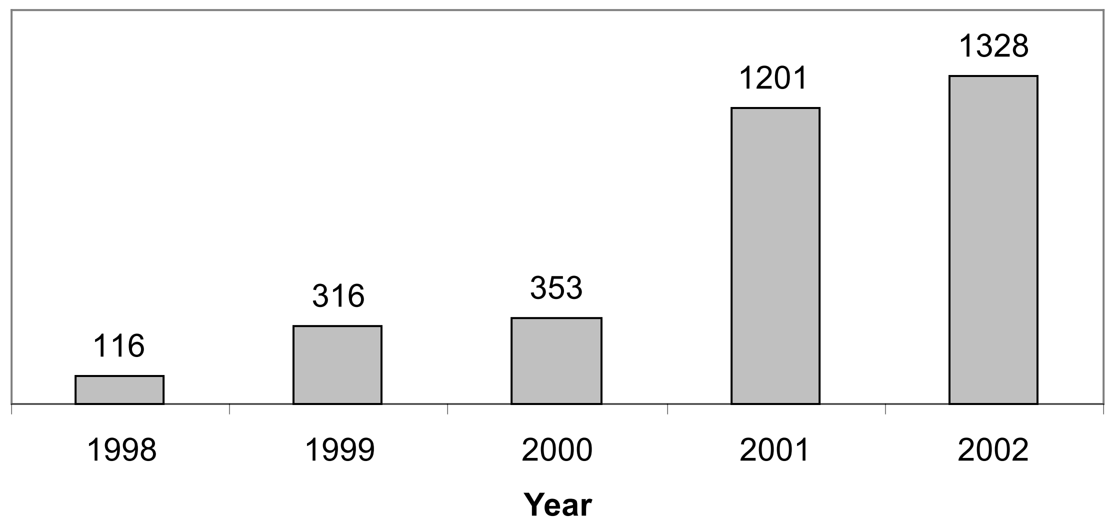
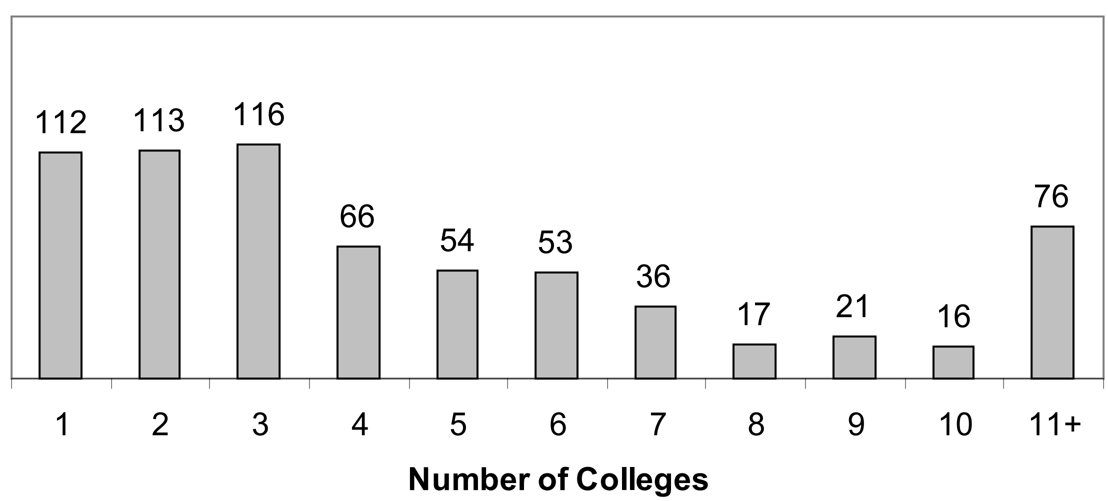


Figure 6
Markets by Number of Colleges



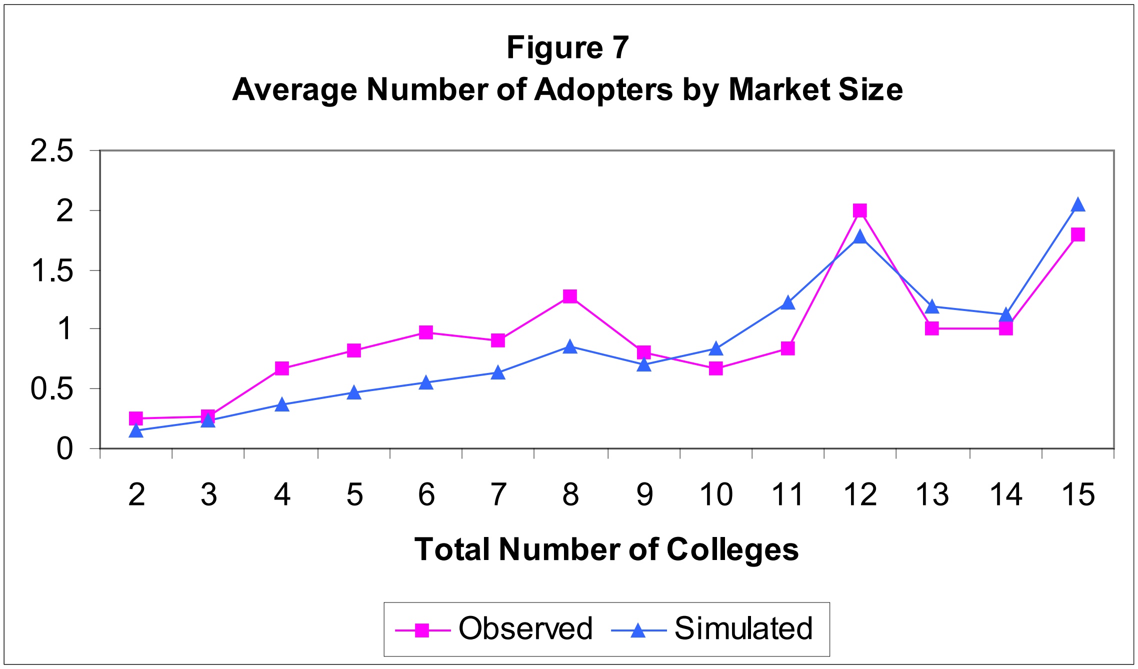


Figure 7
Average Number of Adopters by Market Size
2.5
2
1.5
1
0.5
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15
Total Number of Colleges
Observed
Simulated

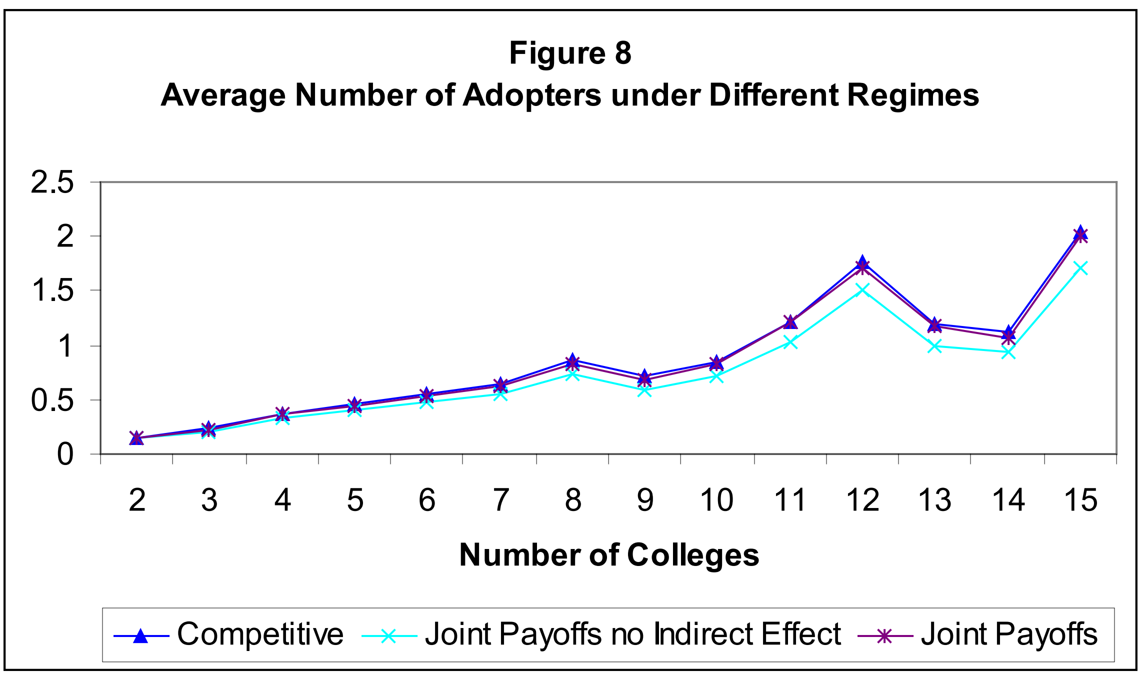


Figure 8
Average Number of Adopters under Different Regimes
2.5
2
1.5
1
0.5
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15
Number of Colleges
Competitive
Joint Payoffs no Indirect Effect
Joint Payoffs

Table 1: Summary Statistics of Market-level Variables

	Variable	Mean	Std. Dev.	Min	Max
High-School Students	**Students Registered for ENEM**	**5,504.80**	**12,963.35**	**76**	**190,957**
	Male Public	2,066.93	5,784.19	43	69,145
	Female Public	2,730.51	7,220.30	65	83,612
	Total Public	**4,797.43**	**12,995.35**	**116**	**150,729**
	Male Private	754.96	1,872.90	6	17,431
	Female Private	896.49	2,183.81	24	22,177
	Total Private	**1,651.45**	**4,057.53**	**22**	**41,636**
	Total Number of Students	**6,448.89**	**17,052.88**	**138**	**192,365**
Colleges	Universities	0.15	0.57	0	7
	Universitarian Centers	0.21	0.83	0	11
	Integrated Colleges	0.36	0.99	0	12
	Single-course Colleges	3.35	6.94	0	71
	Institutes	0.11	0.40	0	4
	Total Private Nonphilanthropic	**4.23**	**9.07**	**0**	**113**
	Universities	0.30	1.06	0	10
	Universitarian Centers	0.11	0.44	0	4
	Integrated Colleges	0.10	0.45	0	6
	Single-course Colleges	1.08	2.66	0	29
	Institutes	0.02	0.16	0	2
	Total Private Philanthropic	**1.62**	**4.23**	**0**	**45**
	Universities	0.21	0.47	0	3
	Universitarian Centers	0.00	0.05	0	1
	Single-course Colleges	0.04	0.23	0	2
	Total Federal	**0.34**	**0.75**	**0**	**6**
	Universities	0.17	0.39	0	2
	Single-course Colleges	0.11	0.39	0	3
	Institutes	0.01	0.09	0	1
	Total State-owned	**0.34**	**0.63**	**0**	**3**
	Universities	0.02	0.15	0	1
	Universitarian Centers	0.01	0.09	0	2
	Integrated Colleges	0.01	0.09	0	1
	Single-course Colleges	0.20	0.52	0	4
	Total Municipality-owned	**0.23**	**0.56**	**0**	**4**
	Total Number of Colleges	**6.58**	**12.81**	**1**	**135**
	Number of Observations	**680**			

Table 2: Summary Statistics of College-level Variables

Variable	Mean	Std. Dev.	Min	Max
Year of Foundation	1983.84	16.61	1910	2001
Number of Courses	13.25	27.35	1	462
Fraction of Faculty with Specialization	0.38	0.13	0.00	0.87
Fraction of Faculty with M.A.	0.38	0.08	0.05	0.76
Fraction of Faculty with Ph.D.	0.12	0.11	0.00	0.89
Adoption of ENEM	0.16			
Number of Observations	**3,995**			

Table 3: Number of College-year Observations by Ownership and Academic Organization

	Ownership					
Academic Organization	Private Nonphil.	Private Phil.	Federal	State-Owned	Municipality-Owned	**Total**
Universities	103	210	156	115	14	**598**
Universitarian Centers	208	142	3	0	8	**361**
Integrated Colleges	242	48	2	0	4	**296**
Single-course Colleges	1,887	503	24	115	124	**2,653**
Institutes	66	11	0	10	0	**87**
Total	**2,506**	**914**	**185**	**240**	**150**	3,995

Table 4: "First Stage" Logit Estimates of Colleges' Adoption Decisions

	Variable	Coeff.	SE	Coeff.	SE
	constant	99.517	52.033	75.870	53.200
	ln(number of courses)	0.517	0.199	0.432	0.205
	ln(year of foundation)	-14.009	6.847	-10.783	7.000
Faculty	fraction specialization	0.312	1.281	0.090	1.310
	fraction M.A.	0.046	1.295	0.156	1.309
	fraction Ph.D.	4.182	1.166	4.314	1.203
Ownership	private nonphilanthropic	0.405	0.308	0.088	0.331
	private philanthropic	0.171	0.314	-0.153	0.337
	federal	-1.202	0.400	-1.523	0.430
	state-owned	-2.161	0.503	-2.335	0.524
Academic Organization	university	2.069	0.938	2.370	0.957
	universitarian center	1.142	0.841	1.422	0.854
	integrated college	1.644	0.769	1.804	0.777
	college	1.611	0.727	1.705	0.736
High-School Students	ln(graduating from high-school)	0.338	0.112	0.394	0.141
	fraction male	2.943	2.409	5.442	2.474
	fraction public high-school	-2.852	0.721	-4.201	0.848
Colleges	ln(colleges)	-0.330	0.131	-0.362	0.183
private nonphilanthropic	universities			-0.122	0.144
	universitarian centers			-0.001	0.103
	integrated colleges			-0.033	0.094
	colleges			0.018	0.017
	institute of superior education			0.123	0.123
private philanthropic	universities			0.430	0.121
	universitarian centers			-0.394	0.196
	integrated colleges			0.010	0.131
	colleges			-0.081	0.038
	institute of superior education			-0.164	0.324
state-owned	universities			0.057	0.219
	universitarian centers			0.368	0.165
	colleges			0.565	0.428
federal	universities			-0.674	0.220
	universitarian centers			2.097	0.995
	colleges			-0.378	0.354
municipality-owned	universities			-1.399	0.565
	colleges			-0.244	0.593
	institute of superior education			-0.153	0.138
	year dummies	yes		yes	
	state dummies	yes		yes	
	Pseudo R-squared	**0.16**		**0.18**	
	Number of Observations	**3874**		**3855**	

Table 5: Students' Utility Function Estimation Results

		OLS			
	Variable	Coeff.	SE	Coeff.	SE
	constant	0.273	1.834	0.131	1.839
Microregions	municipalities with exam centers			0.093	0.089
	municipalities in microregion	-0.081	0.053	-0.105	0.057
High-School	fraction male	0.554	1.628	0.730	1.637
Students	fraction public high-school	-0.330	0.625	-0.329	0.625
Colleges	ln(colleges)	-0.373	0.102	-0.369	0.102
	ln(adopters + 1)	0.280	0.105	0.261	0.107
Faculty	fraction specialization	0.365	1.464	0.366	1.464
	fraction M.A.	1.165	1.714	1.226	1.715
	fraction Ph.D.	-0.407	1.773	-0.380	1.773
private	universities	-0.154	0.116	-0.167	0.116
nonphilathropic	universitarian centers	0.042	0.099	0.038	0.099
	integrated colleges	0.028	0.085	0.026	0.085
	colleges	-0.002	0.016	-0.002	0.016
	institute of superior education	-0.099	0.128	-0.129	0.131
private	universities	-0.006	0.098	-0.012	0.098
philanthropic	universitarian centers	-0.255	0.146	-0.264	0.147
	integrated colleges	-0.077	0.140	-0.086	0.141
	colleges	0.051	0.031	0.047	0.031
	institute of superior education	-0.203	0.279	-0.213	0.279
state-owned	universities	-0.099	0.153	-0.094	0.153
	colleges	0.181	0.148	0.191	0.148
	institute of superior education	-0.085	0.518	-0.046	0.520
federal	universities	0.074	0.177	0.068	0.177
	colleges	-0.110	0.266	-0.154	0.269
municipality-owned	universities	-0.412	0.330	-0.472	0.335
	universitarian centers	0.300	0.783	0.301	0.783
	integrated colleges	-0.108	0.537	-0.101	0.537
	colleges	0.090	0.083	0.091	0.083
	year dummies	yes		yes	
	state dummies	yes		yes	
	R-squared	**0.70**		**0.70**	
	Number of Observations	**520**		**520**	

Table 5: Students' Utility Function Estimation Results (cont.)

		2SLS			
	Variable	Coeff.	SE	Coeff.	SE
	constant	-0.438	2.097	-0.328	2.095
Microregions	municipalities with exam centers			-0.075	0.132
	municipalities in microregion	-0.131	0.064	-0.112	0.065
High-School Students	fraction male	-1.225	2.040	-1.380	2.141
	fraction public high-school	0.582	0.839	0.587	0.846
Colleges	ln(colleges)	-0.530	0.139	-0.534	0.142
	ln(adopters + 1)	1.454	0.600	1.478	0.629
Faculty	fraction specialization	0.673	1.657	0.675	1.665
	fraction M.A.	2.192	1.999	2.150	1.998
	fraction Ph.D.	-0.959	2.017	-0.985	2.031
private nonphilathropic	universities	-0.305	0.151	-0.295	0.147
	universitarian centers	-0.078	0.127	-0.076	0.126
	integrated colleges	0.026	0.096	0.028	0.097
	colleges	-0.029	0.023	-0.029	0.023
	institute of superior education	-0.107	0.144	-0.083	0.150
private philanthropic	universities	-0.227	0.157	-0.224	0.155
	universitarian centers	-0.131	0.176	-0.123	0.181
	integrated colleges	-0.132	0.160	-0.126	0.160
	colleges	0.101	0.043	0.104	0.046
	institute of superior education	-0.148	0.316	-0.139	0.319
state-owned	universities	-0.130	0.173	-0.135	0.174
	colleges	-0.011	0.192	-0.021	0.199
	institute of superior education	-0.361	0.600	-0.395	0.614
federal	universities	0.140	0.203	0.145	0.205
	colleges	-0.118	0.299	-0.082	0.307
municipality-owned	universities	-0.311	0.376	-0.262	0.394
	universitarian centers	1.426	1.047	1.433	1.056
	integrated colleges	0.330	0.644	0.328	0.646
	colleges	0.225	0.115	0.225	0.116
	year dummies	yes		yes	
	state dummies	yes		yes	
	R-squared				
	Number of Observations	**520**		**520**	

Table 6: Colleges' Profit Function Estimation Results

	Variable	Coeff.	SE	Coeff.	SE
	constant	0.093	0.189	0.102	0.225
	ln(year of foundation)	-1.296	0.060	-1.187	0.238
	ln(number of courses)	0.443	0.173	0.413	0.201
Ownership	private nonphilanthropic	-0.744	0.089	-0.877	0.098
	private philanthropic	0.738	0.225	0.772	0.234
	federal	0.738	0.218	0.789	0.230
	state-owned	-0.638	0.232	-0.567	0.289
Academic Organization	university	0.640	0.122	0.687	0.172
	universitarian center	0.617	0.216	0.458	0.269
	integrated college	0.805	0.350	0.772	0.341
	college	-0.096	0.140	-0.213	0.150
High-School Students	ln(registered for ENEM)	1.332	0.132	1.445	0.175
	ln(graduating from high-school)	-0.312	0.102	-0.285	0.099
	fraction male	0.037	0.101	-0.196	0.121
	fraction public high-school	-0.732	0.136	-0.635	0.122
Colleges	ln(colleges adopting ENEM + 1)	-0.637	0.075	-0.589	0.098
	ln(colleges)	0.186	0.081	0.174	0.093
	correlation coefficient			0.942	0.328
	region dummies	yes		yes	
	year dummies	yes		yes	
	Number of Observations (Markets)	**541**		**541**	
	Number of Colleges	**3856**		**3856**	
	Number of Simulations	**100**		**100**	

Table 7: Average Number of Colleges that Adopt ENEM

Number of Colleges in the Market	Observed		Competitive		Joint Profits no Indirect Effect		Joint Profits	
	Number	SE	Number	SE	Number	SE	Number	SE
2	0.26	0.51	0.16	0.11	0.14	0.10	0.15	0.10
3	0.26	0.59	0.23	0.13	0.21	0.12	0.22	0.13
4	0.67	0.93	0.37	0.19	0.33	0.17	0.36	0.19
5	0.82	0.87	0.46	0.23	0.40	0.20	0.45	0.22
6	0.97	1.46	0.55	0.27	0.47	0.23	0.54	0.25
7	0.90	1.33	0.65	0.23	0.54	0.20	0.63	0.22
8	1.28	1.60	0.86	0.40	0.73	0.35	0.83	0.39
9	0.80	0.79	0.71	0.36	0.59	0.31	0.69	0.35
10	0.67	0.89	0.84	0.40	0.71	0.34	0.82	0.39
11	0.83	0.98	1.22	0.37	1.04	0.32	1.21	0.37
12	2.00	1.41	1.77	0.40	1.50	0.35	1.71	0.36
13	1.00	1.15	1.19	0.30	0.99	0.26	1.18	0.30
14	1.00		1.13		0.94		1.07	
15	1.80	1.48	2.05	0.24	1.72	0.21	2.00	0.23

Table A1: Robustness of Students' Utility Function Estimation to Measures of the Number of College Applicants

	Variable	OLS Coeff.	OLS SE	OLS Coeff.	OLS SE
	constant	2.062	2.517	-2.078	1.357
Microregions	municipalities with exam centers	0.178	0.169	0.024	0.076
	municipalities in microregion	-0.040	0.076	-0.149	0.048
High-School Students	fraction male	-1.038	2.231	0.764	1.260
	fraction public high-school	-1.377	0.799	-0.304	0.486
Colleges	ln(colleges)	-0.217	0.130	-0.305	0.082
	ln(adopters + 1)	0.089	0.145	0.231	0.088
Faculty	fraction specialization	2.238	2.035	3.107	1.203
	fraction M.A.	0.727	2.315	4.404	1.416
	fraction Ph.D.	2.160	2.289	3.184	1.479
private nonphilathropic	universities	-0.207	0.158	-0.225	0.100
	universitarian centers	-0.095	0.137	-0.009	0.085
	integrated colleges	0.204	0.113	0.040	0.071
	colleges	-0.011	0.023	0.003	0.014
	institute of superior education	0.378	0.253	-0.009	0.098
private philanthropic	universities	-0.091	0.132	0.163	0.080
	universitarian centers	-0.209	0.193	-0.152	0.125
	integrated colleges	-0.111	0.163	-0.151	0.123
	colleges	0.024	0.038	0.005	0.027
	institute of superior education	-0.484	0.558	-0.290	0.240
state-owned	universities	-0.105	0.189	-0.056	0.128
	colleges	0.384	0.185	0.377	0.114
	institute of superior education	0.279	0.660	-0.167	0.458
federal	universities	0.202	0.217	-0.119	0.144
	universitarian centers				
	colleges	-0.404	0.337	-0.087	0.223
municipality-owned	universities	-0.355	0.384	-0.476	0.294
	universitarian centers	1.098	1.296	0.547	0.686
	integrated colleges	-0.346	0.614	0.241	0.377
	colleges	0.017	0.119	0.078	0.072
	year dummies	yes		yes	
	state dummies	yes		yes	
	R-squared	**0.73**		**0.70**	
	Number of Observations	**285**		**614**	

Table A1: Robustness of Students' Utility Function Estimation
to Measures of the Number of College Applicants (cont.)

		2SLS			
	Variable	Coeff.	SE	Coeff.	SE
	constant	1.864	3.055	-4.008	1.656
Microregions	municipalities with exam centers	0.160	0.205	-0.050	0.108
	municipalities in microregion	-0.074	0.094	-0.150	0.051
High-School	fraction male	-1.926	2.766	0.031	1.509
Students	fraction public high-school	-0.869	1.023	0.326	0.803
Colleges	ln(colleges)	-0.453	0.220	-0.406	0.132
	ln(adopters + 1)	1.591	0.990	0.912	0.676
Faculty	fraction specialization	1.570	2.505	3.161	1.267
	fraction M.A.	0.587	2.808	5.126	1.650
	fraction Ph.D.	0.937	2.886	2.742	1.615
private	universities	-0.397	0.228	-0.294	0.126
nonphilathropic	universitarian centers	-0.278	0.204	-0.079	0.112
	integrated colleges	0.149	0.142	0.054	0.076
	colleges	-0.031	0.030	-0.013	0.021
	institute of superior education	0.452	0.310	-0.043	0.108
private	universities	-0.405	0.259	0.042	0.146
philanthropic	universitarian centers	-0.067	0.251	-0.067	0.157
	integrated colleges	-0.290	0.230	-0.173	0.131
	colleges	0.121	0.078	0.032	0.039
	institute of superior education	-0.440	0.677	-0.249	0.255
state-owned	universities	-0.181	0.234	-0.095	0.140
	colleges	0.087	0.295	0.263	0.164
	institute of superior education	-0.426	0.921	-0.302	0.500
federal	universities	0.258	0.265	-0.062	0.161
	universitarian centers			0.736	0.953
	colleges	-0.329	0.411	-0.079	0.234
municipality-owned	universities	-0.324	0.466	-0.391	0.321
	universitarian centers	3.103	2.040	1.190	0.960
	integrated colleges	0.061	0.790	0.477	0.459
	colleges	0.209	0.191	0.149	0.103
	year dummies	yes		yes	
	state dummies	yes		yes	
	R-squared				
	Number of Observations	**285**		**614**	

Table A2: Robustness of Student Demand Estimation to Measures of Exam Center Availability

		OLS			
	Variable	Coeff.	SE	Coeff.	SE
	constant	0.188	1.874	0.240	1.887
Microregions	available in largest municipality			-0.106	0.422
	weighted average availability	0.066	0.293	0.128	0.381
	municipalities in microregion	-0.074	0.061	-0.071	0.063
High-School	fraction male	0.575	1.633	0.591	1.636
Students	fraction public high-school	-0.320	0.627	-0.316	0.628
Colleges	ln(colleges)	-0.374	0.102	-0.370	0.104
	ln(adopters + 1)	0.276	0.106	0.275	0.107
Faculty	fraction specialization	0.359	1.466	0.346	1.468
	fraction M.A.	1.186	1.718	1.164	1.722
	fraction Ph.D.	-0.402	1.775	-0.431	1.780
private	universities	-0.155	0.116	-0.157	0.116
nonphilathropic	universitarian centers	0.041	0.099	0.040	0.099
	integrated colleges	0.028	0.086	0.028	0.086
	colleges	-0.002	0.016	-0.003	0.016
	institute of superior education	-0.100	0.128	-0.103	0.129
private	universities	-0.007	0.099	-0.008	0.099
philanthropic	universitarian centers	-0.258	0.147	-0.263	0.149
	integrated colleges	-0.076	0.141	-0.075	0.141
	colleges	0.050	0.031	0.050	0.031
	institute of superior education	-0.204	0.280	-0.206	0.280
state-owned	universities	-0.103	0.154	-0.103	0.154
	colleges	0.180	0.148	0.179	0.148
	institute of superior education	-0.088	0.519	-0.084	0.520
federal	universities	0.073	0.178	0.071	0.178
	colleges	-0.110	0.266	-0.111	0.266
municipality-owned	universities	-0.421	0.333	-0.427	0.334
	universitarian centers	0.314	0.786	0.328	0.789
	integrated colleges	-0.099	0.539	-0.084	0.543
	colleges	0.092	0.083	0.094	0.083
	year dummies	yes		yes	
	state dummies	yes		yes	
	R-squared	**0.70**		**0.70**	
	Number of Observations	**520**		**520**	

Table A2: Robustness of Student Demand Estimation to Measures of Exam Center Availability (cont.)

		2SLS			
	Variable	Coeff.	SE	Coeff.	SE
	constant	0.123	2.168	0.034	2.194
Microregions	available in largest municipality			0.179	0.512
	weighted average availability	-0.495	0.446	-0.607	0.586
	municipalities in microregion	-0.189	0.092	-0.196	0.098
High-School Students	fraction male	-1.572	2.190	-1.631	2.226
	fraction public high-school	0.601	0.867	0.607	0.874
Colleges	ln(colleges)	-0.535	0.144	-0.545	0.151
	ln(adopters + 1)	1.605	0.698	1.627	0.717
Faculty	fraction specialization	0.750	1.707	0.778	1.720
	fraction M.A.	2.145	2.048	2.196	2.071
	fraction Ph.D.	-1.053	2.080	-1.014	2.090
private nonphilathropic	universities	-0.315	0.157	-0.314	0.158
	universitarian centers	-0.082	0.131	-0.082	0.132
	integrated colleges	0.029	0.099	0.029	0.099
	colleges	-0.032	0.024	-0.032	0.024
	institute of superior education	-0.094	0.148	-0.090	0.150
private philanthropic	universities	-0.239	0.165	-0.241	0.167
	universitarian centers	-0.093	0.191	-0.083	0.197
	integrated colleges	-0.149	0.167	-0.151	0.168
	colleges	0.110	0.047	0.111	0.048
	institute of superior education	-0.131	0.326	-0.127	0.328
state-owned	universities	-0.104	0.178	-0.104	0.179
	colleges	-0.027	0.202	-0.029	0.203
	institute of superior education	-0.373	0.618	-0.384	0.624
federal	universities	0.149	0.209	0.154	0.211
	colleges	-0.113	0.308	-0.112	0.309
municipality-owned	universities	-0.234	0.397	-0.221	0.403
	universitarian centers	1.436	1.078	1.429	1.081
	integrated colleges	0.306	0.658	0.287	0.660
	colleges	0.229	0.119	0.227	0.119
	year dummies	yes		yes	
	state dummies	yes		yes	
	R-squared				
	Number of Observations	**520**		**520**	