Profiling in Bargaining Over College Tuitions*

Dennis Epple
Carnegie Mellon University and NBER

Richard Romano
University of Florida

Sinan Sarpca
Carnegie Mellon University

Holger Sieg
Carnegie Mellon University and NBER

January 21, 2005

*We would like to thank our discussant Chris Taber as well as Larry Blume, Maria Ferreyra, Charles Manski, Michael Peress, Larry Samuelson, and participants at the symposium on "Social Interactions in Profiling" at Northwestern University for helpful comments and suggestions. We would also like to thank Bill Elliott, Vice President for Enrollment, and Michael Steidel, Director of Admissions, at Carnegie Mellon University for providing us with the data used in this paper and for valuable discussions of the admission process. Financial support for this research is provided by the National Science Foundation and the MacArthur Foundation.

Abstract

College students are uncertain about whether they will be admitted at any given institution. Hence students typically apply to several institutions. Part of this uncertainty is due to the fact that the applicant does not know how the college will "read" his or her record. Different colleges will receive different signals about the underlying skills of a student. The paper models the admission process of a single college as a bargaining game between the college and a potential student with sequential moves and asymmetric information. The model predicts that the college makes an initial offer based on the information in the application package. If a student obtains an outside offer and reveals it to the college, the college receives additional information incorporated in the outside offer. This information may trigger a counter-offer that improves financial aid for the applicant. The empirical analysis in this paper suggests that counter-offers are typically not correlated with any information that is available at the initial admission stage. However, counter-offers respond strongly to the information content of the outside offer received by a potential student. The empirical evidence is consistent with the notion that signaling and profiling are important aspects of the college admission process.

1 Introduction

More than any other institutions in the U.S. economy, colleges and universities can vary access and price (financial aid) with the characteristics of the individuals being served.[1] In granting this wide latitude to educational institutions, legislatures and courts have largely accepted two premises. One is that an applicant's capability is difficult to measure, and colleges may place weight on a variety of attributes in attempting to infer a prospective student's capability.[2] Second, a student's educational experiences are affected by the characteristics of his or her peers, and a college may wish to select from its applicant pool students with differing attributes in order to form a class with peer characteristics that the college deems desirable.[3] While colleges' exercise of discretion in admission and pricing continues to be controversial, the claim that they exercise such discretion is not. We take as given that this latitude exists, and we investigate the role of asymmetric information in the admissions and pricing process.

It is typically the case that a potential college student applies to several institutions. Thus, it is evident that applicants are uncertain about whether they will be admitted at any given institution. This uncertainty may derive from many sources. For example, an applicant may not know the attributes of others in a college's applicant pool, making it difficult for the applicant to determine how his or her credentials measure up relative to others in the pool. However, we believe there is a more fundamental basis for an applicant's uncertainty about prospects for admission at a given college. The applicant does not know how the college will "read" his or her record, and different colleges will read the record

[1] Evidence of varying access and price is provided in Fuller, Manski, and Wise (1982), Manski and Wise (1983), Kane and Spizman (1994), Bowen and Bok (1998), Kane (1998), Long (2002), and Epple, Romano, and Sieg (2003).

[2] College's exercise of discretion in student admissions is frequently challenged and sometimes circumscribed. Examples include the recent Supreme Court decision with respect to affirmative action, bans on the use of affirmative action in several states, and mandates in some states that state colleges accept a specified fraction of the top graduates of each of the state's high schools.

[3] The effects of peer interactions are the subject of extensive research, including Betts and Morell (1999), Dale and Krueger (1998), Sacerdote (2001), Zimmerman (2000), Kremer and Levy (2003), Epple, Romano, and Sieg (2004), and Sarpca (2004).

differently.[4]

As we noted above, there is extensive evidence that colleges rely on a variety of attributes in admission and pricing decisions. An attribute of an applicant might be of interest to a college because it enters the college's objective function or because it provides information about attributes that enter the college's objective function. For example, for otherwise equivalent applicants, college may favor lower-income applicants because their objective is to provide education to all income types or because lower-income applicants with the same credentials are likely to be more talented. It is the latter that conforms to profiling.

Most of the previous literature that has analyzed college admission and enrollment decisions has been based on simple static models. This approach ignores the fact that colleges and potential students often negotiate over the amount of financial aid that is awarded to the student. These negotiations may take some time. To set the stage for our modelling approach, consider the following stylized description of the admission process. This process typically starts with potential students applying to a college. The college then evaluates students based on the submitted application material. The college makes a decision regarding each applicant, sends out admission letters and offers of financial aid to the students that it hopes to attract. Since students apply to multiple colleges, some of them will receive multiple offers. These students sometimes decide to negotiate about the terms of financial aid. These students submit written admission and financial aid offers from other institutions. The college then responds in writing, normally within twenty-four hours, with a statement of the increase in financial aid, if any, that will be given in response to the outside offer. After negotiations are over, students then decide which college to attend and enroll in their preferred schools.

The negotiation process not only takes time, but, more importantly from our perspec-

[4]The recent Supreme Court decision on affirmative action, requiring "holistic review" of each applicant, can be interpreted as a mandate that a college rely less on easily measured attributes and more on a comprehensive reading of each applicant's record. Here "reading" may be interpreted literally as an effort to distill information from letters of recommendation and applicants' statements of purpose, as well as figuratively in the from of effort in evaluating an applicant's qualifications in light of the hardships or advantages that he or she has experienced.

tive, information about student abilities is revealed in this negotiation process. The purpose of this paper is then to analyze the role that informational asymmetries and profiling play in this bargaining process. The paper models the admission process as a bargaining game between a college and a potential student with sequential moves and asymmetric information. In the first stage of the game, the college receives a vector of noisy signals about the characteristics of each applicant. The college needs to to decide whether to admit a given student and how much financial aid it offers. In the second stage of the model, students receive an outside offer. This outside offer is based on a different set of signals received by the outside college. The student then must make a decision whether or to reveal the outside offer to the college. If the student reveals the outside offer, the college can infer the ability signal that the outside school must have received. It thus gains important information about the quality of the applicant from the outside offer. In the last stage of the game, the new information may trigger an increase in the financial aid offer to the applicant.

We construct a Bayesian Nash Equilibrium for this sequential bargaining game. We show that the equilibrium of our model is consistent with the observed stylized facts that (a) not all students negotiate; (b) not all students that negotiate receive more financial aid; (c) some students receive substantially better offers as a result of the negotiation process; (d) students that negotiate do not necessarily enroll at the college, even if they receive attractive counter-offers. Since the game does not generally have an analytical solution, we also provide some numerical examples that illustrate the quantitative properties of the equilibrium.

Our empirical analysis of the bargaining process is based on data from Carnegie Mellon University. Their negotiation process is conducted in writing, with applicants providing written documentation of outside offers and the university providing a written response. From the perspective of empirical research, the formalization of the negotiation process is ideal. The written exchanges provide the necessary data for our analysis, and the uniformity of the process lends itself well to modeling and empirical study. We have obtained access to data from Carnegie Mellon University for the year 2004-05. The data set contains information about this process for all admitted students. The goal of the empirical analysis of this paper is to determine whether our bargaining model is consistent with the data. In particular, we would like to assess the magnitude of the idiosyncratic component in reading of the record relative to the magnitude of the components of the record that are common knowledge among colleges (e.g., SAT scores, race, gender, need, state of residence) and to us as analysts.[5] Moreover, we investigate the extent to which there is overlap in colleges' subjective reading of applicants' records. Identification of profiling in the admissions process, as defined above, is subtle because it depends on the objective function. A key element of our data and analysis regards how colleges respond to applicants with competing offers to attend other colleges. Since it is reasonable to presume that colleges do not care per se about attracting students with competing offers (which would be largely private information), use of this information by colleges provides a credible example of profiling.[6]

To test the main predictions of the model, we estimate a number of reduced form models and investigate the main factors that predict the magnitude of the counter-offer in the bargaining process. Our findings suggest that counter-offers are typically not correlated with any information that is available at the initial admission stage. However, counter-offers respond strongly to the information content of the outside offer received by a potential student. While out estimates are consistent with profiling on several applicant characteristics, our findings related to competing offers constitute the strongest evidence of profiling.

The plan of the remainder of the paper is as follows. Section 2 develops a model of the bargaining game between the university and its applicants. A computational model is presented in Section 3. The data are presented in Section 4. Section 5 discusses the main empirical findings of this paper. A conclusion appears in Section 6.

[5]A distinctive feature of our data set is that we have access to virtually all of the variables that would be common knowledge among colleges. In treating the enumerated variables as common knowledge, we neglect misrepresentation by applicants (e.g., under-reporting family income) and idiosyncratic errors (e.g., clerical errors in colleges' transcriptions of applicants data).

[6]Merlo (1997), Sieg (2000), and Diermeier, Eraslan, and Merlo (2004) are examples of studies that discuss how to estimate the structural parameters of bargaining models.

2 The Game

2.1 The Players

There are two players in this game: a college and a student. The college offers an educational experience with quality q to each student that attends the college. A student has income y, ability v, and faces negotiation costs c. We assume that y is common knowledge. Ability and negotiation costs are private information of the student. For simplicity, we assume that negotiation costs c can take on two values, 0 and $\bar{c} > 0$ with probabilities $(1 - \pi_c)$ and π_c respectively. Ability is continuously distributed with known density $f(v)$.

A key assumption of the model is that the ability v is not perfectly observed by the school. Instead the college observes a noisy signal of ability denoted by $b = v + \eta$, where η captures the noise component of the observed signal. We assume that η has a known distribution $g(\eta)$. We also assume that v, c, and η are mutually independent random variables.

Before negotiations take place, a student receives an outside offer p_o from another college with quality q_o that is common knowledge.[7] The tuition p_o is a known monotonic function of the student's outside signal $b_o = v + \eta_o$.

The private information in this game is captured by the triple (v, b_o, c). With a slight abuse of notation, we will also refer to a student type as the triple (v, b_o, c), keeping in mind that (y, b) and q_o are common knowledge.

2.2 The Game Tree

The tree of the game is depicted in Figure 1. First, nature draws a student type (y, v, b, b_o, q_o, c). The college observes (y, b, q_o). The college then decides whether or not to admit the student and the level of tuition. Let p_1 denote the college's initial offer. The

[7] We assume, for simplicity, that there is only one outside option. In practice, any school will compete with a variety of other schools. Extending our model to deal with multiple outside options is fairly straightforward.

college also commits publicly to a counter-offer tuition policy, $p_2(b_o) \leq p_1$, at this stage.[8] If the student is admitted to the college, he must decide whether or not to negotiate with the college. If the student chooses not to negotiate, he has two options. First, he can accept the initial offer of the college. Alternatively, he can reject the offer by the college and choose the outside option instead.

If the student decides to negotiate, he reveals the outside offer, p_o. Observing p_o, the college can infer b_o. This triggers the counter-offer $p_2(b_o)$, which might just be a re-offer of the initial tuition p_1. We assume that p_2 cannot be higher than p_1, i.e., that the college must honor its initial commitment. After receiving the counter-offer, the student decides whether to enroll or not. Upon enrolling, all private information is revealed to the college, pay-offs are determined, and the game ends.[9]

2.3 Pay-offs

The college is risk-neutral. Its pay-off is increasing in the student's underlying ability v and the tuition p that the student pays. For simplicity, we assume that the pay-off of the college is given the following linear function, if the student enrolls:

$$v + \gamma p \tag{1}$$

for $\gamma > 0$. The payoff is zero if a student does not enroll.

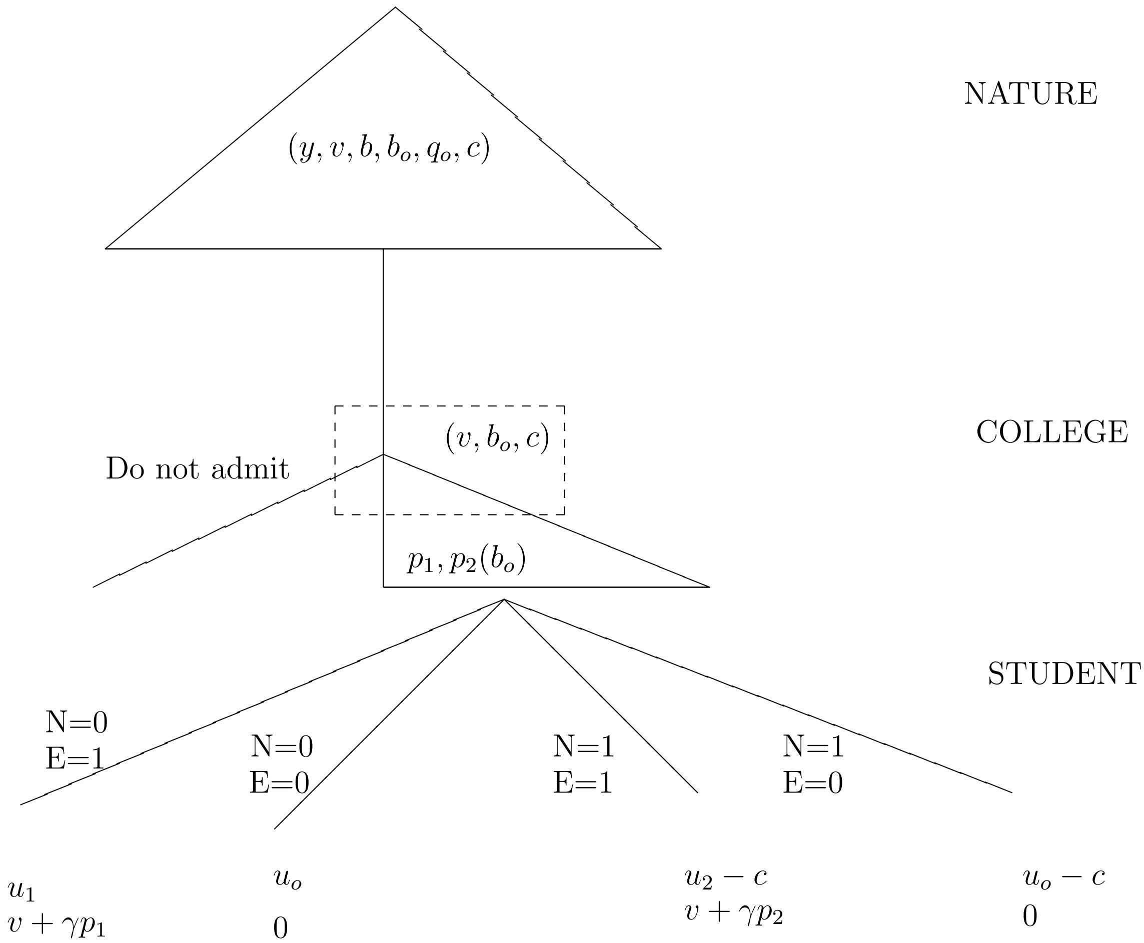
The student's payoff is represented by a utility function $u(y, p, q, v)$ that increases in college quality, his own ability and income, and decreases in tuition. We assume that the utility function satisfies a single crossing condition:

$$\partial\Big(\frac{\partial u/\partial q}{\partial u/\partial y}\Big)/\partial v > 0 \tag{2}$$

[8]While this commitment could be in writing, the college's reputation is likely to provide an adequate means of commitment. Our simplified description of the game with just one student is equivalent to the college having in place a counter-offer policy $p_2(b_o; b, y, q_o) \leq p_1(b, y, q_o)$ for all applicants.

[9]We We assume the student knows these values, learning b and b_o through its initial interactions with the college under study and the outside option respectively.

Figure 1: The Tree of the Game



A choice to (not) negotiate is denoted by N = (0) 1 and a choice to (not) enroll is denoted by E = (0) 1.

This condition states that, among two students with identical characteristics except v, the one with the higher v is willing to pay more for a quality increase.

Let $u_o = u(y, v, p_o, q_o)$, $u_1 = u(y, v, p_1, q)$, and $u_2 = u(y, v, p_2, q)$. The student's payoff is u_o if he is not admitted to the college or prefers to enroll in the outside school without negotiating. It is u_1 if he enrolls at the college without negotiating. If the student chooses to negotiate, he bears the negotiation cost c measured in units of utility. In that case the payoffs are $u_2 - c$ if he accepts the college's offer, and $u_o - c$ otherwise.

2.4 Equilibrium

The equilibrium concept used in this paper is a Bayesian Nash Equilibrium in pure strategies. Given an arbitrary strategy of the college $(p_1, p_2(b_o))$, it is straightforward to derive the optimal strategy for each student type. For a student type with zero cost, it is a weakly dominant strategy to always negotiate, i.e. negotiation cannot make him worse off. We will therefore assume that all zero cost types always negotiate. A zero cost type will accept the second offer of the school if and only if:

$$u_2 \geq u_o \tag{3}$$

A student type with positive costs will only negotiate if

$$u_2 - \bar{c} \geq \max[u_o, u_1] \tag{4}$$

He will accept the initial offer if

$$u_1 \geq \max[u_o, u_2 - \bar{c}] \tag{5}$$

Otherwise he does not negotiate and enrolls in the outside option. Thus a type $\bar{c}$ student that negotiates will always enroll after the negotiation process, while a type 0 student may or may not enroll.

Since equilibrium strategies are common knowledge, the college's optimal strategy is the solution to the following decision problem:

$$\max_{p_1, p_2(b_o)} \int\int \Big\{ (1-\pi_c)\, 1\{u(y,v,p_2(b_o),q) \geq u(y,v,p_o(b_o),q_o)\}\, [v+\gamma p_2(b_o)] \tag{6}$$

$$+\pi_c\, 1\{u(y,v,p_1,q) \geq \max[u(y,v,p_o(b_o),q_o), u(y,v,p_2(b_o),q)-\bar{c}]\}\, [v+\gamma p_1]$$

$$+\pi_c\, 1\{u(y,v,p_2(b_o),q)-\bar{c} \geq \max[u(y,v,p_1,q), u(y,v,p_o(b_o),q_o)]\}\, [v+\gamma p_2(b_o)] \Big\}$$

$$f(v,b_o|b,y,q_o)\, dv\, db_o$$

subject to the constraint that:

$$p_2(b_o) \leq p_1 \tag{7}$$

where the integration is over the support of (v, b_o). The function $1\{.\}$ is an indicator function that takes on the value 1 when the condition it describes is satisfied, and takes the value zero otherwise.

Consider the college's incentives in setting the initial price p_1. By inspection of (6) and (7), one can see that p_1 would be set high enough to not constrain $p_2(b_o)$ if every applicant had 0 negotiation cost. In this case, $\pi_c = 0$ and p_1 does not appear in the objective function, implying p_1 is set so that (7) is non-constraining. If all students are willing to negotiate, then the college prefers to induce them to do so to gather more information.

When some applicants have positive negotiation costs, additional incentives arise. These costs will keep some students from negotiating, but they will matriculate for low enough p_1. These are the students in the second indicator group in (6). There is an incentive then to decrease p_1 to increase their numbers (some drawn from the third indicator group in (6)), although limited by the reduced revenues from the inframarginal types in the second indicator group. We show by example below that these incentives can lead to lower p_1 that constrains $p_2(b_o)$.

The college's incentives that determine the shape of $p_2(b_o)$ are complex, and it is then difficult to make general statements. To see this, consider the relatively simple case where negotiation costs are prohibitively high for those with positive negotiation cost. In this case, p_1 is set to attract some of them, but since they never negotiate $p_2(b_o)$ is determined only by the zero-negotiation-cost types.[10] Further assume initially that $q_o = q$, implying all zero-negotiation-cost types v will attend the college if and only if $p_2(b_o) \leq p_o(b_o)$. As b_o rises, the college's expectation of v rises for any b. But for b_o sufficiently low, the new information can be sufficiently bad news that $p_2(b_o) = p_1$. For b_o higher such that the college wants the students and must set $p_2(b_o) < p_1$ to attract them, obviously $p_2(b_o) = p_o(b_o)$ and thus p_2 declines with b_o. If the outside option's pricing function is sufficiently steep, then $E[v \mid b_o, b, y, q_o] + \gamma p_o(b_o)$ will become negative for high enough b_o. The college ceases to compete for these students, e.g., $p_2(b_o)$ flattens out so as not to attract them.

Even in this case with no negotiation by high-cost applicants, the incentives become considerably more complicated if $q_o \neq q$. One may think of the first term in the objective function (that continues to determine $p_2(b_o)$) as the number of applicants for which the first indicator function is switched on, multiplied by $E[v \mid b_o, b, y, q_o] + \gamma p_2(b_o)$. Over the range of b_o where the latter is positive, consider the incentive to vary p_2 with b_o. As b_o rises, the number of observationally equivalent types that will matriculate will decline for given p_2 since their outside option improves, implying an incentive to decrease p_2 with b_o. But with $q_o \neq q$, p_2 also selects the set of v types that choose the college. Using the single-crossing assumption on preferences, if $q_o <\ (>)\ q$, then those with v exceeding (less than) a threshold value will choose the college. For $q_o <\ (>) q$, lowering p_2 will then decrease (increase) $E[v \mid b_o, b, y, q_o]$. This increases the incentive to lower p_2 with b_o when $q_o > q$, but counters this incentive when $q_o < q$. Moreover, the discussion ignores cross effects (e.g., the cross derivative of the number of students for which the indicator function is on with respect to b_o and p_2). Hence, we cannot be sure analytically how $p_2(b_o)$ will be shaped when $q_o \neq q$ even in this relatively simple case. The perhaps surprising complexity of the problem leads us to pursue a computational analysis.

[10] In the vicinity of the optimum, the third indicator group vanishes in (6) and the maximum in the second indicator group is always $u(y, v, p_o(b_o), q_o)$.

3 Computational Analysis

The ability v and errors η (η_o) are assumed to have normal distribution in the population: $v \sim N(\mu_v, \sigma_v)$, $\eta(\eta_o) \sim N(0, \sigma_\eta)$. A student's preferences are represented by the utility function:

$$u(v, y, p, q) = (\alpha(y-p)^\rho + (1-\alpha)(qv)^\rho)^{\frac{1}{\rho}} \tag{8}$$

for $\rho, \alpha \in (0, 1)$. This function satisfies the single-crossing condition described in (2). The outside school's price is linear in a student's ability signal and the quality of the outside option:[11]

$$p_o \;=\; \omega_1 \,+\, \omega_2\, q_o \,+\, \omega_3\, b_o \tag{9}$$

It is reasonable to assume that $\omega_2 \geq 0$ and $\omega_3 \leq 0$. When the college learns the outside price p_o, it infers b_o accordingly:

$$b_o = \frac{p_o \,-\, \omega_1 \,-\, \omega_2\, q_o}{\omega_3} \tag{10}$$

Next we calibrate the model. In our computational examples, we calibrate the distribution of ability using SAT scores. The national average and standard deviation for SAT are 10 and 2 respectively (measured in hundreds). The averages for the CMU-or-equivalent applicants are higher, and are occasionally censored by the upper bound 16. We assume the underlying distribution of v is normal with mean 13 and standard deviation 1.2. We assume that the measurement error η (η_o) has a mean of zero and a standard deviation of $\sigma_\eta = 0.6$. We set the quality of the college equal to the mean of the calibrated distribution, i.e. $q = 13$. In our computational examples, we hold the value of the inside signal equal to $b = 14$.

[11] School-competition models studied by Epple, Romano, and Sieg (2004) imply pricing functions linear in a student's ability when ability can be observed perfectly and prices are close to effective marginal costs, i.e. markets are competitive.

The average family income among enrolling students in our sample is about 110, hence we set $y = 110$ where we measure dollar amounts in thousands. The average tuition is 24. We set the parameters $\alpha = 0.6$ and $\rho = 0.5$, these implying a utility function with budget share that matches the preceding. We set γ, the tuition coefficient in college's utility function, to 1. We also assume the pricing function of the outside school is $p_o = 94 - 6\, b_o$.

We initially consider a simplified version of the model, in which we set $\pi_c = 0$. The main advantage of this simplification is that the solution of the model can be computed efficiently as discussed in detail in Appendix A. Computation is relatively easy because the optimal solution implies setting p_1 high enough such that the constraint $p_2(b_o) \leq p_1$ is not binding. Furthermore, the function $p_2(b_o)$ can be computed pointwise for each value of b_o. We evaluate all integrals numerically using 100,000 random draws from the conditional density function of v. The objective function of the college is assumed to be $(v - \mu_v) + \gamma p$ which implies that some students below the mean are potentially undesirable. We solve the optimization problem using a simple line search algorithm.

Table 1: Optimal Pricing: $q = 13$ and $q_o = 13$

b_o	p_o	$E[v\|b, b_o]$	objective function
10.00	34.00	11.67	32.67
10.50	31.00	11.89	29.89
11.00	28.00	12.11	27.11
11.50	25.00	12.33	24.33
12.00	22.00	12.56	21.56
12.50	19.00	12.78	18.78
13.00	16.00	13.00	16.00
13.50	13.00	13.22	13.22
14.00	10.00	13.44	10.44
14.50	7.00	13.67	7.67
15.00	4.00	13.89	4.89
15.50	1.00	14.11	2.11
16.00	-2.00	14.33	-0.67

Cut-off point is equal to 15.88.

First we consider an example in which the quality of colleges is equal to the quality of the outside option, i,e, $q = 13 = q_o$. The main advantage of this example is that the optimal strategy of the college has a closed form solution as derived in detail in appendix A. The intuition is that the college will set $p_2(b_o) = p_o(b_o)$ provided that attracting these types of students is profitable, i.e. provided that $E[v|b, b_o] - \mu_v + \gamma p_o(b_o) > 0$. In our example the college will price so as to attract almost all students that have an outside signal b_o that is less than 15.88. The main properties of this equilibrium are summarized in Table 1.

Table 2: Optimal Pricing: $q = 13$ and $q_o = 12$

b_o	p_2	p_o	objective function	acceptance probability	minimum ability
10.00	39.31	34.00	38.40	0.999	10.81
10.50	36.48	31.00	35.79	0.999	11.05
11.00	33.65	28.00	33.17	0.999	11.33
11.50	30.81	25.00	30.56	0.999	11.56
12.00	27.98	22.00	27.94	0.999	11.81
12.50	25.13	19.00	25.33	0.999	12.02
13.00	22.29	16.00	22.71	0.998	12.26
13.50	19.45	13.00	20.09	0.998	12.48
14.00	16.62	10.00	17.48	0.998	12.74
14.50	13.78	7.00	14.86	0.998	12.96
15.00	10.95	4.00	12.25	0.997	13.24
15.50	8.11	1.00	9.64	0.996	13.49
16.00	5.28	-2.00	7.03	0.994	13.77

Next we consider two example in which the college competes against an alternative with a different quality level. First consider an example, in which the college competes against a lower ranked college. We assume that $q_o = 12$. In this case, the college can charge a higher price $p_2(b_o) > p_o(b_o)$ and still attract a large number of students. The equilibrium is summarized in Table 2. Table 2 shows that the optimal strategy for the college is to charge a tuition that exceeds the tuition of the lower ranked alternative by a few thousand dollars. Adopting this strategy will allow the college to attract the majority of the students. Due to the single crossing property of student preferences, there will be a minimum ability level that students have to satisfy to select themselves into the college.

Table 3: Optimal Pricing: $q = 13$ and $q_o = 14$

b_o	p_2	p_o	objective function	acceptance probability	maximum ability
10.00	28.12	34.00	27.20	0.999	13.33
10.50	24.95	31.00	24.26	0.999	13.55
11.00	21.79	28.00	21.32	0.999	13.76
11.50	18.63	25.00	18.39	0.999	13.98
12.00	15.48	22.00	15.45	0.998	14.16
12.50	12.32	19.00	12.52	0.998	14.39
13.00	9.17	16.00	9.59	0.997	14.56
13.50	6.01	13.00	6.66	0.997	14.77
14.00	2.88	10.00	3.73	0.993	14.89
14.50	-0.23	7.00	0.84	0.976	14.91
15.00	—	4.00	0.00	0.000	—
15.50	—	1.00	0.00	0.000	—
16.00	—	-2.00	0.00	0.000	—

Finally, we consider an example in which the college competes against a higher ranked college. In the example, we assume that $q_o = 14$. The equilibrium is summarized in Table 3. The results are qualitatively similar to the previous example. The main difference is that the college now competes against a higher ranked school and hence needs to charge a lower price than the outside option. Single crossing implies that there will be a maximum ability level for each student type. Students with higher abilities will prefer to enroll in the outside option. Moreover, the college will not find it profitable to compete for a set of students with high outside signals. These students have very attractive outside offers, that indicates that they are likely to be highly qualified. Everything else equal these students have strong preferences for the higher ranked outside alternative. The college can only attract these students by charging tuition rates which are so low that the objective function would be negative. Hence the college does not compete for these students in equilibrium.

4 Data

Our sample consists of applicants at Carnegie Mellon University for the academic year 2004-2005. The data set consists of 8869 applications, with about two thirds applying for financial aid. We focus in this analysis on the subsample of students that applied for financial aid. Figure 2 provides a graphical breakdown of our sample in the relevant subsamples. The data set includes almost all the information that the student sent in the application file, as well as some variables constructed by the university representing their valuation of that information. The information sent by a student includes scores on standardized tests (SAT), and high school achievement variables as signals of the student's ability. The summary variables calculated by the university include an estimate of the student's academic success.

For those who applied for financial aid, the family income as well as the financial aid offered (initial and final) are also included in the data. For students who negotiated, the alternative school's name and the amount of the financial aid offer are included. Often, the students have provided multiple outside offers. If the offer is improved for a student, and that student has multiple outside offers, the one that underlies the improvement decision is highlighted in the data set. For the schools the students present offers from, we obtained quality and pricing information from college guide sources such as the US News web site and publications by Princeton Review and Peterson's. For each applicant who did not receive an improved offer, the admission's office has indicated for us which of the outside offers they consider to be the strongest.

Figure 2: The Sample

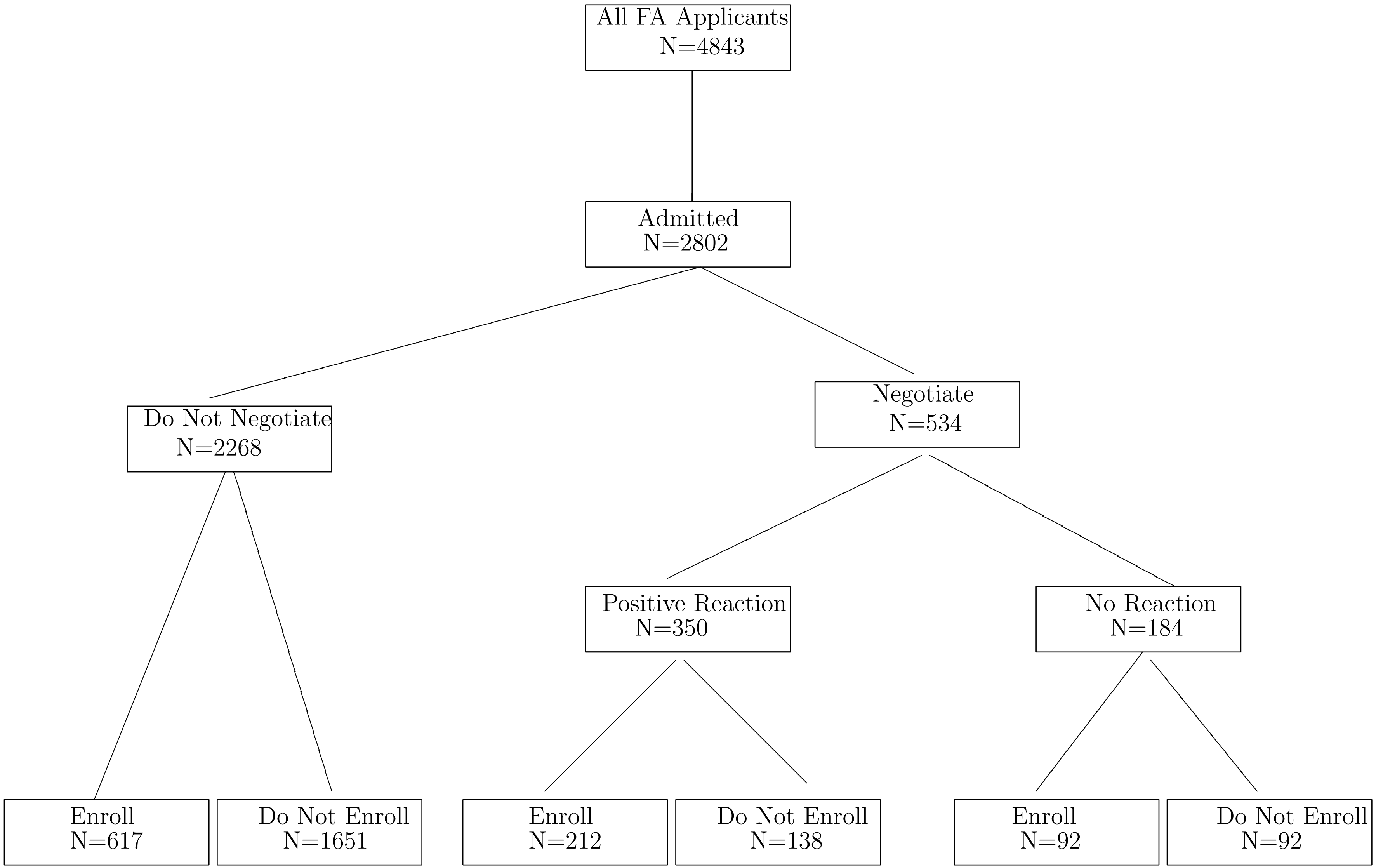


Table 4: Descriptive Statistics of the Sample

	All FA Appl		Admitted FA Appl.		Do Not Negotiate		Negotiate		Positive Reaction		No Reaction	
	Mean	St.Dev	Mean	St.Dev.	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
SAT Score	1354	140	1396	116	1398	116	1387	119	1384	121	1395	115
Predicted GPA	3.06	0.53	3.25	0.38	3.26	0.38	3.21	0.36	3.19	0.36	3.23	0.35
Household Income	109	83	115	82	113	83	122	79	102	54	160	101
Female	0.39	0.49	0.42	0.49	0.42	0.49	0.43	0.50	0.47	0.50	0.36	0.48
Black/Hispanic	0.13	0.34	0.15	0.35	0.15	0.36	0.12	0.33	0.15	0.35	0.08	0.27
In-State Applicant	0.17	0.37	0.18	0.38	0.16	0.37	0.23	0.42	0.25	0.43	0.21	0.41
Initial Offer			12.31	9.02	12.34	9.10	12.19	8.67	13.53	7.86	9.64	9.53
Reaction									4.42	1.94		
SAT, Other School							1268	108	1276	87	1243	154
Fin.Aid Offer, Other Sch.							19.24	9.86	20.67	9.83	14.99	8.67
N	4843		2802		2268		534		350		184	

Table 4: Descriptive Statistics (cont.)

	Do Not Neg. Enroll		Do Not Neg. Do Not Enroll		Positive Reaction Enroll		Positive Reaction Do Not Enroll		No Reaction Enroll		No Reaction Do Not Enroll	
	Mean	St.Dev	Mean	St.Dev.	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
SAT Score	1356	120	1414	110	1370	118	1405	123	1378	114	1411	115
Predicted GPA	3.13	0.40	3.31	0.36	3.14	0.37	3.27	0.33	3.19	0.39	3.27	0.31
Household Income	105	91	116	79	98	57	108	49	155	91	164	111
Female	0.38	0.49	0.44	0.50	0.48	0.50	0.46	0.50	0.38	0.49	0.35	0.48
Black/Hispanic	0.15	0.36	0.15	0.36	0.17	0.38	0.11	0.31	0.05	0.23	0.10	0.30
In-State Applicant	0.21	0.41	0.14	0.35	0.26	0.44	0.22	0.42	0.28	0.45	0.14	0.35
Initial Offer	13.53	9.28	11.89	8.99	14.15	7.84	12.57	7.82	10.17	9.82	9.11	9.25
Reaction					4.50	2.17	4.30	1.53				
Avg.SAT, Other School					1263	91	1297	78	1249	94	1237	203
Fin.Aid Offer, Other Sch.					20.24	9.70	21.32	10.03	13.46	8.47	16.83	8.64
N	617		1651		212		138		92		92	

Table 2 provides descriptive statistics of the sample. It shows that more than half of all financial aid applicants, 2802 people, were offered admission with varying financial aid awards. The mean offer was around $12,300, with a standard deviation of $9,020. The mean offer is a little below one third of the mean total cost of attending CMU.

Approximately one fifth of the admitted financial aid applicants chose to negotiate. The mean aid offer for those students was $12,270. About two thirds were offered a better financial aid package. For those, the mean initial offer increased from $13,530 to $18,000. The standard deviation of the increase is $1,940. About forty percent of those students chose not to matriculate even though they were offered close to $17,000 on average. The one third that did not get anything from negotiation had lower initial offers ($9,640 versus $13,530) and higher incomes on average ($160,000 versus $102,000). Half of them decided to matriculate despite a lack of response.

The average family income for financial aid applicants is $109,210. For our admitted sample, the average is $115,000. The negotiating group has an average income of $122,310. For those to whom the university responds with a positive offer, the average is $102,200. The gender and race composition is as follows: About 42 percent of our sample is female. About a quarter of the sample classify themselves as Asian, and 15 percent as African-American or Hispanic.

We have also included variables indicating the applicant's location of residence. As crude measures of proximity, we have constructed an "in-state applicant" variable, and an "in-or-neighboring-state applicant" variable. About 18 percent of the sample are from Pennsylvania. We find that about 60 percent of the sample are from either Pennsylvania, or from one of its neighboring states. For the negotiating subsample, those percentages are 22% and 63%.

Table 5: Probit Models

	(A)	(B)
Intercept	-0.2787	-1.6050
	(0.3761)	(1.2327)
SAT	-0.0501	-0.00182
	(0.0257)	(0.0692)
Income	0.00097	-0.00469
	(0.0004)	(0.00122)
Initial offer	0.00689	0.0202
	(0.00418)	(0.0128)
Female	0.0257	0.1436
	(0.0576)	(0.1521)
Black	-0.3592	0.4471
	(0.1216)	(0.3843)
Hispanic	-0.3103	0.1335
	(0.1235)	(0.3298)
Asian	-0.3926	-0.1305
	(0.0745)	(0.1975)
Other nonwhite	-0.0693	0.0850
	(0.0821)	(0.2068)
In-state applicant	0.18	0.1522
	(0.0707)	(0.1729)
Amount outside offer		0.0127
		(0.0103)
Quality outside offer		0.1861
		(0.0748)
N	2802	451

Estimated standard errors are in parentheses.

5 Empirical Analysis

The summary statistics in Table 2 reveal that 212 applicants who currently attend the university received improved financial aid offers as a result of negotiating. Thus, approximately 20% of the members of the entering class received a response from the outside offers that they submitted. Among these individuals, the average increase in financial aid was approximately 30% relative to the average amount of the initial offer. These data suggest that the university places considerable weight on the information that it obtains from the outside offers that applicants submit.

To provide more rigorous tests of the main predictions of our bargaining model, we estimate some probit models. The measurement unit for SAT and the quality of outside offers is 100 points, the latter measured by mean SAT in the student body. The measurement unit for income and initial offers is in thousand dollars. Negotiating students often present multiple outside offers. The results of the probit models are summarized in Table 5.

Column A in Table 5 considers the sample of admitted aid applicants. The dependent variable is 1 if the student negotiates and 0 otherwise. The purpose of this analysis is to investigate the determinants of negotiation behavior. We find significant positive coefficients for income and in-state applicant indicator, and significant negative coefficients for black, hispanic, and asian indicator variables. The initial offer is insignificant in this regression.

Next, we analyze the factors that determine whether the college responds with a counter-offer. Column B displays the results of another probit regression using the sample of negotiating students. The dependent variable is 1 if $p_2 < p_1$ and 0 otherwise. Most regressors are insignificant. Since these variables other than those associated with the outside offer are known at the time of the initial offer it is encouraging to see that they have no important effect on the response received. Aside from variables associated with the outside offer, only income is significant. However, the effect of income is exceedingly small with a marginal probability of -0.00026. We also see that the average quality of the outside offer is highly significant. Recall that our model assumes that the quality of the school that makes the outside offer is common knowledge. If we observed the signal b_o and controlled for it in the regression, we would not expect that the quality of the outside option would be a good predictor for the response of CMU. However, we do not observe b_o in the sample. Instead we must infer the quality of signal, b_o, from the observed outside offer and the quality of the school which makes the outside offer.

Equation (10) implies that $\frac{\partial b_o}{\partial p_o} \leq 0$, which implies that the derivative with respect to outsider aid, $\frac{\partial b_o}{\partial a_o} \geq 0$, is positive. Outside schools that give a generous outside aid offer to a student must have received a favorable ability signal. Moreover, a strong outside offer from a higher quality school implies a higher value of b_o than the same outside offer from a lower ranked school, i.e $\frac{\partial b_o}{\partial q_o} \geq 0$. From the perspective of the econometrician, who does not observe b_o, the quality of the outside school and the magnitude of the outside offer convey important information about the unobserved signal b_o. The finding that the coefficients of q_o and a_o are positive in the probit model is thus consistent with the prediction of the model. However, we notice that only q_o is significantly different from zero.

To get additional insights into the bargaining process we also investigated the factors that determine the magnitude of the counter-offer and estimated Tobit models. Columns A through D in Table 6 summarize the estimation results for the subsample of negotiating students. The dependent variable is $p_1 - p_2$, and is treated as censored at zero. Estimated standard errors are given in parentheses.

The estimation results in Column A of Table 4 do not control for the new information that is incorporated in q_o and a_o. In Column B (C) we include the amount (quality) of the outside offer as a regressor in our model. In Column D we include both regressors. The results again reveal that coefficients of the regressors that reflect information that was available prior to making the counter offer are not significant in explaining the magnitude of the counter-offer. At the same time, we find that the regressors that measure the quality of the outside option and attractiveness of the outside option are significant when we only control for them separately in columns B and C.

When we include both regressors in column D, the quality measure is still highly significant while the amount of aid is only significant for a level of confidence slightly below 95 %. Jointly the two variables are highly significant. For each 100 point increase in the quality of the outside offer, CMU increases the aid offer by about \$375, and for each thousand dollars of outside offer, CMU increases the aid offer by about \$40. The average outside SAT of those who receive a response is about \$ 1280, and their average outside offer is about \$20 thousand. The coefficient estimates then imply that CMU increases its aid by about \$5,000 in response to quality of outside offer and about \$800 in response to magnitude.

This evidence then suggests that counter-offers are primarily driven by the new information that becomes available in the negotiation process, and not by information that was

Table 6: Tobit Models

	(A)	(B)	(C)	(D)
Intercept	1.2781	0.8996	-3.1991	-2.7683
	(1.9815)	(1.9660)	(2.4955)	(2.4571)
SAT	0.2154	0.1817	0.1344	0.1215
	(0.1357)	(0.1350)	(0.1373)	(0.1363)
Income	-0.0159	-0.0144	-0.0160	-0.0149
	(0.0029)	(0.0029)	(0.0029)	(0.0029)
Initial offer	0.0266	-0.034	0.0211	-0.0015
	(0.0238)	(0.0263)	(0.0236)	(0.0262)
Female	0.0315	0.1524	0.0144	0.1096
	(0.3111)	(0.3116)	(0.3083)	(0.3102)
Black	1.1845	1.2280	1.1003	1.1486
	(0.6467)	(0.6408)	(0.6416)	(0.6380)
Hispanic	1.0006	0.9817	0.9607	0.9528
	(0.6673)	(0.6607)	(0.6607)	(0.6564)
Asian	-0.3732	-0.4442	-0.4282	-0.4748
	(0.4240)	(0.4211)	(0.4209)	(0.4191)
Other nonwhite	-0.0294	-0.0743	0.0162	-0.0208
	(0.4239)	(0.4200)	(0.4209)	(0.4184)
In-state applicant	0.3753	0.3239	0.4740	0.4169
	(0.3513)	(0.3481)	(0.3499)	(0.3484)
Qual. outside offer	-	-	0.4474	0.3748
	-	-	(0.1533)	(0.1519)
Amount outside offer	-	0.0510	-	0.0396
	-	(0.0201)	-	(0.0206)
N	451	451	451	451
Censored	111	111	111	111
Log likelihood	-959.105	-955.935	-954.547	-952.721

Estimated standard errors are in parentheses.

available at the first stage of the admission process. We view this evidence as supportive of our bargaining game. Information about unobserved abilities of applicant is revealed in the bargaining process.

6 Conclusions

The analysis in this paper is based on the premise that a college applicant does not know how the college will "read" his or her record. Different colleges will receive different signals about the underlying skills of a student and hence make different decisions regarding admissions and financial aid. We modeled the admission process of a single college as a bargaining game between the college and a potential student with sequential moves and asymmetric information. We characterized the equilibrium of this game and provided some numerical examples that illustrate the properties of the equilibrium. Our model predicts that colleges make initial offers based on the information in the application package. We have shown that it can be in the interest of applicants to reveal outside offers in the bargaining process that determines admission and financial aid outcomes. Revealing the information incorporated in the outside offer allows the student to convey important information about his underlying ability. The college updates its beliefs about the quality of the students and often responds with a more attractive counter-offer. The empirical analysis in this paper suggests that counter-offers are typically not correlated with information that is available at the initial admission stage. However, counter-offers respond strongly to the information content of the outside offer received by a potential student. The empirical evidence is consistent with the notion that signaling and profiling are important aspects of the college admission process.

The reduced form analyses that we have presented provide some useful evidence regarding negotiation and the associated outcomes. However, there are many questions that this reduced-form analysis cannot answer. We would like to know, for example, what fraction of those who received a reaction would have accepted the initial admission offers anyway. We would also like to quantify the gain to the university of the negotiation process rather than a one-shot offer. Perhaps most importantly, from the perspective of profiling, we would like to evaluate the importance of common information relative to college-specific assessments in determining financial aid that students receive. These questions should provide ample scope for future research.

A APPENDIX: Solving the Model for $\pi_c = 0$

If $\pi_c = 0$, the objective function of college simplifies to

$$\max_{p_2(b_o)} \int\int 1\{u(y, v, p_2(b_o), q) \geq u(y, v, p_o(b_o), q_o)\} \, [v + \gamma p_2(b_o)] \, f(v, b_o|b, y) \, dv \, db_o \tag{11}$$

which does not depend on p_1. Note that maximizing the objective function above is equivalent to maximizing:

$$\max_{p_2} \int 1\{u(y, v, p_2, q) \geq u(y, v, p_o, q_o)\} \, [v + \gamma p_2] \, f(v, |b, b_o, y) \, dv \quad \forall b_o \tag{12}$$

i.e. we can solve the functional optimization problem by pointwise optimization.

Consider first the case in which $q = q_o$. Note that if

$$p_2(b_o) \;\; = \;\; p_o(b_o) \tag{13}$$

all students will attend the college. In that case the objective function for every type b_o is simply given by:

$$E[v \,|b_o, b, y] \; + \gamma \; p_o(b_o) \tag{14}$$

and the optimal decision rule will be

$$\begin{aligned} E[v \,|b_o, b, y] \; + \gamma \; p_o(b_o) \;\; &\geq \;\; 0 \;\; \Rightarrow \;\; p_2(b_o) \; = \; p_o(b_o) \\ E[v \,|b_o, b, y] \; + \gamma \; p_o(b_o) \;\; &< \;\; 0 \;\; \Rightarrow \;\; p_2(b_o) \; = \; \infty \end{aligned} \tag{15}$$

In our example, signals and ability are normally distributed and hence:

$$E[v \,|b_o, b, y] \;\; = \;\; \xi_0 \; + \; \xi_1 \, b \; + \; \xi_2 b_o \tag{16}$$

and by assumption

$$p_o(b_o) \;=\; \omega_1 \;+\; \omega_2\, b_o \tag{17}$$

In that case, the function $E[v\;|b_o, b, y] \;+\gamma\; p_o(b_o)$ is linear in b_o, and there will exist a unique threshold value $\bar{b}_o$ such that

$$E[v\;|\bar{b}_o, b, y] \;+\gamma\; p_o(\bar{b}_o) \;=\; 0 \tag{18}$$

which defines the optimal solution. Substituting the functional form above into equation (18) yields:

$$\bar{b}_o \;=\; \frac{-\gamma\omega_1 - \xi_0 - \xi_1 b}{\gamma\omega_2 + \xi_2} \tag{19}$$

For suitable parameter restrictions, the optimal solution then satisfies the following inequality conditions:

$$\begin{aligned} b_o \;\leq\; \bar{b}_o \;\Rightarrow\; p_2(b_o) \;=\; p_o(b_o) \\ b_o \;>\; \bar{b}_o \;\Rightarrow\; p_2(b_o) \;=\; \infty \end{aligned} \tag{20}$$

Now consider the case in which $q < q_o$. Substituting the utility function in equation (8) in (12) yields

$$\int 1\{(\alpha(y-p_2)^\rho \;+\; (1-\alpha)\;(q\;v)^\rho) \;>\; (\alpha(y-p_o)^\rho \;+\; (1-\alpha)\;(q_o\;v)^\rho)\}\;[v+\gamma p_2]\; f(v,|b_o,b,y)\;dv$$

Note that the condition inside the indicator function simplifies to

$$v \;\leq\; \left[\frac{\alpha(y-p_2)^\rho \;-\; \alpha(y-p_o)^\rho}{(1-\alpha)\;(q_o^\rho \;-\; q^\rho)}\right]^{1/\rho} \;\equiv\; V(p_2) \tag{21}$$

Hence we can write the objective function as

$$\int_0^{V(p_2)} [v \ + \ \gamma \, p_2] \; f(v \,|b_o, b, y) \; dv \quad = \quad Pr\{v \leq V(p_2)|b_o, b, y\} \; \Big[E[v \,|v \leq V(p_2), b_o, b, y] \ + \ \gamma \, p_2\Big]$$

which can be maximized using standard rule of calculus.

References

Betts, J. and Morell, D. (1999). The Determinants of Undergraduate Grade Point Average: The Relative Importance of Family Background, High School Resources, and Peer Group Effects. *Journal of Human Resources, (34:2)*, pp. 268-293.

Bowen, W. and Bok, D. (1998). The shape of the river: Long term consequences of considering race in college and university admissions. Princeton: Princeton UP.

Dale, S. and Krueger, A. (1998). Estimating the Payoff to Attending a More Selective College: An Application of Selection on Observables and Unobservables. Working Paper.

Diermeier, D., Eraslan, H. and A. Merlo (2004). A Structural Model of Government Formation, forthcoming in Econometrica.

Epple, D., Romano R., and Sieg, H. (2003). Peer Effects, Financial Aid, and Selection of Students into Colleges and Universities: An Empirical Analysis. *Journal of Applied Econometrics 18(5)*, pp. 501-526.

Epple, D., Romano R., and Sieg, H. (2004). Admission, Tuition, and Financial Aid Policies in the Market for Higher Education. Working Paper, Carnegie Mellon University.

Fuller, W., Manski, C., and Wise, D. (1982). New Evidence on the Economic Determinants of Postsecondary Schooling Choices. *Journal of Human Resources, 17*, 477-498.

Kane, J. (1998) Do Test Scores Matter? Racial and Ethnic Preferences in College Admissions, in *The Black-White Test Score Gap,* Christopher Jencks and Meredith Phillips, eds., Washington, D.C., Brookings Institution Press.

Kane, J., and Spizman, L. (1994) Race, Financial Aid Awards, and College Attendance. *American Journal of Economics and Sociology, vol. 53, 1*, pp. 85-98.

Kremer, M., and Levy, D. (2003) Peer Effects and Alcohol Use Among College Students. NBER Working Paper No. w9876

Long, M. (2002) Race and College Admissions: An Alternative to Affirmative Action? Working Paper, University of Michigan.

Manski, C., and Wise, D.(1983) College Choice in America, Harvard, 1983

Merlo, A. (1997), Bargaining over Governments in a Stochastic Environment, Journal of Political Economy, 105, 101-131.

Sacerdote, B., (2001). Peer Effects with Random Assignment: Results for Dartmouth Roommates. *Quarterly Journal of Economics, 116(2)*, 681-704.

Sarpca, S. (2004), Specialization in Higher Education: Theory and Evidence, Working Paper, Carnegie Mellon University.

Sieg, H. (2000), Estimating a Bargaining Model with Asymmetric Information: Evidence from Medical Malpractice Disputes, Journal of Political Economy, 108 (5), 1006-1021.

Winston, G., and Zimmerman, D. (2003). Peer Effects in Higher Education. NBER Working Paper 9501.

Zimmerman, D. (1999). Peer Effects in Academic Outcomes: Evidence from a Natural Experiment. Williamstown, MA, The Williams Project on the Economics of Higher Education.