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Early Admission at Selective Colleges

By
Christopher Avery
Harvard University

Jonathan Levin
Stanford University

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Stanford Institute for Economic Policy Research
Stanford University
Stanford, CA 94305
(650) 725-1874

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Christopher Avery and Jonathan Levin†

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Abstract

Early admissions is widely used by selective colleges and universities. We identify some basic facts about early admissions policies, including the admissions advantage enjoyed by early applicants and patterns in application behavior, and propose a game-theoretic model that matches these facts. The key feature of the model is that colleges want to admit students who are enthusiastic about attending, and early admissions programs give students an opportunity to signal this enthusiasm.

JEL Classification: C78, D82, I20

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†Avery is at the Kennedy School, Harvard University and NBER, christopher_avery@ksg.harvard.edu. Levin is at the Department of Economics, Stanford University and NBER, jdlevin@stanford.edu.

1 Introduction

Applying to college is an increasingly anxious and high-stakes process for many American families. Admission at the nation's elite universities has become extraordinarily competitive. In 2007-08, Harvard and Yale's acceptance rates reached record lows of 7.1 and 8.3 percent, respectively, and Stanford, Princeton and Columbia all admitted fewer than one in ten applicants. Just a decade ago, acceptance rates at these schools were fifty percent higher.[1] At the same time, a large number of Americans have come to view admission to an elite university as a ticket to future success.[2] Not surprisingly these developments have focused enormous attention on the college admissions process.

We focus in this paper on a particular aspect of the process, the use of early admissions programs by selective schools. Though versions of early admissions have been used for many years, these programs have become ubiquitous in the last two decades. Over two-thirds of top colleges offer some form of early admissions, and many schools fill a sizeable fraction of their entering class with early applicants. Schools primarily use one of two types of early admissions programs: Early Action programs where students are accepted well before the standard March announcement date, but are not committed to enroll, and Early Decision programs where students commit to enroll if accepted.

Participants in the market tend to focus on the relatively high rates of admission for early applicants. In 2007-08, for instance, Yale admitted 16.7 percent of its early applicants and Stanford 18.1 percent, about twice the rate for the regular pool. As we discuss below, some of the difference can be attributed to systematic differences between the early and regular pools of applicants, but applying early does appear to convey a significant advantage. In part because this benefit tends to be captured by students who are both well-off and well-informed, some prominent academic leaders have argued that early admissions should be curtailed. This has led to some notable recent developments. In 2003-04, Yale and Stanford switched from Early Decision to Early Action, and in 2007-08, Harvard and Princeton eliminated early admission entirely. The attention generated by these changes underscores the perceived

[1] Admission rates in 2007-08 were Stanford 9.5%, Princeton 9.2%, Columbia 8.7%. In 1997-98, admission rates were: Harvard 12.3%, Yale 16.8%, Princeton 13.1%, Stanford 13% and Columbia 14.2%. These changes have been much remarked on; see for example "Elite Colleges Reporting Record Lows in Admissions," *New York Times*, April 1, 2008.

[2] As just one example, Ramey and Ramey (2008) argue that since the 1990s competition to secure slots for their children at selective colleges has led college-educated parents to substantially reallocate their time toward childcare.

importance of early admissions.

The current situation raises questions about why schools are drawn to use early admissions, how the programs operate, and what effects they have. We start in this paper by describing a collection of empirical patterns drawn from data on high school seniors applying to college. The findings dovetail with those reported in Avery, Fairbanks and Zeckhauser (2003), and include the following.

First, early applicants at top schools are stronger than regular applicants in their numerical qualifications, but the reverse is true at lower-ranked schools. Second, admission rates of early applicants are higher than those of regular applicants, and this remains true after conditioning on students' observable characteristics. Early application is associated with a 20 to 30 percentage point increase in acceptance probability, about the same as 100 additional points on the SAT. Third, an admissions benefit provides an incentive for students to strategize: to apply early even if they are undecided about their preferences, or to apply early to a school that is not their absolute first choice. Fourth, students who are admitted early are more likely to enroll than students who are admitted through regular admissions. Fifth, the type of early admission program varies with school characteristics: non-binding Early Action is offered disproportionately by the highest ranked universities.

These patterns can be understood in the context of a simple economic model in which early application programs create an opportunity for applicants to signal their preferences. To capture this idea, we consider a setting in which colleges value academic talent but also want to attract students who are good matches and will take advantage of the school's particular strengths. Colleges view an early application as a signal of interest and therefore favor these applicants in their admissions decisions. The admissions advantage gives students an incentive to apply early — generally, though not always, to their preferred school. Together, these incentives create an equilibrium dynamic in which an early application credibly signals interest and early applicants enjoy favorable admissions. Moreover, the schools prefer the equilibrium outcome under early admissions to the outcome that is achieved if there are no early applications. The reason is that early admissions leads to a finer sorting of students than is possible with regular admissions only.

The logic we have described applies with non-binding early action programs. We also consider the binding early decision programs that are the norm outside of the top ten universities. Early decision leads to a similar equilibrium dynamic, but with different welfare consequences. Notably a lower ranked school can benefit from early decision not just because of the sorting effect but because it conveys a competitive benefit. With early decision, a lower-ranked school can capture some highly-qualified students who are unsure about their ability at the time of application. As a result, a highly-ranked school may prefer a situation where all schools eliminate their early programs. We also show that this model can help to explain how a school such as Harvard could eliminate its early admissions program without incurring large costs.

The signaling aspect of early admissions is likely just one of several reasons why colleges have adopted early admissions. We view it as interesting because, as we show, it can explain on its own all of the empirical patterns mentioned above, in particular sorting and strategizing in application behavior, a lower admissions threshold for early applicants, and the use of early action primarily at high-ranked schools. The last section of the paper discusses some additional aspects of early admissions that are not captured in our model, such as the interaction with financial aid policies and the desire of some schools to engage in forms of yield management.

2 Early Admissions at Selective Colleges

2.1 Background

Prior to the increase in college applications following World War II, colleges admitted virtually all qualified applicants. Starting in the 1950s, admission became more competitive and elite schools began to adopt various forms of early admissions, initially motivated by an attempt to limit uncertainty about class size. Many schools relied heavily on these programs. Avery, Fairbanks and Zeckhauser (henceforth, AFZ) give the example of Amherst College, which by 1965 was accepting the majority of its class Early Decision and continued to do so until 1978 when it decided to limit early admissions to one-third of its entering class.

As initially implemented at the Ivy schools, early application did not actually lead to early admission. Instead the school provided an early indication of a student's chances. At Harvard, Yale and Princeton, students were graded on an A-B-C basis, with A meaning the student was virtually ensured admission. The Ivies and MIT adopted modern early admission programs in the fall of 1976. Harvard, Yale, Princeton, MIT and Brown introduced non-binding Early Action programs while the remaining schools adopted Early Decision.[3]

The early admission programs offered by the Ivy schools started small and typically attracted a select set of applicants. This began to change in the late-1980s and 1990s as students perceived an admissions advantage from applying early. The number of early action applications at Harvard, which had hovered below two thousand since the program was introduced, doubled to almost four thousand between 1990 and 1995 and continued to increase after that. Meanwhile the number of students Harvard admitted early climbed from under five hundred to over a thousand, meaning that around half of Harvard's admitted students and an even higher percentage of those enrolling at Harvard came from the early pool (AFZ, 2003).

As reliance on early admissions increased, more and more schools signed on, typically favoring the more restrictive Early Decision approach. More than a hundred colleges adopted some form of early admissions program in the 1990s (AFZ, 2003). These developments ushered in the current environment where the vast majority of elite institutions offer early admissions. Thirty of the thirty-eight universities deemed "most selective" by *U.S. News and World Report* currently offer some form of early admissions, including twenty-one that offer Early Decision.[4] The situation is even more dramatic at selective liberal art colleges, where twenty-four of the twenty-five most selective offer Early Decision, and the remaining school (Colorado College) offers Early Action.

Public discussion in the last decade, however, has led to several important changes. In December 2001, Yale President Richard Levin suggested in an interview with the *New York Times* that early admissions was not benefiting students, and that Yale would consider eliminating it if peer institutions did the same.[5] The following year Yale announced that it would switch to Early Action (it had used Early Decision since 1995) and was followed immediately by Stanford. Then, in a surprise move, Harvard and Princeton were the first elite schools to entirely eliminate their early admissions programs in 2007-08. This means

[3] With the exception of two periods (1976-1979 and 1999-2003), Ivy League colleges offering Early Action programs have used a "Single-Choice Early Action" rule, where early applicants are not allowed to apply early to any other college.

[4] Of the schools with no early programs, five are public institutions (four schools in the UC system and Michigan).

[5] "Yale President Wants to End Early Decisions For Admissions," by Karen Arenson, *New York Times,* December 13, 2001. In discussing whether Yale would eliminate its program (at the time Early Decision), Levin noted the aspect of competition, saying that if Yale were to move unilaterally it "would be seriously disadvantaged relative to other schools."

that of the six schools ranked highest by *US News*, two now eschew early admissions and the remaining four offer non-binding early action.[6] We return to these developments below as they relate to our analysis.

2.2 Evidence on Early Admissions

This section identifies a set of stylized facts that we attempt to explain in our theoretical model. These are based on data from the "College Admissions Project," a survey of high school seniors who provided information about their college applications and financial aid packages during the 1999-2000 academic year.[7] Counselors from 510 prominent high schools around the United States selected ten students at random from the top of their senior classes as measured by grade point average. The surveys asked each participant to provide quantitative information from the Common Application, now accepted at many colleges, and supplemental information about their results and decisions. The survey produced a response rate of approximately 65%, including information for 3,294 students from 396 high schools. One caveat is that the participants in the survey data have been selected because they placed at the top of the class at a well-known high school, so that results from the survey only apply to a subset of possible applicants, those most likely to be admitted to very selective colleges.

We analyze the aggregated data for the set of 28 colleges that received early applications from more than ten survey participants. Table 1 lists these colleges along with summary statistics. Applicants from the survey were admitted at significantly higher rates than the aggregate rates for the entire applicant pool at each college, as one would expect given the design of the survey. A total of 2,376 participants in the survey applied to at least one of these 28 colleges, and 1,354 (57.8%) of these participants applied early to at least one of these colleges. These 28 colleges received a total of 7,243 applications from survey participants.

We base our analysis on several numerical measures. We use the recentered scale for SAT-1 scores, which include one mathematics score and one verbal score, with each score ranging from 200 to 800. In addition, survey respondents listed their three most significant accomplishments to provide a feel for extracurricular activities. We categorized these accomplishments in terms of attractiveness to college admissions officers on a 1 to 5 scale, with 5 as the most desirable and 1 the least. This student activity rating serves as a proxy for

[6] In addition to Harvard, Princeton, Yale and Stanford, the remaining two schools are MIT and Caltech.

[7] The College Admission Project was run jointly by Christopher Avery and Caroline Hoxby.

an admissions office rating. An experienced college admissions officer classified the quality of the high schools that participated in the survey on a similar 1 to 5 scale.

(F1) *At the very top schools, early applicants have stronger test scores on average than regular applicants. At schools just below the very top, early applicants tend to have lower test scores on average than regular applicants.*

Table 2 presents detailed statistics for the fourteen individual colleges that received early applications from more than 30 survey participants. The five top-ranked schools are Harvard, Yale, Princeton, Stanford and M.I.T. At four of these schools, early applicants had higher SAT scores on average than regular applicants. Across these schools, the average SAT score of early applicants was 1468, compared to 1450 for regular applicants. The remaining nine schools are also very selective, but at six of them early applicants had lower test scores on average than regular applicants. Across these slightly lower-ranked schools, the average SAT score of early applicants was 1389, compared to 1405 for the regular applicants.

(F2) *Students who are admitted early are more likely to enroll than students who are admitted through regular admissions to those same colleges.*

Table 3 provides information about matriculation rates (i.e. "yields") for admitted students in the survey data. Almost all early admits to Early Decision colleges enroll. More notably, early admits were also more likely to enroll than regular admits at all eight of the most popular Early Action colleges. At six of the eight, the difference in yield rates was more than ten percentage points.

(F3) *Colleges favor early applicants – both Early Action and Early Decision – in their admissions decisions.*

As Tables 1 and 2 make clear, admit rates for early applicants were higher than for regular applicants at all of the schools, and notably higher in almost every case. Of course, this sort of raw comparison does not account for differences in the early and regular applicant pools. To this end, we estimated a single probit regression using a sample of all applications by survey students to one of the twenty-eight colleges listed in Table 1. The dependent variable is the admission outcome (1 if admitted, 0 if not admitted). The unit of observation is an application, so a survey participant who applied to several of the colleges is included multiple times in the sample.

The results from various specifications are reported in Table 4. We control for application characteristics including the student's SAT scores, demographic and other student variables, and characteristics of the student's high school. The specifications reported in Table 4 treat the effect of an early application as additively separable; similar results are obtained with a full set of pairwise interactions between the control variables and the early application indicators.

Applying early is associated with a substantial increase in acceptance probability conditional on application characteristics. The estimated effect is similar across specifications, and larger for early decision than early action. An EA application is associated with a 17 to 20 percentage point increase in admission probability, and an ED application with a 31 to 37 percentage point increase. These numbers are calculated for an applicant with the average characteristics across applications to these thirty colleges. In every specification, the EA coefficient and the ED coefficient are highly significant; the minimum t-statistic across all specifications is 5.11 for Early Action and 9.90 for Early Decision.

We also estimated separate specifications for each of the fourteen individual colleges that received the most early applications in the survey data, and used these estimates to compute early and regular acceptance probabilities at each college for a student with mean characteristics in the survey. These "conditional" admit rates are reported in the last column of Table 2. Conditional on application characteristics, applying early is associated with a significantly larger admit rate at all eight Early Decision colleges and four of the six Early Action colleges.

One obvious critique of these estimates of the admissions advantage of an early application is that our regression specification does not control directly for self-selection. In particular, admissions officers often suggest that early applicants are relatively more attractive than regular applicants in ways that are not captured by the numerical measures that we use as independent variables (e.g. early applicants demonstrate important organizational skills by compiling their materials in time for the early application deadline).[8] While we recognize

[8] Ideally, if all applicants applied to a substantial number of selective colleges, we could correct for self-selection in the choice to apply early by comparing the results of early and regulalr applications for individual students (e.g. with a fixed effects Probit specfication). However, since the majority of selective colleges in our sample offer Early Definition, most students who were admitted early could not apply to any other

the importance of this concern, we believe that the qualitative finding that colleges favor early applicants withstands this critique for three reasons. First, the students in the study were selected to be representative of high-caliber applicants from well-known high schools, so the homogeneity of the sample likely limits the degree of differentiation among students due to omitted variables. Second, since early applicants are weaker than regular applicants in terms of observable measures at all but the most selective colleges (as indicated above in the discussion of (F1), it would be natural to assume that they would also be weaker than regular applicants in non-observable qualities at all but the most selective colleges. Third, the student activity rating captures a reasonable amount of information about each student's non-academic accomplishments. A student activity rating of 2 represents an ordinary level of activity in school activities and clubs, while a rating of 4 represents superior achievement in some activity, such as a state championship in some event. The estimated effect of an Early Decision application on one's admissions probability is four times as large as the estimated effect of an increase in student activity rating from 2 to 4. It does not seem possible that any unmeasured difference in average applicant quality between early and regular applicants could be of this magnitude.

(F4) *Students may benefit from two forms of strategic application behavior: (1) applying Early Decision even if there is considerable uncertainty about a first-choice college; (2) applying early to a college that is not one's first choice.*

To the extent that early application conveys a sizeable advantage, students can face difficult choice in applying. The dilemma is widely recognized. As one college counselor put it: "Early applications give students a 'hook' that they should use strategically." Students applying Early Decision have a particularly acute trade-off because they must weigh the admissions advantage against the potential cost of premature commitment. Avery, Fairbanks and Zeckhauser (2003) found that in retrospective interviews, less than two-thirds of students who applied early and were attending Early Decision colleges had a strong preference for that college at the time that they applied.

A further complication is that for a given student, the benefit of early application may vary across colleges. For example, a student who is substantially below or above the bar for admission at a given college will not get an admissions benefit from applying early.

colleges once they were accepted.

Instead, early application is likely to be most efficacious at a college where the student is competitive but not certain (or possibly not likely) to be admitted as a regular applicant. As a result, it frequently may be optimal for a student to apply early to a second or lower choice college rather than to a long-shot first-choice college. Again, this situation seems to be well understood. As another college counselor explained: "If you are willing to lower expectation one rung lower, you might be able to get better outcomes [by applying early]."

(F5) *EA is disproportionately used by the highest ranked schools, whereas lower ranked schools typically use ED.*

This last stylized fact relates to the use of early admissions programs by different institutions, and we have already mentioned the evidence. Of the top six schools in the current *US News* rankings, four offer EA and none offer ED. Of the remaining thirty-two "most selective" schools, twenty-one offer ED and only five offer EA.

3 The Model

We now develop a model that allows us to organize and explain the evidence presented above. Its key feature is that students are differentiated in their academic ability and also in their "fit" for different schools. The attraction of early admission programs is that they allow schools to identify students who are particularly enthusiastic and likely to be a good match. For a lower-ranked school, an Early Decision program also offers the opportunity to capture very qualified students who in a more orderly admissions market might end up enrolling at a higher-ranked institution. As we will see, this latter effect does not operate to the benefit of the very best schools.

Our model is quite stark. There is a population of students of unit measure, and three schools: selective colleges A and B, and a third school C that accepts all applicants. Each of the two selective schools can enroll $K < 1/2$ of students. We will assume that students generally favor school A, which consequently is the most selective and which we think of as the more "highly-ranked" school.

Each student is described by a pair of characteristics (v, y), where v indicates the student's ability as it will be assessed by colleges, and y indicates the student's relative preference or fit for the selective colleges. A student of type (v, y) receives utility $u(s, y)$ from attending school s. We normalize $u(C, y) = 0$, and assume that $u(A, y), u(B, y) > 0$, and also that $u(A, y)/u(B, y)$ is increasing in y and crosses one at $y = 0$. Students with high y are therefore enthusiastic about school A, while students with a low y are enthusiastic about B.[9]

Let G denote the distribution of student types in the population, where G has rectangular support $\mathcal{V} \times \mathcal{Y}$. To capture the idea that the most academically-oriented students may be the ones with the greatest desire to attend the higher-ranked school, we assume that (v, y) are affiliated. The assumption that students tend to prefer school A is captured by letting $G_y(0|v) \in (0, 1/2)$ for all v. A limiting case of the model that proves useful below relaxes this assumption and instead assumes the schools are "symmetric" in the sense that (v, y) are independent and $G_y(0) = 1/2$. For future reference, we define $V = G_v^{-1}(1 - 2K)$ to be the quality threshold such that if all students of ability $v \geq V$ matriculate at selective schools, and divide themselves equally, both schools are exactly at capacity.

Both selective schools prefer students of high academic ability and students who are a better fit. We denote the value that school A and B assign to a student with characteristics (v, y) as $\pi_A(v, y)$ and $\pi_B(v, y)$, where π_A is increasing in (v, y) and π_B is increasing in $(v, -y)$.[10] We assume that each school wants to maximize its average value for the students who enroll. To ensure that school B is not tempted to admit low ability students indiscriminately in search of better fits, we assume that for any set $\Omega \subset \mathcal{Y}$, $\mathbb{E}_y[\pi_B(v, y)|v, y \in \Omega]$ is increasing in v. This is immediate if v and y are independent, and holds under affiliation provided school B places sufficient weight on student ability.

Early applications can play an important role in signaling student preferences when the information required to implement an efficient match between students and colleges is dispersed. In the baseline version of the model, we assume a clean separation of information. Students know their preferences at the time they apply, but not how colleges will assess their academic ability (i.e. each student knows her y, but not her v). Later we will show that our results carry through even if students have a fair amount of information about v, so long as the information isn't perfect. In contrast, we assume each school can assess the academic ability of applicants accurately (i.e. each college learns the true value v for each student) but cannot infer enthusiasm (the true value y) directly from a student's application. Of course

[9]There are many reasons why elite colleges may attract different types of students. For instance, A might emphasize undergraduate research while B's relative strength is how it integrates academics with residential life. These comparative strengths may appeal to different types of applicants.

[10]One implication of each college maximizing its average value for individual students is that we rule out peer effects in the colleges' payoff function.

if v, y are correlated, knowledge of one of these values may provide some information about the other.

Throughout the paper, we consider the following admissions game. Colleges first announce if they will offer early admissions. Students then submit applications and can potentially designate one application as an "early" application. We assume the cost of submitting applications is negligible, so that students find it optimal to apply everywhere.[11] The schools then make their admission decisions, and finally students choose among the colleges where they were admitted. Naturally students enroll at their preferred school, except that a student admitted Early Decision must enroll at that school. We analyze equilibria of this game in which the colleges cannot commit in advance to favoring (or disfavoring) early applicants by any particular amount; this focus rules out the possibility that a school would seek to influence applicant decisions by pre-committing to a specific admissions rule that is subsequently suboptimal. Such behavior might benefit a school in theory, but seems inconsistent with the actual operation of the market.

4 Regular Admissions Equilibrium

Suppose the schools offer only regular admissions. Each student will apply to all three colleges, and the selective schools will choose their admissions policies to maximize their expected payoff subject to the constraint that they expect to enroll K students. In equilibrium, each school correctly anticipates the overall pattern of admission and enrollment decisions, and hence will exactly meet its enrollment target. We say that a school uses a *threshold admissions policy* if it admits all applicants with ability above some cut-off, and a *threshold equilibrium* is one in which both selective colleges use threshold policies.

There is a unique regular admissions equilibrium and it has a threshold structure. In equilibrium, school A admits all students with $v \geq A_R$ and school B admits all students with $v \geq B_R$, where $A_R > B_R$. Students with ability above A_R are admitted at both schools and choose their preferred school. This leads to full enrollment at A. School B's remaining spaces are filled by the students with abilities between A_R and B_R.

Proposition 1 *There is a unique equilibrium in which students apply to both schools and*

[11] The problem of application costs, and the issues they raise for early admissions, has been studied by Chade, Lewis and Smith (2006) and Lien (2007).

the schools use admission thresholds A_R, B_R *with* $\overline{G}_v(A_R|y \geq 0) = K$ *and* $B_R = V < A_R$.

The equilibrium thresholds can be found constructively, and are illustrated in Figure 1. When both schools use threshold policies, the top students are admitted everywhere and the majority enroll at school A. So A must have the higher threshold and A_R must satisfy $\overline{G}_v(A_R|y \geq 0) = K$, where $\overline{G}_v$ the mass of students with abilities above A_R, or the reverse cdf. Meanwhile B_R must equal V (i.e. $\overline{G}_v(B_R) = 2K$) because all students with abilities above B_R will enroll at one of the selective schools and their numbers must total $2K$.

Proposition 1 rules out the possibility of non-threshold equilibria. These equilibria may exist in the limiting "symmetric" case where (v, y) are independent and $G_y(0) = 1/2$. The reason is that each school benefits from admitting students who are also admitted at the other school, because such students will self-select on the basis of fit in making their enrollment decision. In the symmetric case, therefore, there can be equilibria in which the schools use identical admissions policies but do not admit only the best students. These equilibria involve a coordination failure: the schools would be better off using threshold policies, but neither school individually wants to switch to one. The proof of Proposition 1, in the appendix, shows that this type of coordination failure cannot occur if there is even a bit of hierarch between the schools.

An important feature of the regular admissions equilibrium is that the highest ranked-students — those with abilities A_R or higher — self-select into their preferred college. This provides an element of preference-based sorting even in the absence of an explicit signaling method such as an early application. Nevertheless, it should be clear from Figure 1 that at least school B would be anxious to have additional information about the fit of marginal candidates who do not self-select in their enrollment choice. This gives rise to a *sorting rationale* for early admissions that we explore in the next section.

5 Early Action Programs

Early action programs create a signalling opportunity because a student can apply early to only one school. In our model, this effect operates only if both schools accept early applicants. If a single school introduced early action and students expected an advantage, they all would apply early, making the application uninformative. If both schools offer early action, however, and students expect an early advantage, their application choices will be informative. This provides schools with an incentive to favor early applicants, rationalizing student expectations.

To investigate this possibility, we look for early action equilibria in which market participants use threshold strategies. In such an equilibrium, schools A and B use separate thresholds for early and regular applicants, denoted A_{EA}, A_{RA} and B_{EA}, B_{RA}, and students apply early to A rather than to B if their relative preference for A lies above some cut-off. As it turns out, there are always threshold equilibria that simply replicate the regular admissions outcome. In one such equilibrium, students expect A to disadvantage early applicants and so all apply early to B. In this case, an early application conveys no information, so any early admission policy is optimal for A, including the conjectured behavior of favoring regular applicants. To rule out this uninteresting case, we focus on equilibria that are robust to a small perturbation of application behavior in which a vanishing fraction of students with the strongest preferences for schools A and B apply early to these schools. We prove the following result in the Appendix.

Proposition 2 *There is always a robust threshold equilibrium when both colleges offer Early Action. In any such equilibrium: (1) students apply early to A if and only if $y \geq Y_{EA} > 0$; (2) admission thresholds satisfy $B_{EA} < V < B_{RA}$ and $B_{EA} < A_{EA} < A < A_{RA}$; and (3) early admissions yields are higher than regular admissions yields.*

The equilibria described in Proposition 2 match the empirical patterns described earlier. First, it is easier to be admitted early: both schools apply a strictly lower admission threshold for early applications. Second, this advantage leads some students to apply early to their lower-ranked second choice. Third, provided that (v, y) are correlated, the more highly-ranked school A has an early applicant pool that has higher average academic quality than its regular pool, while the reverse is true for the lower-ranked school B. Fourth, both schools enjoy yields from early admits that are at least as high as their regular admission yields.

Figure 2 depicts an early action equilibrium. To understand the incentives in this equilibrium, consider first the application decision. With $B_{EA} < A_{EA}$, it is clearly optimal for a student who prefers B ($y \leq 0$) to apply early to B. This maximizes both the probability of admission to a selective school (A or B) and the probability of admission to the most preferred school (B). There is a trade-off, however, for a student who strictly prefers A ($y > 0$). In this case, applying early to A maximizes the probability of admission to the most preferred school (A), but not the probability of admission to a selective school (A or B).

Specifically, if the student turns out to be a candidate who would be admitted to A only as an early applicant (ability between A_{EA} and A_{RA}), an early application to A rather than B increases the student's payoff by $u(A, y) - u(B, y)$. Alternatively, if the student turns out to be a candidate whose ability falls between B_{EA} and $\min\{A_{EA}, B_{RA}\}$, an early application to A rather than B leads to a loss of $u(B, y)$. Each student assesses this trade-off probabilistically, and optimally applies early to A if

$$\frac{G_v(A_{RA}|y) - G_v(A_{EA}|y)}{G_v(\min\{A_{EA}, B_{RA}\}|y) - G_v(B_{EA}|v)} \cdot \frac{u(A, y) - u(B, y)}{u(B, y)} \geq 1. \tag{1}$$

Optimal application behavior follows a cut-off rule because both the relative likelihood of benefiting from an early application to A, and the preference for A are increasing in y. In addition, any student who prefers B ($y \leq 0$) strictly prefers to apply early to B, so that if Y_{EA} is the cut-off above which students apply early to A, $Y_{EA} > 0$ and at least some students who prefer A nevertheless apply early to B.

Now consider what determines the school's admission thresholds in Figure 2. For school A's thresholds to be optimal, it cannot benefit by slightly increasing or decreasing its early threshold and making a corresponding change in its regular threshold to keep its class size constant. In other words, school A must be just indifferent between the marginal enrollees from its early and late application pools, taking into account both the information revealed in the application decision and the information that will later be revealed in the enrollment decision. That is,

$$\mathbb{E}\left[\pi_A(v, y)|v = A_{EA}, y \geq Y_{EA}\right] = \mathbb{E}\left[\pi_A(v, y)|v = A_{RA}, 0 \leq y < Y_{EA}\right]. \tag{2}$$

In addition, A's admissions thresholds must satisfy its yield target

$$m(v \geq A_{EA}, y \geq Y_{EA}) + m(v \geq A_{RA}, 0 \leq y < Y_{EA}) = K, \tag{3}$$

Here $m(\cdot, \cdot)$ denotes the measure of students satisfying the stated conditions. These two conditions pin down school A's admission thresholds, A_{EA} and A_{RA}, in Figure 2.[12]

[12] It is possible that in equilibrium all students apply early to B and so A enrolls no regular applicants. Nevertheless, the focus on robust equilibria means that conditions (2) and (3) still hold.

School B's equilibrium thresholds in Figure 2 satisfy a similar condition ensuring that B is just indifferent between marginal matriculants. The condition for school B is that

$$\mathbb{E}\left[\pi_B(v,y)|v=B_{EA},y<Y_{EA}\right]=\mathbb{E}[\pi_B(v,y)|v=B_{RA},y\geq Y_{EA}]. \tag{4}$$

Furthermore, its admission thresholds must satisfy the yield target

$$\begin{aligned} m\left(v\geq B_{EA},y\leq 0\right)+m(A_{RA} &> v\geq B_{EA},Y_{EA}>y\geq 0) \\ +m(A_{EA} &> v\geq B_{RA},y\geq Y_{EA})=K. \end{aligned} \tag{5}$$

These two equations pin down the admissions thresholds B_{EA} and B_{RA} in Figure 2. Proposition 2 leaves open the possibility that in equilibrium B optimally sets its regular admission threshold B_{RA} above A_{EA}, and so does not enroll any regular applicants.[13] Then its thresholds still satisfy the yield target (5), but the marginal early matriculant is strictly preferred so that the equality in (4) becomes an inequality.

Our next result states that the additional sorting allowed by early action operates to the benefit of the selective schools.

Proposition 3 *Both selective schools benefit from early action relative to regular admissions.*

Proof. The argument relies on revealed preference. To start, fix the students and B at their equilibrium behavior. School A can replicate its regular admissions outcome by setting $A_{EA}=A_{RA}=A$. With this policy it ultimately will enroll all students with $v\geq A$ and $y\geq 0$, despite some of these students having applied early to B. Instead, A's equilibrium thresholds involve $A_{EA}<A<A_{RA}$, and so by revealed preference it prefers the early action outcome.

Now consider school B. Fix the students and A at their equilibrium behavior. If B uses its regular admissions policy $B_{EA}=B_{RA}=V$, it already does strictly better than in the regular admissions equilibrium. It loses students with $v\in[A_{EA},A)$ and $y\geq Y_{EA}$, but gains an equivalent mass of students with $v\in[A,A_{RA})$ and $y\in[0,y)$. The new group has higher

[13] For this reason, it is natural to solve first for A's admissions thresholds and then subsequently for B's admissions thresholds in any constructive approach to identifying a threshold equilibrium.

v's and lower y's. Additionally B's equilibrium strategy departs from its regular admission policy so by revealed preference the early action outcome is even better. *Q.E.D.*

Early action benefits the schools but not all the students. This can be seen in Figure 2. Students who prefer the lower-ranked school B are unambiguously better off. But students who prefer A can lose from the introduction of early action if it results in them: (1) enrolling at C rather than B (if $y \geq Y_{EA}$ and $B_R < v < \min\{A_{EA}, B_{RA}\})$), or (2) enrolling at B rather than A (if $0 < y < Y_{EA}$ and $A_R \leq v < A_{RA}$). In general, each action helps match enthusiasts to the college they prefer, so students with a preference for B or a strong preference for A benefit, but students with just a mild preference for A may lose. Under slightly stronger assumptions than we have made, in particular if $u(y, A)$ is increasing in y and $u(y, B)$ decreasing in y, then early action induces an improvement over the regular admissions equilibrium (in the sense of first-order stochastic dominance) in the distribution of realized student utilties. *on average* the benefits of early admissions outweigh the costs so the average student utility is increased by early action.[14] Thus, early action can be said to produce an ex ante Pareto improvement over regular admissions. Though some student achieve ex post lower utilities with early action than with regular admissions, it is still the case that average student utilities are higher with early action than in the regular admissions equilibrium.

Propositions 2 and 3 extend to a more realistic setting in which students have information about their academic standing when they are deciding where to apply. Suppose that in addition to knowing their relative preference for the schools, each applicant observes a signal w that is informative about v. Such a signal conveniently captures observable aspects of academic standing such as grade point average or test scores. A student is then characterized by a triple (v, w, y). We assume the joint distribution of characteristics in the population is affiliated, again with rectangular support. We also assume that $\pi_k(v, y) f(w|v)$ in strictly increasing in v for $k = A, B$, and that conditional on w, (v, y) are independent. These assumptions imply that students have some residual uncertainty about their academic standing, and ensure that schools are not tempted to depart from threshold policies.

In the extended model, the regular admissions situation is the same as before. Students

[14]This can be seen in Figure 2 by noting that the students enrolling in A under early action have weakly higher y's than the students enrolling in A under regular admissions. Similarly, the students enrolling in B under early action have weakly lower y's than those enrolling in B under regular admissions.

still apply to all schools and the schools set their admissions thresholds A, B to just fill their classes. When early action is introduced, however, students use their information about relative rank in deciding where to apply. All else equal a student who is more optimistic about her academic standing will be more inclined to reach for the more selective school A, leading to the following conclusion about equilibrium behavior.

Proposition 4 *Suppose students are heterogenous in both their preferences and their beliefs about their academic standing. A robust threshold equilibrium still exists with early action, and in any such equilibrium: (1) all students apply early to A if and only if $y \geq Y_{EA}(w)$, where $Y_{EA}(w)$ is strictly positive and decreasing in w; and (2) school policies satisfy $B_{EA} < V < B_{RA}$ and $B_{EA} < A_{EA} < A_{RA}$. As before, both schools benefit from early action relative to regular admissions.*

The sorting behavior described in Proposition 4 provides an explanation for why highly ranked schools receive relatively strong early applications on dimensions such as test scores and grades that are readily accessible, and also why lower ranked schools receive relatively weak early applications on these dimensions. Students with strong observable characteristics are more optimistic about admission and hence see less reason to play it safe with their early application. So early applicants tend to be stronger than regular applicants at college A, but weaker at college B even if there is no correlation between ability (v) and preferences (y).

The welfare properties we have described depend to some extent on frictionless communication of preferences via early action signaling. In the model we've proposed, it is possible that if some students are unable to apply early, or if students do not have full information about their preferences at the early appliction deadline, then equilibrium forces may lead the schools to accept and favor early applicants but the schools would be collectively better off if they accepted only regular applications.

Proposition 5 *If a fraction of students cannot apply early, it is possible to have an Early Action equilibrium in which both schools do worse than under regular admissions.*[15]

This point can be understood in the context of a simple example. Suppose that a fraction $1 - \gamma$ of students cannot apply early, and that these students are otherwise no different from

[15] Avery (2008) produces a similar result for the case where all students can apply early, but they do not have complete information about their preferences at the early application deadline.

the general population. Suppose in addition that students have no w signal and v, y are independently and uniformly distributed on $[0,1] \times [-1,1]$. This corresponds to a limiting "symmetric" case of our model. If the schools accept only regular applications then regardless of the exact school preferences there is a unique threshold equilibrium in which $A = B = V = 1 - 2K$.[16]

The introduction of early admissions in this example can lead to an equilibrium that is Pareto inferior for the schools. Suppose that school preferences satisfy $\pi_A(v, y) = v + \alpha y$ and $\pi_B(v, y) = v - \alpha y$. The parameter α represents the weight that colleges place on fit relative to academic ability. Figure 3 illustrates a symmetric early action equilibrium. In equilibrium, the students apply early to their preferred school, except for the fraction $1 - \gamma$ that cannot apply early, and the schools use identical admission thresholds. The thresholds satisfy $A_{EA} = B_{EA} = V - \frac{1}{2}\alpha(1 - \gamma)$ and $A_{RA} = B_{RA} = V + \frac{1}{2}\alpha\gamma$.[17]

The early action equilibrium depicted in Figure 3 is worse for the schools than the regular admissions equilibrium. In both cases, college A enrolls only students who view it as their first choice (i.e. have $y \geq 0$), and similarly for B. But in the early action case, the colleges enroll some students with abilities below V, and reject others with abilities above V because those students failed to apply early. Compared to the regular admissions equilibrium, each school's entering class has lower academic quality and no improvement in student fit. The problem is that once some students are applying early to their first choice college, and one school favors early applicants, the other has a strict incentive to do so as well in order to cherry-pick students on the basis of fit. The result is a coordination failure along the lines discussed above, but one that does not disappear if a small asymmetry is introduced between the schools.[18]

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[16] There are also non-threshold equilibria, but they are not robust to even the slightest asymmetry between the schools. That is, suppose students have a slight preference for school A, so that $G_y(0) = 1/2 - \varepsilon$. For each ε there is a unique regular admission equilibrium and as $\varepsilon \to 0$ the equilibrium thresholds $A(\varepsilon), B(\varepsilon)$ approach V.

[17] For these thresholds to be interior, we require that $1 - \frac{1}{2}\alpha\gamma < 1 - 2K < \frac{1}{2}\alpha(1 - \gamma)$. With the stated thresholds, each school enrolls $\gamma\left[K + \frac{1}{4}\alpha(1 - \gamma)\right]$ early applicants and $(1 - \gamma)\left[K - \frac{1}{4}\alpha\gamma\right]$ regular applicants to just meet its yield target. Neither school wants to deviate because the marginal early enrollee is valued at $A_{EA} + \alpha/2$, the same value a school would obtain from slightly lowering its regular admission threshold and admitting students of quality $v = A_{RA}$. As with the regular admissions case, there are other equilibria as well, including one in which both schools apply the same threshold V to early and late applicants. The equilibrium we have described, however, is robust to small asymmetry between the schools, while the equilibrium that replicates the regular admissions equilibrium is not.

[18] One can view this as a form of adverse selection. If $B_{EA} < V < B_{RA}$, then if A were to set $A_{EA} = V = A_{RA}$, the marginal regular admits would be adversely selected on the basis of fit relative to the marginal early admits.

6 Early Decision Programs

We now investigate the effects of Early Decision programs in which students are required to make a binding commitment to enroll if admitted early. Our main insight is that Early Decision enables lower-ranked schools to capture some highly desired students who are unsure of their abilities at the time of application. This *competitive effect* operates to the detriment of top-ranked schools, providing a reason for them to be less enthusiastic about early admissions, at least when their competitors require a commitment from students.

The setting is the same as before, except that early admission is now a binding commitment. We again look for robust threshold equilibria in which schools use distinct admissions thresholds for their early and late applicants, and students apply early to A if and only if they have a sufficiently strong preference for it. Our next result, characterizes such equilibria.

Proposition 6 *With early decision, there is at least one robust threshold equilibrium. In any such equilibrium: (1) students apply early to A if and only if $y \geq Y_{ED}$, where $Y_{ED} > 0$; and (2) school admission policies satisfy $B_{ED} < V < B_{RD}$ and $B_{ED} < A_{ED} < A_{RD}$.*

Figure 4 illustrates an Early Decision equilibrium; the incentives are similar to the case of early action. Consider, for instance, the application behavior of students. In equilibrium, students realize an admissions benefit from applying early to B, but at a cost to students with $y > 0$. Students who prefer B simply apply early to B. Students who prefer A trade off the admissions benefit of applying early to B against the cost of not being able to enroll at A if they are that have sufficient academic standing to be admitted. Following the same argument from the early action setting, a student should optimally apply early to A, rather than B, whenever

$$\frac{1 - G_v(A_{ED}|y)}{G_v(\min\{A_{ED}, B_{RD}\}|y) - G_v(B_{ED}|y)} \frac{u(A,y) - u(B,y)}{u(B,y)} \geq 1. \tag{6}$$

The left hand side is strictly increasing in y and equal to zero at $y = 0$. So the optimal policy for students involves a cut-off $Y_{ED} > 0$, just as with early action.

On the school side, A's enrollees come entirely from its early applicant pool, because any student admitted regular has also been admitted to B and is obligated to enroll. So A's early admissions threshold is pinned down by its yield target:

$$m\{v \geq A_{ED}, y \geq Y_{ED}\} = K. \tag{7}$$

School A is indifferent between a range of regular admissions thresholds, but we show in the Appendix that if the equilibrium is robust, A's regular threshold must be set so that $\mathbb{E}_y[\pi_A(v, y\}|v = A_{RD}, y \geq 0]$ is just equal to the expected payoff from a marginal early admit, $\mathbb{E}\left[\pi_A\left(v, y\right)|v = A_{ED}, y \geq Y_{ED}\right]$.

School B's problem is similar to the early action case. In the equilibrium depicted in Figure 4, school B must be just indifferent between a marginal enrollee from its early and regular applicant pools, so that (4) holds with ED subscripts in place of EA, and B must also admit just enough students to satisfy its yield target. The latter implies that in equilibrium

$$m\{v \geq B_{ED}, y < Y_{ED}\} + m\{v \in [B_{RD}, A_{ED}], y \geq Y_{ED}\} = K. \tag{8a}$$

As in the early action case, it is also possible to have an equilibrium in which school B fills its class entirely from its early applicant pool, in which case the optimality conditions are again similar to early action.

An interesting point about the early decision equilibria described in Proposition 6 is that the form of admission offered by school A is not in fact important. All of the students who in equilibrium apply early to A would choose to attend even if the binding commitment was relaxed. So having A switch to a policy of early action would not affect the set of possible equilibria. Moreover, in equilibrium A fills its class entirely with students who chose not to apply early to B. So if A eliminates early admissions entirely, there is an equilibrium in which exactly the students who would have applied early to A instead submit only regular applications, and A applies its early decision threshold A_{ED} to all its all applicants. This equilibrium gives rise to precisely the same allocation of student to schools.

This argument suggests why very top-ranked schools such as Harvard, Princeton, Yale, Stanford and M.I.T. may incur the least cost from moving away from Early Decision toward Early Action, or even from eliminating early admissions entirely. These schools have less reason to think they will lose top students by making the admissions commitment non-binding. Flipping this around, of course, it is lower-ranked schools that stand to gain the most from binding early admissions because it allows them to capture some highly qualified students who might otherwise turn them down. The next Proposition states this formally, showing that the welfare properties of Early Decision are quite different from the Early Action case.

Proposition 7 *School B prefers Early Decision to Regular Admissions, and may or may not prefer Early Decision to Early Action. School A may prefer both Early Action and Regular Admissions to Early Decision.*

Proof. Consider school B first. Suppose we fix the students and school A at their Early Decision equilibrium behavior. Then one way for school B to meet its yield target is to use a uniform threshold $B_{ED} = B_{RD} = V$. With this policy, school B does better than with regular admissions because it captures a set of students with higher v's and lower y's. So by revealed preference, school B prefers an Early Decision equilibrium to the regular admissions outcome. The remaining claims are shown in the Appendix via a series of numerical examples. *Q.E.D.*

In comparing Early Decision to regular admissions, school B obtains two benefits. First, it is able to obtain some highly ranked students who prefer A but nevertheless apply early to B. This provides a competitive rationale. Second, as in the previous section, it is able to favor enthusiasts on the admissions margin. This provide a sorting rationale. The situation for school A is different. It does get the sorting effect of having only students with $y \geq Y_{ED}$ in its pool of potential enrollees, but it suffers from the loss of some highly ranked students. Because of this cost, it is straightforward to construct examples in which the introduction of Early Decision policies makes school A less well off.

The comparison between Early Decision and Early Action is more subtle. If the students were to use the same application rule under both Early Decision and Early Action, i.e. a fixed threshold $Y > 0$ for deciding whether to apply early to A or B, then school B would certainly prefer Early Decision. Because students anticipate the possibility of being locked in to a binding commitment, however, they are more reluctant to apply early to B. All else equal this reduces the number of students who want to apply early to B, and this can has ambiguous sorting consequences for the firms. For example, if almost no students apply Early Decision to B in equilibrium, then B will likely do better with Early Action than Early Decision. More generally, if introducing Early Decision has limited effect on the set of students applying early to B, then B will generally do best with Early Decision, but if introducing Early Decision causes a substantial shift of early applicants from B to A, then it is quite possible that B will prefer Early Action to Early Decision.

7 Discussion

We have focused on a simple model that explains many of the basic empirical facts about early admissions. The model emphasizes two effects of early admissions: the *sorting effect* under which early applications convey enthusiasm about a school, and the *competitive effect* under which a lower ranked school, by adopting and early decision policy, can attract some highly ranked but cautious students from a more highly ranked school. These effects shed light on why schools appear to favor early applicants, why student application behavior exhibits particular patterns of sorting, and why selective schools, particularly those not at the very top, may benefit from the use of early admission programs.

The aspects of early admissions highlighted in our model are likely not the only reasons why schools have adopted such policies. One role of early admissions that we do not capture is yield management. Particularly at small colleges, there may be a significant downside to over-enrollment if it leads to crowded dorms or strained resources, and making conservative admissions decisions may require excessive reliance on the wait list. Admitting a fraction of the class early, with a binding commitment, may mitigate this risk.[19] Schools may also want to increase yield for less benign reasons. Historically, yield was one of the metrics used by *US News and World Report* in their college rankings, and it is possible that this created an incentive for schools to rely more heavily on early decision in order to manipulate the rankings process.

For students, early decision policies also interact with the provision of financial aid. One issue of particular concern is that a binding early commitment may preclude a student from "shopping around" for the best financial aid package. This creates a dilemma for students with limited resources who want the admissions benefit of applying early.[20] Of course, some students may also benefit from early admissions for reasons we have not emphasized. Some students may enjoy learning mid-way through senior year that they have a secure position, and receiving an early notification of admission may allow them to avoid some of the time-consuming process of filling out applications.

[19] Indeed, when Harvard and Princeton eliminated early admissions in 2007-08, both found that enrollment fell far short of target, leading to heavy reliance on their waitlists.

[20] Kim (2007) argues that need-blind colleges could even use early decision programs to surreptitiously attract wealthy applicants. In practice, the latter concern seems somewhat unlikely given that the objectives of need-blind universities clearly go well beyond maximizing tuition revenue, and these institutions seem to be the ones that employ the least restrictive practices are the most ambivalent about early admissions.

It is also possible that for certain students the signaling aspect of an early application is somewhat richer than is captured in our specific model. For example, an early application from a student at a high school that does not send many students to a selective college may indicate a promising level of ambition. Lee (2009) has also highlighted a related informational issue, namely that early decision policies could protect a school against a winner's curse in enrollment decisions. We observed a related phenomenon in the proof of Proposition 5, where we argued that under certain conditions schools might adopt early admission programs to match competitors but be collectively better off if these programs were eliminated.

Finally, we note that early admissions programs can be viewed as a form of "market unravelling" of the kind described by Roth and Xing (1994). In many of the markets they consider, a social cost of unravelling is that it appears to reduce the efficiency of market assignments by precluding the use of late-arriving information. Our analysis suggests that one benefit of early admissions may in fact be to increase the flow of information across the market by creating a credible opportunity for students to signal interest. Nevertheless, a similar point can be made that by moving up the entire college admissions process, early admission programs force young students to make committing decisions even as their preferences may be evolving. Certainly all of these aspects of early application need to be considered if one is to evaluate possible reforms to the market.

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Appendix: Omitted Proofs

Proof of Proposition 1

First, it is easy to see that if the schools use threshold policies, the yield constraints imply that $A = \overline{G}_v(A|y \geq 0)$ (otherwise A would enroll either more or less than K students) and hence $B = V$. Now, consider *any* two admissions policies, not necessarily of threshold form. If B admits only students that are admitted by A, then B will enroll strictly fewer students than A. So satisfying both yield constraints implies there is some set of students $[v', v'']$ who are admitted only by B. In equilibrium, A can't admit any students with ability below v'', or it could benefit by rejecting some of these students in favor of students with abilities in $[v', v'']$. Moreover, B can't reject any students with abilities above v'' or else it could benefit by accepting them in favor of students in $[v', v'']$. It follows that in equilibrium B must use a threshold policy, and therefore A must use one as well. *Q.E.D.*

Proof of Propositions 2 and 4

Here we establish our existence and characterization results for Early Action equilibria. As described in the text, we are interested in equilibria that are robust to having a vanishing fraction of students with the strongest preference for schools A and B apply early to those schools. Say that student behavior is ε-perturbed if each student is constrained with probability ε to apply early to A if $y \geq \overline{Y}(\varepsilon)$, apply early to B if $y \leq \underline{Y}(\varepsilon)$ and otherwise apply regular to both, where we define $\overline{Y}(\varepsilon), \underline{Y}(\varepsilon)$ to satisfy $F_y(\underline{Y}(\varepsilon)) = 1 - F_y\left(\overline{Y}(\varepsilon)\right) = \varepsilon$. A threshold equilibrium of the unperturbed game is *robust* if it is the limit as $\varepsilon \to 0$ of a sequence of threshold equilibria of ε-perturbed games.

In what follows, we describe properties of optimal admissions and application behavior. We then prove that robust equilibria exist and characterize their properties.

Optimal Admissions Policies

1. (Monotonicity) Suppose students use a threshold application policy. If one school uses a threshold admissions policy, then the other school has a threshold policy that is a best response.

Proof. We establish that given the stated conditions, a school strictly prefers to admit high-v students to low-v students if acceptance leads to some students enrolling. We consider the case where students get a w signal; the no w case is essentially identical.

Start with school A. If A accepts a v applicant early, the student will enroll if $y \geq e_A(v,w)$, where $e_A(v,w)$ equals $Y(w)$ if $v < B_{RA}$ and $\max\{0, Y(w)\}$ if $v \geq B_{RA}$. Note that e_A is increasing in v. Therefore A's expected value,

$$\int_{\underline{w}}^{\overline{w}} \mathbb{E}_y \left[\pi_A\left(v,\tilde{y}\right)|w, \tilde{y} \geq e_A(v,w)\right] f(w|v)dw,$$

is increasing in v because the integrand is increasing.

If A accepts a v applicant regular, the student will enroll if $y \geq r_A(v)$, where $r_A(v)$ equals $\underline{y}$ if $v < B_{EA}$ and 0 if $v \geq B_{EA}$. Again $r_A(v)$ is increasing in v, and so is A's expected value

$$\int_{\underline{w}}^{\overline{w}} \mathbb{E}_y \left[\pi_A\left(v,\tilde{y}\right)|w, r_A(v) \leq \tilde{y} \leq Y(w)\right] f(w|v)dw.$$

Now consider B. If B accepts a v applicant early, the student will enroll if $y \leq e_B(v,w)$, where $e_B(v,w)$ equals $Y(w)$ if $v < A_{RA}$ and $\min\{0, Y(w)\}$ if $v \geq A_{RA}$. So e_B is decreasing in v, and B's expected payoff

$$\int_{\underline{w}}^{\overline{w}} \mathbb{E}_y \left[\pi_B\left(v,\tilde{y}\right)|w, \tilde{y} \leq e_B(v,w)\right] f(w|v)dw,$$

is increasing in v, again because the integrand is increasing.

Finally, if B accepts a v applicant regular, the student will enroll if $v \leq r_B(v)$, where $r_B(v)$ equals $\overline{y}$ if $v < A_{EA}$ and 0 if $v \geq A_{EA}$. So r_B is decreasing in v, and B's expected payoff

$$\int_{\underline{w}}^{\overline{w}} \mathbb{E}_y \left[\pi_B\left(v,\tilde{y}\right)|w, Y(w) \leq \tilde{y} \leq r_B(v)\right] f(w|v)dw,$$

is increasing in v. *Q.E.D.*

2. (Favoritism) Suppose students use a threshold application policy. Then each school has greater expected payoff from an v candidate who applied early than a v candidate who applied regular.

Proof. Consider school A. An early application reveals that $y \geq Y(w)$, so A's average value from early v applicants is at least $\mathbb{E}_w\left[\pi_A(v, Y(\tilde{w}))|v\right]$, and strictly higher provided $Y(w) < \overline{y}$ for some fraction of w signals. Its value from regular v applicants is no greater than this amount. Similarly, B's payoff from an early (regular) v candidates is bounded below (above) by $\mathbb{E}_w\left[\pi_B(v, Y(\tilde{w}))|v\right]$. *Q.E.D.*

3. Suppose students use a threshold application policy. If one school uses a threshold policy, the other can optimally use a threshold policy that weakly favors early applicants.

Proof. This follows from the previous two claims. If A considers a non-threshold policy for one applicant pool, switching to the highest threshold that satisfies the yield target will be at least a weak improvement. Similarly, if A considers thresholds $A_{EA} > A_{RA}$ satisfying its yield target, lowering A_{EA} and raising A_{RA} while keeping yield constant will be at least a weak improvement. The same argument applies for school B. *Q.E.D.*

4. Suppose students use an threshold application policy and school B uses a threshold admission policy. Let $\alpha(Y, B)$ be A's optimal threshold choices that satisfy $A_{EA} \leq A_{RA}$. Then $\alpha(Y, B)$ is non-empty, upper semi-continuous, convex and compact-valued. The same properties hold for $\beta(Y, A)$, similarly defined for school B.

Proof. Consider school A. Given Y, B, it wants to choose thresholds $A_{EA} \leq A_{RA}$ that meet its yield target and achieve the highest expected payoff $\mathbb{E}_{w,y}\left[\pi_A(v, \tilde{y}) | (v, \tilde{w}, \tilde{y}) \in \mathcal{A}\right]$, where $\mathcal{A}$ denotes the set of types that will enroll and depends on its admission choices. The optimal policy (or policies) can be found constructively. Start with $A_{EA} = A_{RA}$ equal to the unique value that satisfies the yield target given Y, B.[21] If there are no early applicants, this is the uniquely optimal choice of A_{RA} and any A_{EA} is optimal. Similarly if there are no regular applicants, A_{EA} is uniquely optimal along with any A_{RA}. If there are early and late applicants but at the uniform thresholds no regular matriculants, i.e. if $Y(w) \leq 0$ for all w and $A_{RA} \geq B_{EA}$, then A_{EA} is uniquely optimal along with any $A_{RA} \geq B_{EA}$.

The last case is where the uniform threshold results in early and late matriculants. From the proof of Claim 2, the marginal early matriculant is strictly preferred to the marginal late matriculant. So consider lowering A_{EA} and raising A_{RA} while maintaining yield. By the proof of Claim 1, each such adjustment results in a strictly smaller improvement to average payoff. Continue until either: (i) the marginal matriculants are equal value, in which case we've found the unique optimum; or (ii) there are no regular matriculants (if A_{RA} hits B_{EA} and $Y(w) \leq 0$ for all w) in which case we've found the uniquely optimal A_{EA} and any higher A_{RA} is optimal; or (iii) $A_{EA} = \underline{v}$ in which case we've again found a unique optimum. In each case, optimal behavior involves $A_{EA} < A_{RA}$.

The constructive argument establishes that $\alpha(Y, B)$ is non-empty, compact and convex. Upper semi-continuity follows from Berge's Theorem (A's average payoff objective is continuous in A, B, Y, and its set of thresholds meeting the yield constraint is usc in B, Y). The same arguments apply for school B, showing that $\beta(Y, A)$ has the stated properties and will want to strictly favor early applicants if a uniform admissions policy that meets the yield requirement leads to early and late matriculants. *Q.E.D.*

5. Suppose student behavior is ε-perturbed. For sufficiently small ε, properties (1)-(4) above all hold. Furthermore $\alpha(Y, B; \varepsilon)$ and $\beta(Y, A; \varepsilon)$ are upper semi-continuous in ε and for $\varepsilon > 0$, single-valued with strict preference for early applicants.

[21] Such a value always exists because a uniform threshold of $\overline{v}$ results in no students and dropping the threshold increases enrollment to an amount strictly greater than K at $\underline{v}$. We assume for convenience that the same is true for B (if B cannot always meet its yield target, a few small modifications are needed in the proof but our results still hold).

Proof. The first three properties above follow from the same arguments. For small ε, each school will still prefer to admit higher v students and prefer early to regular applicants. For the last part, consider the construction of optimal policies in the proof of Claim 4. For $\varepsilon > 0$, the uniform admissions policy leads to both early and late matriculants, so any optimal policy must involve strictly favoring early applicants and in fact the optimal policy is unique. That α, β are usc in ε again follows from Berge's Theorem. *Q.E.D.*

Properties of Student Best Responses

1. Suppose both schools strictly favor early applicants. If $A_{EA} \leq B_{EA}$, any student with $y \geq 0$ should apply early to A. If $A_{EA} > B_{EA}$, a student should apply early to A if $y \geq Y(w)$ and otherwise to B, where $Y(w)$ is strictly positive and decreasing in w.

Proof. If a student prefers a school and it has the lower early threshold, it's optimal to apply early to that school because for any realization of v applying early to the other school can only lead to worse outcomes. For the last claim, suppose $A_{EA} > B_{EA}$. It is optimal to apply early to A if and only if

$$\frac{G_v(A_{RA}|w,y) - G_v(A_{EA}|w,y)}{G_v(\min\{A_{EA}, B_{RA}\}|w,y) - G_v(B_{EA}|w,y)} \cdot \frac{u(A,y) - u(B,y)}{u(B,y)} \geq 1. \tag{9}$$

The second term is strictly increasing in y and equal to zero at $y = 0$. The first term is strictly positive and weakly increasing in y by affiliation. So the student optimally uses a cut-off rule: apply early to A if and only if $y \geq Y(w)$, where $Y(w) > 0$. Moreover, if w takes multiple values, the first term is increasing in w by affiliation, so $Y(w)$ is decreasing. *Q.E.D.*

2. Suppose the schools use thresholds that weakly favor early applicants, and that students are constrained to apply early to B if $y < 0$. Then there is some threshold policy that is optimal for students with $y \geq 0$. Let $\gamma(A, B)$ denote the set of threshold policies, nonincreasing in w, that are optimal subject to the constraint that all students with $y < 0$ apply early to B. Then γ is non-empty, convex-valued and usc in A, B.

Proof. If neither school strictly favors early applicants, any early application behavior is optimal including all threshold rules, with $Y(w) \geq 0$ and nonincreasing in w. If only one school strictly favors early applicants, it is optimal to apply early to that school to the extent possible, again implying a threshold policy (either $Y(w) = \overline{y}$ or $Y(w) = 0$ given the constraint). If both schools favor early applicants and $A_{EA} \leq B_{EA}$, then $Y(w) = 0$ is optimal given the constraint. Finally, if both favor early applicants and $A_{EA} > B_{EA}$, then there is a uniquely optimal threshold rule $Y(w) > 0$ as described above. From this characterization, it is straightforward to check that γ has the claimed properties. *Q.E.D.*

Robust Threshold Equilibria

1. Suppose student behavior is ε-perturbed, for sufficiently small $\varepsilon > 0$. At least one threshold equilibrium exists, and any threshold equilibrium involves $B_{EA} < B_{RA}$, $B_{EA} < A_{EA} < A_{RA}$, and either $Y > 0$ or if students have a signal of ability, $Y(w)$ strictly positive and decreasing in w.

Proof. Consider the case with a w signal. Let $\mathbf{A}$ denote the set of possible admission thresholds A_{EA}, A_{RA} with $A_{EA} \leq A_{RA}$, and similarly define $\mathbf{B}$. Let $\mathbf{Y}$ denote the set of application thresholds $Y(w)$, with $Y(w) \geq 0$ and nonincreasing in w. Define the set-valued function:

$$T(A, B, Y; \varepsilon) = (\alpha(B, Y; \varepsilon), \beta(A, Y; \varepsilon), \gamma(A, B)) .$$

This correspondence maps $\mathbf{A} \times \mathbf{B} \times \mathbf{Y}$ into itself. For sufficiently small $\varepsilon > 0$ satisfies all the requirements of the Glicksberg-Fan version of Kakutani's Fixed Point Theorem. Let $A(\varepsilon), B(\varepsilon), Y(\varepsilon)$ denote a fixed point.

We claim these strategies are an equilibrium, and satisfy the stated properties. By definition $A(\varepsilon), B(\varepsilon)$ are optimal for the schools, and from Claim 5 above, A and B must strictly favor early applicants. Moreover, we must have $B_{EA} < A_{EA}$. If instead $A_{EA} \leq B_{EA}$, any student with $y > 0$ that behaves optimally will enroll at A with at least probability $1 - \varepsilon$ whenever $v \geq A_{EA}$. So A's yield constraint implies that $A_{EA} > V$, which in turn implies that less than $2K$ students are admitted to a selective school, violating optimality for the schools. Finally given that both A and B favor early applicants and $B_{EA} < A_{EA}$, it is strictly optimal for all students with $y \leq 0$ to apply early to B. Therefore $Y(\varepsilon)$ is the unique best-response for students even if we remove the constraints imposed in defining γ. Furthermore $Y(w; \varepsilon) > 0$. *Q.E.D.*

2. There is always a robust threshold equilibrium of the unperturbed model, and any such equilibrium (a) students use a strictly positive threshold $Y > 0$ or if they have a w signal, a strictly positive and decreasing threshold $Y(w)$; (b) schools thresholds satisfy $B_{EA} < B_{RA}$ and $B_{EA} < A_{EA} < A_{RA}$; and (c) early yields exceed regular yields.

Proof. Existence follows from the continuity properties established above. Consider a sequence of strategies $A(\varepsilon), B(\varepsilon), Y(\varepsilon)$ where for each $\varepsilon > 0$, the profile $A(\varepsilon), B(\varepsilon), Y(\varepsilon)$ is an equilibrium. They must have a convergence subsequence because $\mathbf{A} \times \mathbf{B} \times \mathbf{Y}$ is compact. Moreover, if the limit A, B, Y were not an equilibrium some party can do strictly better with an alternative strategy. But that same strategy, say A', will be preferred to $A(\varepsilon)$ as a response to $B(\varepsilon), Y(\varepsilon)$ for sufficiently small ε, a contradiction.

We now establish necessary properties of a robust threshold equilibrium $Y(w)$, A_{EA}, A_{RA}, B_{EA}, B_{RA}.

First, $A_{EA} \leq A_{RA}$, $B_{EA} \leq B_{RA}$ and $Y(w) \geq 0$, or else the equilibrium cannot be the limit of ε-perturbed equilibria.

Second, $B_{EA} < A_{EA}$. If instead $A_{EA} \leq B_{EA}$, then any student with $y \geq 0$ who behaves optimally will enroll in A if $v \geq A_{EA}$. So $V < A_{EA} \leq B_{EA}, B_{RA}, A_{RA}$ and hence less than $2K$ students are admitted in total to A and B violating the yield constraints.

Third, if A receives no early applications, i.e. $Y(w) = \overline{Y}$, its optimal policy must satisfy $\pi_A(A_{EA}, \overline{Y}) = \mathbb{E}_y[\pi_A(A_{RA}, y) \,|y \geq 0]$, and in particular $A_{EA} < A_{RA}$. This follows because A's optimal policy must be the limit of optimal policies where A receives early applications from a vanishingly small fraction of students who prefer it most, and this limit must involve indifference (as opposed to $A_{EA} = \underline{v}$) because $A_{EA} > V$.

Fourth, $B_{EA} < B_{RA}$. Suppose to the contrary that $B_{EA} = B_{RA}$. Because $Y(w) \geq 0$, B must receive early applicants, and some will enroll. If in addition B receives regular applications, some must subsequently enroll because $B_{RA} = B_{EA} < A_{EA}$. But that would mean a uniform threshold could not be optimal. So the only way that $B_{EA} = B_{RA}$ could be optimal is if all students apply early to B. If that is so, however, then $A_{EA} < A_{RA}$ from above, and we arrive at another contradiction to optimality because students with $y > 0$ would apply to A early if A but not B strictly favored early applicants.

Fifth, $Y(w) > 0$. This follows because B strictly favors early applicants and uses a strictly lower threshold than A for early applicants.

Sixth, $A_{EA} < A_{RA}$. We have already established this to be the case if A receives no early applications, and if it receives early applications it must matriculate some of them. Moreover, because $Y(w) > 0$ it must matriculate some of its regular applicants if it uses a uniform threshold. So from (5) above, it must be the case that $A_{EA} < A_{RA}$.

The last property is that early yields exceed regular yields. This is clearly true for A, which enrolls all early admits. For B, it can be seen immediately in Figure 2, and the other cases are that either no students apply regular, which makes the claim trivial, or that $B_{RA} > A_{EA}$ so that the regular yield is zero. *Q.E.D.*

Proof of Proposition 6

The argument is essentially the same as for Propositions 2 and 4, so we provide only a sketch. First, it is easy to verify that optimal admissions and application behavior has the same properties described above. Schools can optimally use threshold rules in response to threshold rules and want to strictly favor early applicants if they get matriculants from both pools. If the schools strictly favor early applicants and $B_{ED} < A_{ED}$, it is optimal for students to use a threshold policy with $Y > 0$. The existence of a robust threshold equilibrium follows from the same arguments made in the Early Action case.

Consider properties of a robust equilibrium. As above, we must have $A_{ED} \leq A_{RD}$, $B_{ED} \leq B_{RD}$ and $Y \geq 0$. Similarly, we must have $B_{ED} < A_{ED}$ to satisfy the yield constraints. It must also be the case that $B_{ED} < B_{RD}$. The only way this could not happen is if all students were applying early to B, in which case the yield constraints would imply that $B_{ED} > A_{RD} \geq A_{ED}$ violating the previous condition. So $B_{EA} < B_{RA}$ and $B_{EA} < A_{ED}$ and it follows that students must use a threshold $Y > 0$. Finally $A_{ED} = A_{RD}$ is optimal for A but inconsistent with A's thresholds being nearly optimal for small perturbations in student application behavior along the lines above. So $A_{ED} < A_{RD}$. *Q.E.D.*

Proof of Proposition 7

The following example shows that preference toward Early Decision are sensitive to parameters. Suppose v, y are independently distributed, with v uniform on $[0, 1]$, and y taking values $\eta, 2/3$, and 1, with probabilities $1/4, 1/4$ and $1/2$, where $\eta > 0$ is very small. (The example can be extended to match our continuous model; having three types simplifies calculations.) School preferences are $\pi_A(v, y) = v + \alpha y$ and $\pi_B(v, y) = v - \alpha y$, with $\alpha \in (0, 3K/2)$. Student preferences satisfy $u(A, y)/u(B, y) > 2$ for $y = 1$, and $1 + (2/3)(\alpha/K) < u(A, y)/u(B, y) < 2$ for $y = 2/3$.

Regular Admissions. Students with abilities between $1-K$ and 1 enroll at A, and students with abilities between $1-2K$ and $1-K$ enroll at B. The average y of students at A and B is the same, 2/3. So A's payoff is $1-(1/2)K+(2/3)\alpha$ and B's payoff is $1-(3/2)K-(2/3)\alpha$.

Early Action. There is an equilibrium in which students with $y=1$ apply early to A and the others apply early to B, and schools use thresholds $A_{EA}=1-K-\alpha/3$, $A_{RA}=1-K+\alpha/3$, and $B_{EA}=1-2K-\alpha/3$ and $B_{RA}=1-2K+\alpha/3$. For school A, the marginal early and regular enrollee have expected y's of 1 and 1/3, making it optimal to set $A_{RA}-A_{EA}=(2/3)\alpha$, and satisfy its yield constraint. A similar calculation applies for B. For students, applying early to A rather than B has a benefit of $(2\alpha/3)[u(A,y)-u(B,y)]$ and a cost of $(2\alpha/3)\,u(B,y)$, so student behavior is also optimal. In equilibrium, school A enrolls $K/2+\alpha/6$ early applicants with an average ability of $1-(1/2)K-\alpha/6$, and $y=1$, and an $K/2-\alpha/6$ regular applicants with average ability $1-(1/2)K+\alpha/6$ and an average y of 1/3. So its equilibrium payoff is $1-(1/2)K+(2/3)\alpha+\alpha^2/(18K)$. A similar calculation shows that school B's payoff is $1-(3/2)K-(2/3)\alpha+\alpha^2/(18K)$.

Early Decision. With early decision, there is an equilibrium in which students with $y=2/3$ and $y=1$ apply early to A, and students with $y=0$ apply early to B, and the schools use thresholds $A_{ED}=1-(4/3)K$ and $A_{RD}=1-(4/3)K+(2/9)\alpha$, and $B_{ED}=1-2K-(2/3)\alpha$, $B_{RD}=1-2K+(2/9)\alpha$. School A's early threshold just satisfies its yield constraint, and its regular constraint is pinned down by the robustness requirement that $A_{RD}-A_{RD}=(2/9)\alpha$. For school B, $B_{RD}-B_{ED}=(8/9)\alpha$, so B is just indifferent between marginal early and late enrollees, and its yield constraint is just satisfied. For students, applying early to A rather than B increases payoff has a benefit of $(4/3)\,K[u(A,y)-u(B,y)]$ and a cost of $(8/9)\alpha u(B,y)$, and so our assumptions about student preferences imply that student behavior is also optimal. The equilibrium payoffs can be derived as follows. School A gets an average quality of $1-(2/3)K$ and student taste of 8/9, so its payoff is $1-(2/3)K+(8/9)\alpha$. School B admits a fraction $1/2+(1/6)(\alpha/K)$ of its class early with average quality $1-K-(1/3)\alpha$ and $y=0$; the remainder of its class arrives regular with average quality $1-(5/3)K+(1/9)\alpha$ and taste 8/9. So its payoff is $1-(4/3)K-(4/9)\alpha+(2/27)\,(\alpha^2/K)$.

Preferences of Schools. For school A, Early Decision produces an entering class with lowest average ability but the best preference match. School A prefers Early Decision to Regular Admissions if and only if $\alpha\geq(3/4)K$, and Early Decision to Early Action if and only if $\alpha\geq(3/4)K+(1/4)(\alpha^2/K)$. These inequalities can go either way.

With the given probability distribution for y, B prefers Early Decision to Early Action for any α. However, if we change the probability distribution for y slightly to $P(y=1)=1/2$, $P(y=2/3)=1/2-p; P(y=0)=p$, then for small values of p,(in combination with additional assumptions about $u(A,y),u(B,y)$ to ensure that the student strategies described above remain optimal), the Early Decision equilibrium produces approximately the same assignment of students and same utilities for colleges as in the Regular Admissions equilibrium, whereas Early Action produces a distinct gain in utilities for the colleges. Under these conditions in the example, B will prefer Early Action to Early Decision. *Q.E.D.*

Table 1: Descriptive Statistics on Survey Colleges

	Apps. (Survey)	Early Apps. (Survey)	Admit Rate (Survey)	Admit Rate (Overall*)	Early Admit Rate (Overall*)
Early Action Schools					
Boston College	190	51	71%	35%	N/A
Brown	509	219	38%	17%	24%
Cal. Tech	65	30	34%	18%	23%
Georgetown	247	100	53%	23%	23%
Harvard	573	314	28%	11%	26%
M.I.T.	214	97	39%	19%	23%
U. Chicago	160	49	79%	48%	57%
Notre Dame	82	30	63%	35%	52%
Early Decision Schools					
Amherst	174	24	47%	19%	35%
Columbia	320	44	40%	14%	37%
Cornell	326	32	57%	33%	N/A
Dartmouth	256	42	41%	21%	33%
Duke	350	40	42%	28%	41%
Middlebury	133	16	56%	26%	33%
N.Y.U.	230	17	76%	32%	33%
Northwestern	275	21	68%	32%	57%
Penn	400	62	48%	26%	46%
Princeton	359	70	28%	11%	31%
Stanford	464	74	34%	15%	24%
Swarthmore	107	11	49%	N/A	N/A
Tufts	307	25	49%	32%	43%
U. Virginia	239	23	70%	34%	42%
Vassar	123	11	65%	43%	57%
Washington U.	306	15	79%	34%	35%
Wellesley	59	12	75%	34%	67%
Wesleyan	163	13	54%	N/A	N/A
Williams	168	24	41%	23%	39%
Yale	444	102	33%	16%	36%

* Overall rates of admission are given for 1998-1999, as reported by *US News*. We believe that early applicants who were deferred and subsequently admitted are not counted as early admits.

Table 2: Applicant Characteristics and Admit Rates (Survey Data)

	Application Type	Average SAT-1	High School Quality	Student Activity Rating	Overall Admit Rate	Survey Admit Rate	Conditional Admit Rate*
Early Action Schools							
Boston College	Early	1334	2.67	2.56	N/A	77%	77%
	Regular	1327	2.38	2.44	35%	68%	77%
Brown	Early	1432	2.89	2.58	24%	52%	45%
	Regular	1410	2.70	2.46	17%	27%	25%
Georgetown	Early	1399	2.85	2.61	23%	61%	68%
	Regular	1388	2.73	2.62	23%	47%	44%
Harvard	Early	1483	3.05	2.76	26%	40%	29%
	Regular	1440	2.66	2.51	11%	14%	11%
M.I.T.	Early	1471	2.73	2.64	23%	47%	31%
	Regular	1450	2.89	2.58	19%	31%	25%
U. Chicago	Early	1423	2.82	2.61	57%	84%	98%
	Regular	1450	2.77	2.49	48%	78%	92%
Early Decision Schools							
Columbia	Early	1407	2.73	2.48	37%	73%	85%
	Regular	1420	2.63	2.55	14%	34%	25%
Cornell	Early	1344	2.66	2.41	N/A	66%	81%
	Regular	1407	2.56	2.49	33%	56%	56%
Dartmouth	Early	1391	3.02	2.63	33%	50%	59%
	Regular	1419	2.64	2.57	21%	39%	28%
Duke	Early	1381	2.90	2.44	41%	55%	81%
	Regular	1419	2.70	2.59	28%	46%	44%
Penn	Early	1391	2.87	2.41	46%	74%	84%
	Regular	1410	2.70	2.48	26%	43%	39%
Princeton	Early	1447	2.69	2.75	31%	57%	68%
	Regular	1462	2.75	2.67	11%	20%	10%
Stanford	Early	1466	2.43	2.62	24%	50%	45%
	Regular	1448	2.82	2.60	15%	31%	23%
Yale	Early	1474	3.41	2.59	36%	57%	44%
	Regular	1453	2.80	2.67	16%	25%	18%

* The conditional admit rates are obtained by running probit admission regressions on the sample of applicants to each college. The conditional admit rates are the predicted probability of admission for an applicant with mean characteristics in the survey data, applying early and regular to the school. The same probit specification was used for each college, and includes as controls: SAT scores, rating of high school quality, rating of reported activities, and dummy variables for race (Asian, Asian American, Black, Hispanic, Other), family connections (alumni child, sibling attended given college), and indicators for athletic recruit, male, private school student, financial aid applicant, applying from high school in the same state as the college, and having at least one parent attend graduate school.

Table 3: College Yield Rates (Survey Data)

	Regular Admits	Early Admits	Regular Yield	Early Yield
Boston College	95	39	20%	28%
Brown	79	113	38%	55%
Cal. Tech	8	14	25%	64%
Georgetown	69	61	32%	46%
Harvard	35	127	43%	85%
M.I.T.	36	46	31%	63%
U. Chicago	86	41	17%	29%
Notre Dame	31	21	45%	52%
20 ED Colleges	2039	425	29%	97%

Table 4: Probit Estimates of Admissions Probability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
EA Applicant	0.20	0.21	0.19	0.19	0.18	0.18	0.21
	(7.35)	(7.36)	(6.54)	(6.48)	(5.57)	(5.57)	(5.11)
ED Applicant	0.29	0.31	0.31	0.32	0.32	0.34	0.33
	(12.09)	(12.30)	(12.13)	(12.45)	(11.24)	(11.21)	(9.90)
SAT Verbal	0.15	0.17	0.17	0.17	0.19	0.19	0.19
	(7.46)	(8.32)	(8.14)	(8.25)	(7.40)	(7.24)	(6.43)
SAT Math	0.13	0.18	0.17	0.17	0.18	0.20	0.21
	(5.66)	(7.99)	(7.54)	(7.24)	(6.64)	(7.81)	(6.56)
SAT-2 Writing	0.08	0.10	0.10	0.12	0.12	0.15	0.10
	(4.59)	(5.41)	(5.33)	(6.38)	(5.60)	(6.46)	(3.60)
SAT-2, High Score	0.07	0.09	0.09	0.09	0.07	0.09	0.03
	(2.64)	(3.22)	(3.16)	(3.18)	(2.04)	(2.70)	(0.76)
SAT-2, 2^{nd} Score	0.07	0.08	0.07	0.10	0.10	0.10	0.09
	(2.96)	(3.35)	(3.12)	(4.09)	(3.82)	(3.82)	(2.85)
Home State	0.16	0.16	0.15	0.17	0.17	0.18	0.20
	(7.39)	(6.78)	(6.57)	(7.11)	(6.21)	(6.20)	(5.60)
Male	-0.03	-0.03	-0.02	-0.02	-0.02	-0.01	-0.01
	(1.54)	(1.39)	(1.23)	(0.96)	(0.88)	(0.41)	(0.31)
Financial Aid Applicant	0.05	0.03	0.02	0.01	0.01	0.01	0.02
	(2.93)	(1.46)	(1.09)	(0.37)	(0.41)	(0.51)	(0.66)
Private School	0.087	0.075	0.07	0.075	0.086		0.062
	(4.71)	(4.06)	(3.68)	(3.65)	(3.47)		(2.07)
Student Activity Rating			0.06	0.05	0.05	0.05	0.05
			(4.17)	(3.81)	(3.31)	(3.67)	(2.81)
High School Quality Rating			0.01	0.01	0.01		0.03
			(1.65)	(0.84)	(1.01)		(2.51)
College Dummy Variables	X	X	X	X	X	X	X
Institutional Priority Variables		X	X	X	X	X	X
State Dummies				X	X	X	X
HS Dummies						X	
HS Comparison Variables					X		X
Early Apps included as Regular	X	X	X	X	X	X	
Pseudo-R2	0.22	0.29	0.29	0.31	0.31	0.37	0.32
Observations	6,495	6,495	6,218	6,218	5,097	5,053	3,022

Notes: (1) Coefficients are reported as marginal effects on the probability of acceptance at sample means; (2) T-statistics are in parentheses; standard errors were adjusted to account for correlation across multiple applications by each student; (3) SAT scores are in hundreds of points; (4) Institutional priority variables include five dummy variables for race, two dummy variables for alumni child status, and a dummy variable for athletic recruits; (5) High school comparison variables control for the average SAT score and the number of AP courses taken by other participants in the study from the same high school: these variables are only computed for high schools that had at least eight students complete the surveys.

Figure 1: Regular Admissions Equilibrium

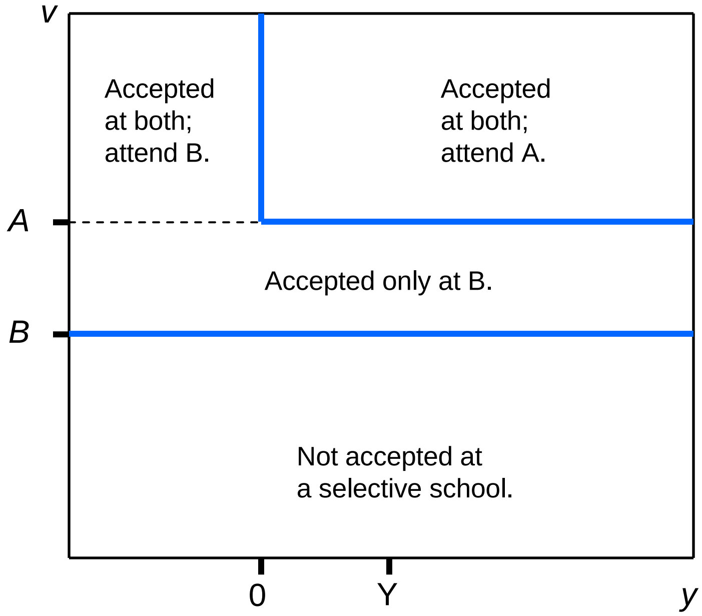

Figure 2: Early Action Equilibrium

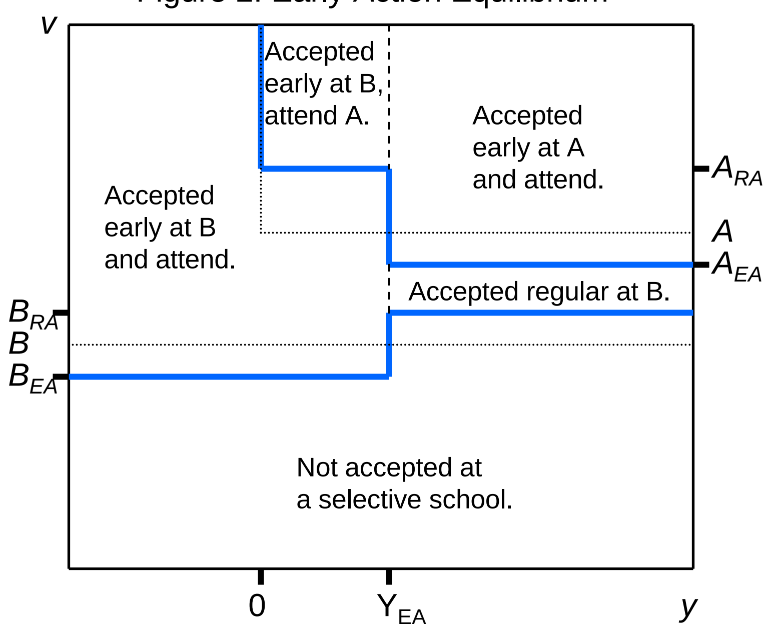

Figure 3: "Bad" Early Action Equilibrium

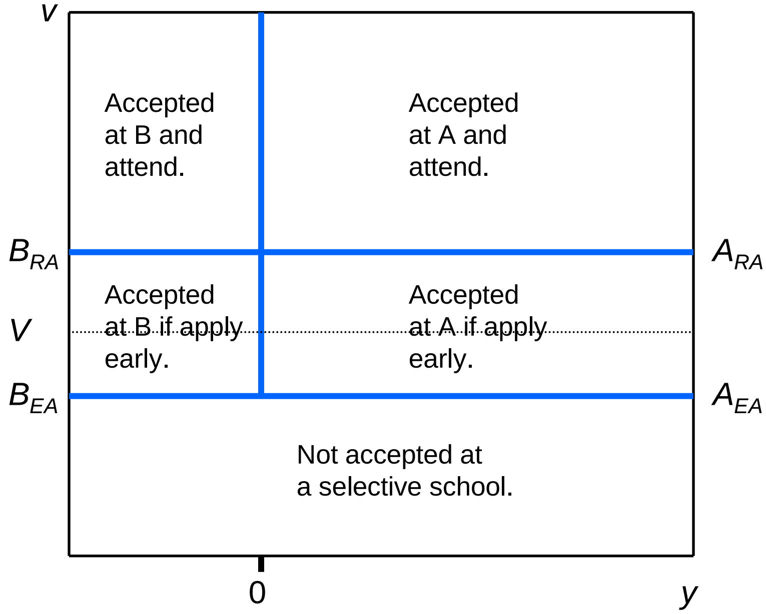

Figure 4: Early Decision Equilibrium