Preference Submission Timing in School Choice Matching: Testing Efficiency and Fairness in the Laboratory

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Abstract:

We investigate the relative merits of the Boston and Serial Dictatorship mechanisms when the timing of students' preference submission over schools varies within the structure of the mechanism. Despite the well-documented disadvantages of the Boston mechanism (Abdulkadiroglu and Sonmez, 2003), we propose that a Boston mechanism where students are required to submit their preferences *before* the realization of their exam scores, can in fact have fairness and efficiency advantages compared to the often favored Serial Dictatorship mechanism. We test these hypotheses in a series of laboratory experiments which vary by the class of mechanism implemented, and the preference submission timing by students, reflecting actual policy changes which have occurred in China. Our experimental findings confirm the efficiency hypothesis straightforwardly, and lend indirect support to the fairness hypothesis. The results have important policy implications for school choice mechanism design when students' relative rankings are initially uncertain.

Key words: School choice matching, uncertainty, experiments, college admission

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1. Introduction

In school choice matching procedures, schools often have imprecise or uncertain information about potential students they may admit, the realization of which may affect their stated preferences over students. Students on their part, may be faced with a corresponding dilemma: schools' perceptions of their qualifications during the admissions process may be either largely determined by previous academic performance, or some soon-to-be-realized measure of their academic ability such as a centralized exam. In such a situation, students and schools may have good reason to be interested in the timing of students' application (ie. preference) submissions in the matching procedure.

This paper explores and experimentally tests this timing issue in the context of a school choice problem. We investigate the fairness and efficiency results of the Boston mechanism (BOS) and Serial Dictatorship mechanism (SD), under two timing variants for preference submission (which can be thought of as an "application" in a centralized admission process). In the "after" setting, students submit their preference ordering after their exam score is realized. In the "before" setting, students submit their preference ordering before their exam score is realized, but when distributions of possible scores (ex-ante rankings) among the pool of students are known.

Our primary insight is that when students are required to submit their preference ordering before exam scores are realized, the often-criticized, non-strategy proof Boston mechanism can in fact outperform SD by two measures: efficiency and ex-ante fairness. We find that while that our efficiency hypothesis is experimentally robust, our ex-ante fairness hypothesis depends crucially on the strategy choice of the ex-ante middle-ranked student. Only when this student plays equilibrium rather than a truth-telling strategy is the fairness advantage of the Boston mechanism under pre-score submission borne out empirically. Potential non-equilibrium behavior of agents in a matching mechanism is indeed important for any real-world implementation, and truth-telling by a "close-to-top" ranked student is a realistic scenario.

Our paper adds to a recently growing school choice matching literature which has increasingly focused on the role of information uncertainties. These uncertainties may arise from several possible sources: for example students' incomplete information about other students' preferences, or incomplete information about schools' priorities and quotas. These cases have been studied theoretically by Ehlers and Masso (2007), and in experiments by Pais and Pinter (2008), and Featherstone and Niederle (2008). Uncertainties may also arise from the matching mechanism design itself, for example via tie-breaking rules (see Edril and Ergin (2008), Abdulkadiroglu, Pathak and Roth (2009), and Abdulkadiroglu, Che and Yasuda (2011)).[2]

When uncertainties are introduced into a school choice mechanism, some typical conclusions about desirable properties of various mechanisms become questionable. The Gale-Shapley (GS) mechanism and Top Trading Cycles (TTC) mechanism (of which Serial Dictatorship (SD) is a special case) have been considered superior to the Boston (BOS) mechanism with respect to strategy-proofness, efficiency and/or fairness. However, when uncertainty is introduced (via tie-breaking or asymmetric information) those advantageous results may no longer hold.

[2] Sonmez and Unver(2009), and Budish and Cantillon(forthcoming)) examine matching mechanisms with lotteries in a non-school choice setting, which are another source of uncertainty.

Abdulkadiroglu, Che and Yasuda (2011) found that when students have identical ordinal preferences, schools have no priorities among students, and assuming that random tie-breaking rules are introduced, the Boston mechanism Pareto dominates the GS mechanism in terms of ex-ante welfare. Featherstone and Niederle (2008) also found that in an asymmetric information treatment, where all the schools have equal quotas and all the students' preferences are randomly drawn from a uniform distribution of all possible preference orderings, truth-telling can be an equilibrium under BOS, and BOS can first-order stochastically dominate Deferred Acceptance (DA, a special case of GS) in terms of efficiency, both in theory and in the laboratory. Thus, when some forms of uncertainties are involved in the school choice mechanisms, from an ex-ante welfare criteria, the BOS mechanism is no longer necessarily dominated by other commonly considered mechanisms.[3]

Our study is also related to Chiu and Weng (2009). They describe a model in which schools may pre-commit admissions slots to students (ie. early admissions), and endogenously derive strategic motives for schools in adding such a feature to their admission process. Our paper is similar to theirs in the sense that we also explore a particular component of matching mechanisms seen in the real world, but has not yet been previously analyzed in detail. Furthermore, as in their work, our primary variable of interest involves the timing of events occurring within the mechanism.

Our experiments are inspired by China's college admission system, which is the largest centralized school matching problem in the world. In the Chinese context, students in some provinces have been required to submit their preferences before their college entrance exam scores are fully realized. Since 1978, China's college admissions system has undergone frequent reforms along two main lines. One reform addresses preference submission timing. Before 1989, almost all provinces in China were using a submission-before-exam procedure. Provinces then gradually (and irreversibly) switched to submission-after-exam procedures. Yet to this day there are still two major provinces, Beijing and Shanghai, which adhere to the original procedure.

The advantage of the submission-after-exam system under any of the mechanisms is clear: when students submit their preferences, they can base their submission on their realized scores (typically students even know their absolute ranking among all students in their province) and can thus have a better prediction about what kinds of colleges they can be admitted to.

However, there are also some "hidden" advantages of the submission-before-exam system which we would like to explore in this paper. First, ex-ante submission protects students with higher *expected* scores (arguably, those students with higher academic abilities or long term effort). When students submit their preferences before the exam, those students with higher expected scores are more willing to apply to better schools, while those with lower expected scores are less willing. Students with stronger overall academic performance before the exam are thus able to separate themselves from those of lesser average overall performance in advance.

Second, the submission-before-exam procedure takes into account not only students' ordinal preferences but also their cardinal preferences. When facing uncertain scores, students have to factor in their preference intensities, not just preference orderings, in order to achieve higher expected utility from the submission decisions. It turns out that students having higher preference intensities

[3] It can be shown that in the context of China's college admissions system, the GS (or Deferred Acceptance (DA)) mechanism is equivalent to the TTC (or SD) mechanism. Therefore, the conclusions here can be extended to the TTC or SD mechanisms. For details, see Wu and Zhong (2012).

for good schools are more willing to apply for them than those having lower preference intensities, which is beneficial for an ex-ante efficient matching outcome.

In summary, although preference submission before the exam seems like a disadvantageous idea since it increases the uncertainty faced by students, it turns out to have advantages as well – the practice of submitting one's preferences beforehand may serve as a pre-screening device which can potentially improve ex-ante efficiency and fairness. By fairness, we mean that students of demonstrated ability and/or effort (in the ex-ante case, this means before the exam), are matched to schools of corresponding rank. The issue of ex-ante fairness is particularly policy relevant in the case of China, since the college entrance exam is the sole determinant of admissions for the great majority of students, and exam scores are well-acknowledged as an often noisy proxy of ability or future qualifications (see Wu (2008), Qian and Wu (2002), Gu and Yang (2009)).

We also address a further aspect of the school choice matching problem, commonly discussed in school choice mechanism policy in the United States. There, the primary reforms have focused on changing existing BOS mechanisms to the TTC/SD mechanism, heeding implications from Abdulkadiroglu and Sonmez (2003). A BOS class mechanism prioritizes students' preference orderings over their score rankings, while a TTC/SD mechanism prioritizes students' score rankings over their preference orderings.[4] The school choice literature has found the SD mechanism to be strategy-proof, efficient and fair, thus making it superior to the BOS mechanism which at the very least, is not strategy-proof.[5] China has also been rapidly implementing policy changes from a BOS-style mechanism to an SD-style mechanism over the last several years. We wish to highlight the interaction of preference submission timing and BOS versus SD matching procedures in generating fair and efficient matching outcomes.

We also explore how personal characteristics, including risk attitudes affect students' behavior. In particular, we use the risk attitude test developed by Tanaka, Camerer, and Nguyen (2010) to measure participants' risk and loss aversion and connect them to subjects' behaviors in the matching procedure. We find that in general, risk aversion and loss aversion do not significantly influence subjects' behavior. One possible reason is that our treatment is very simple - thus maximizing expected payoffs without particular regard to risk attitude may play a dominant role in individual behaviors.

The remainder of the paper is organized as follows: In section 2, we describe our hypotheses and experimental treatments, while also previewing our results. In section 3, we report the overall results on fairness, efficiency from the experiments. In section 4, we explore behavioral differences among different subjects, focusing on when truth-telling behaviors are more likely. Section 5 concludes.

2. Experimental Design, Hypotheses and Implementation

We specifically consider four frequently implemented mechanisms in China's college admission system and compare them by looking at both ex-ante and ex-post welfare consequences. Those four mechanisms are: preference submission before the exam under the Boston mechanism ("BOS-before"

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[4] In China, these two classes of mechanisms are called "submission without parallel preferences" and "submission with parallel preferences" matching procedures respectively.

[5] The literature so far has proven that the Boston mechanism, in China's context, can achieve the unique efficient and fair matching in its Nash equilibrium. See Wu and Zhong (2012), and for a more general discussion, see Ergin (2002), Kesten (2006) and Haeringer and Klijn (2009).

hereafter), preference submission before the exam under the Serial Dictatorship mechanism ("SD-before"), preference submission after the exam under the Boston mechanism ("BOS-after"), and preference submission after the exam under the Serial Dictatorship mechanism ("SD-after").

We consider two possible measurements of fairness in the paper which correspond to the notion of stability in the general 2-sided matching literature, following Balinski and Sonmez (1999) and subsequent works: 1. The average number of blocking pairs occurring, where a blocking pair is defined by a (school, student) pair that have a mutual desire to alter their current assignment such that they are now assigned to one another. The lower the average number of blocking pairs, the more fair the matching outcome is. 2. The likelihood of a matching outcome which is completely fair, or in other words, where no blocking pairs exist. The higher this likelihood, the more fair the matching outcome is.

We use the sum of payoffs across players in a given match as our primary measure of efficiency. Where possible we also consider Pareto dominance as measured by payoffs of every student type being higher in some mechanisms than others (only possible in certain of our experimental designs).

We implement two different designs for each of the four mechanisms listed above, to address two hypotheses. The first hypothesis is that the BOS-before mechanism can be more ex-ante fair than the others in the sense that students with higher *expected* scores are more likely to be admitted by good schools under this mechanism than under other mechanisms. The second hypothesis is that the BOS-before mechanism can be more ex-ante efficient than others in the sense that students with higher preference intensities for good schools are more likely to be admitted by good schools.

Our experimental results strongly support the second hypothesis, while not rejecting the first hypothesis. The result for the first hypothesis is not significant, partly because it is sensitive to strategies played by students with medium level abilities (or expected scores). Under the BOS-before mechanism, students with medium level abilities may retreat by the threat of the BOS mechanism, i.e., if they fail to get into the best school, they may fail to get into the second best school. In this case, the result under BOS-before is significantly fairer ex-ante than other mechanisms. Instead, if those students want to take the risk of competing for the best school, the outcome is overturned. Note that from an ex-post consideration, our findings are largely consistent with the existing literature (Abdulkadiroglu and Sonmez (2003)). The SD-family of mechanisms is more strategy-proof, ex-post efficient and/or fair than the BOS-family of mechanisms.

2.1 Experimental Designs

Each of the four mechanisms of interest (BOS-before, SD-before, SD-after, and BOS-after) is implemented in two different design: One design (which we call "ability-wise") aims at testing ex-ante fairness while the other design (which we call "preference-wise") aims at ex-ante efficiency.

In each of these two designs, three students (labeled 1, 2 and 3) are to be matched with three schools (labeled A, B and C). Each school has just a single slot to be allocated. Exam scores are determined by a single draw from a uniform distribution, and are the only determinants of schools' priority rankings over students – that is, schools always give higher priority to students with higher scores. In the ability-wise design, students have different expected scores which we interpret as their underlying ability. Students have the same ordinal and cardinal preferences over the three schools. In the preference-wise design, students have the *same* expected scores and the same ordinal preferences, however their cardinal preferences differ. Subjects are asked to submit their strict preference ordering over schools, where each school is appears in the ordering once.

Our experiment is "small-scale" in the sense that every matching treatment consists of just three students and three schools. The advantage of testing the mechanisms on a small scale is that we can have clear theoretical predictions across matching outcomes to compare. The other advantage is that for a given number of subjects in our entire study, we can have a relatively large sample of matching outcomes so our comparison of welfare consequences can be statistically valid. This is particularly valuable for cases of testing ex-ante fairness and efficiency, which requires a large enough sample for different realizations of exam score rankings across students.

Before we begin to analyze equilibrium behaviors under any specific mechanism, we note that for each player in any of the mechanisms, there are only two non-dominated pure strategies: (A, B, C) which in our design always corresponds to truth-telling, and (B, A, C).

2.1.1 Ability-wise Design

Under the ability-wise design designed to test ex-ante fairness, subjects have different expected scores depending on the role (student 1, 2, or 3) they are playing. Students' score distributions by role are shown in Table 1:

Table 1: Score Distributions under Ability-wise design

Role	Score 1 (high)	Score 2 (normal)	Score 3 (low)	Avg. score
Probability	1/3	1/3	1/3	
Student 1	95	90	85	90
Student 2	91	86	81	86
Student 3	87	82	77	82

Thus each student will have an equal and independent probability of getting high, normal and low scores, where we suppose that 100 represents full possible marks. The numerical value of the three types of scores differs for each of the three students so that score rankings easily follow from the random draws. In other words, student 1 has the highest average score, followed by students 2 and 3 respectively. However, in the score distributions specified in Table 1, there is a high level of uncertainty over the final score ranking in the sense that when student 1 gets a normal score and student 2 gets a high score, student 2 will have a higher realized score than student 1. If student 1 gets a low score and student 3 gets a high score, student 3's ranking even surpasses that of student 1. Analogous outcomes are possible between students 2 and 3.

In the ability-wise design all student roles have the same payoff result conditional on the school they are assigned to. That is, not only are ordinal preferences homogeneous across students, but cardinal preferences are as well. These payoffs, expressed in Experimental Currency Units (ECU) are shown in Table 2:

Table 2: Payoffs for School Assignments, Ability-wise Design

Slot received at school	A	B	C
Student (1,2, or 3)'s payoff	30	25	15

Both the score distributions (Table 1) and payoffs (Table 2) are common knowledge to all the subjects. Note that under this payoff scheme, all matching outcomes are equally ex-ante and ex-post efficient, since the sum of expected or realized payoffs under any mechanism is constant at 70.

We now derive the equilibrium under each of our four mechanisms of interest (BOS-before, BOS-after, SD-before, SD-after) under the ability-wise design. Mechanisms often have multiple equilibria, but we focus here on the equilibrium where truth-telling is a weakly dominant strategy for every student. From here on, we will refer to this as the "truth-telling equilibrium".

BOS-before Mechanism

Under the BOS-before mechanism, students are required to submit their preference ordering over schools before knowing their realized exam score. After scores are randomly drawn and score rankings are realized, students are matched under the Boston mechanism. Note that in our design (as shown in Table 1), each student has a different realized score so that score rankings are uniquely determined.

The procedure in our experimental design is as follows: Students submit their preference ordering over schools, knowing the distribution of possible score outcomes in Table 1. Scores are then drawn, determining the score ranking. Then according to the Boston mechanism: First, each student's first choice school is applied to by that student. If more than one student applies to the same school, the student with the highest score will be admitted to that school. Next, for students not admitted to any school in the first round, an application is made to their second choice school, and each remaining vacant school admits their applicant with the highest score, and so on. In our design, this admission procedure lasts at most three rounds, and every student is admitted to a school in the final matching outcome.[6]

In this three-player simultaneous-move game, assuming players maximize expected payoffs, our Nash equilibrium outcome of interest is characterized by any strategy profile satisfying the following: student 1 lists school A as her first choice, and both students 2 and 3 list school B as their first choice. Every student can order the remaining two schools (B and C in the case of student 1, and A and C in the cases of students 2 and 3) in any order as their 2nd and 3rd choices. We can express this as ((A,*,*), (B,*,*), (B,*,*)) where with slight abuse of notation, * denotes any school not yet listed by that particular student.

The matching result is that student 1 gets admitted to school A regardless of the realized score ranking, and that the student with the higher realized score between students 2 and 3 gets admitted to

[6] In the general case, all students ranking school "S" as their first choice apply to school S, and are admitted according to the school's rankings over the applicants and the slots available at school S. Students without admission after the first round, apply in the second round to their second choice school, and are admitted according to the slots available at each school and schools' rankings over the students applying in that round. This procedure proceeds into the nth round (with students applying to their nth choice school) for any students who have not received admission in the 1st through (n-1)st rounds. The mechanism ends when either every student has been successfully admitted to one of the schools, or when all schools in the preference list of any remaining student have filled all of their slots. See Ergin and Sonmez (2006) for general equilibrium and welfare analysis of the Boston mechanism.

school B. The remaining student gets admitted to school C. See Appendix 1 for details.

BOS-after Mechanism

The BOS-after mechanism differs from the BOS-before mechanism in just one feature: it asks students to submit their preference orderings after scores are realized for all students, and score rankings are common knowledge. Under this submission-after-exam procedure, what really matters is the realized score, or its ranking, rather than the pre-assigned roles of student 1, 2 or 3.

It is straightforward to verify the following Nash equilibrium: The student with the *highest realized score* will submit her preference list as (A, *, *), student with the *second highest score* will submit a preference list as (B, *, *), and student with the *lowest score* can submit any list, where again, * represents any school not yet listed by that particular student.

The matching outcome is that the student with the highest score gets admitted to school A, the student with the second highest score gets admitted to school B, and the student with the lowest score gets admitted to school C. Note that this outcome has the desirable property that students with higher realized scores get admitted to schools with higher payoffs (which we later call *complete fairness*).

SD-before/after Mechanism

The Serial Dictatorship mechanism in our experiment works as follows: first, the student with the highest realized score gets admitted to her first choice school. Then, the student with the second highest realized score is admitted to one of the remaining unoccupied school slots according to her preference ordering. Finally, the student with the lowest score is admitted to the remaining unoccupied school.[7]

Similarly to the cases of BOS-before and BOS-after, the SD-before and SD-after mechanisms differ only in the timing of preference submission. Again, the SD-before mechanism has students submitting their preferences before their exam scores are realized, while the SD-after mechanism has preference submission after the exam scores are drawn and become common knowledge. In both cases the SD matching algorithm then proceeds as described above based on the realized score rankings.

The SD mechanism is strategy proof – no student benefits from misrepresenting his or her preference in equilibrium. Our truth-telling equilibrium of interest has each student submitting their preference orderings as (A, B, C). In both SD-before and SD-after, the matching outcome is the same as in the BOS-after mechanism: that is, the student with the highest *realized* score gets admitted to school A, the student with the next highest realized score gets admitted to school B, and the student with the lowest score gets admitted to school C.

Fairness Measures

We follow previous literature (ex. Balinski and Sonmez (1999)) in using the concept of stability to measure the fairness of matching outcomes. We define a (i,S) as a *blocking pair* when student i prefers school S to her current matched school, while at the same time, school S prefers student i to

[7] In the general case of simple serial dictatorship, students are strictly ordered (based on some dimension, such as exam score). According to this ordering of students, each student one-by-one, applies to schools in sequence determined by her preference ordering and is admitted to the first school that has a slot available. The mechanism ends when either every student has been successfully admitted to one of the schools, or when all schools in the preference list of remaining un-admitted students have filled all their slots.

its currently admitted student. If a matching outcome has at least one such blocking pair, then the matching is not stable in the sense that student i and school S have incentive to terminate their current matching, and self-match with one another.

The link between fairness and stability arises from the basic logic that each side of the market (students and schools) should have success in being matched to their preferred choices in accordance with the qualifications that make them desirable to the other side of the market. In our school choice context this implies that those students who are more preferred by schools (by means of a high test score), should receive admissions at a high-payoff school (where we use high payoff to proxy for school quality and reputation). Furthermore, higher-payoff yielding schools should successfully enroll high scoring students.[8]

Keeping this reasoning in mind, we are interested in using the number of blocking pairs in the match as one measure of fairness. We call a match *completely fair* if there are *no* blocking pairs in the match. The degree of fairness can either be measured by the likelihood of a completely fair matching outcome, or by the average number of blocking pairs across student score ranking scenarios. A smaller number of blocking pairs or a higher likelihood of a completely fair matching in equilibrium implies a more fair match. We define ex-ante fairness as using the expected score ranking as the measure of schools' preferences over students, whereas ex-post fairness uses the realized score ranking.

Our analysis up until now has shown that of the four mechanisms considered, the BOS-before mechanism's resulting allocation differs from the other three mechanisms. It is intuitive that BOS-before should be more ex-ante fair than the other three mechanisms (although not completely ex-ante fair, due to the uncertain placements of students 2 and 3). In fact, BOS-before weakly dominates in terms of the number of blocking pairs present under each score ranking scenario; in other words, if student i and school S form a blocking pair in BOS-before under some realized score ranking, then there exists a school S' such that (i,S') form a blocking pair in the other three mechanisms. More generally, this will remain true in our experimental design, holding all else equal, if the payoff for being assigned to school B is at least 22.5.[9] However, the BOS-before mechanism is less ex-post fair than the other three. In fact, the other three mechanisms attain complete ex-post fairness under every possible realized score ranking.

One of the main points we wish to highlight in this paper is that although BOS-before is in general less ex-post fair than the other mechanisms we consider, it can have the favorable property of being more ex-ante fair under certain payoff structures, thus distinguishing it from the other three mechanisms. Table 3 shows the ex-ante and ex-post fairness properties for BOS-before as well as the other three mechanisms, under each possible realized score ranking outcome.

The third sub-column in each column (labeled BOS-before (s2 deviates)) considers the possibility that student 2 plays a truth-telling strategy rather than her equilibrium strategy.[10,11,12] We

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[8] In the Chinese university admissions process, it is generally the case that preferences among schools over students are largely homogenous (schools would prefer to have students who score higher on the CEE exam), and further, that student preferences over universities are also largely homogeneous (students prefer to attend a university with a good reputation).

[9] This can be demonstrated by normalizing the payoffs for school A and C such that 1 and 0 are the associated payoffs respectively. The only remaining payoff to determine is that for school B. In our design, it can be shown that the equilibrium strategy profile is ((A,*,*), (B,*,*),(B,*,*)) if and only if the payoff for school B is no less than 1/2.

[10] Note that it is only necessary to consider this deviation in the BOS-before case, since the other mechanisms already have truth-telling as their equilibrium strategy of interest.

are particularly interested in the consequences of potential deviations by student 2 due to the high frequency of occurrence in our experimental data. In particular, student 2's in the BOS-before mechanism play truth-telling 45% of the time. (See Table 5A in the Appendix for details) Specifically, consider when student 2 deviates from equilibrium strategy (B, A, C) to truth-telling strategy (A, B, C). Such a deviation can result from a miscalculation of the whole ranking distribution and/or her expected payoffs. In this case, BOS-before mechanism has a probability of zero to be fully ex-ante fair, less than that of other mechanisms. Its average number of blocking pairs is 4/3, larger than that of other mechanisms. The BOS-before mechanism becomes even less ex-ante fair than others. Thus our hypothesis may be sensitive to student 2's behavior.[13]

Table 3: Ex-ante and Ex-post Fairness Under Ability-wise Design

Realized Score rankings	Prob.	Matching result = (A,B,C)			Completely Ex-ante fair? (number of blocking pairs in parentheses)			Completely Ex-post fair? (number of blocking pairs in parentheses)		
		BOS -before	Others	BOS-before (s2 deviates)	BOS -before	Others	BOS-before (s2 deviates)	BOS -before	Others	BOS-before (s2 deviates)
(1, 2, 3)	10/27	1, 2, 3	1, 2, 3	1,3, 2	Yes	Yes	No(1)	Yes	Yes	No(1)
(1, 3, 2)	7/27	1, 3, 2	1, 3, 2	1, 3, 2	No(1)	No(1)	No(1)	Yes	Yes	Yes
(2, 1, 3)	7/27	1, 2, 3	2, 1, 3	2, 3, 1	Yes	No(1)	No(2)	No(1)	Yes	No(1)
(2, 3, 1)	1/27	1, 2, 3	2, 3, 1	2, 3, 1	Yes	No(2)	No(2)	No(2)	Yes	Yes
(3, 1, 2)	1/27	1, 3, 2	3, 1, 2	1, 3, 2	No(1)	No(2)	No(1)	No(1)	Yes	No(1)
(3, 2, 1)	1/27	1, 3, 2	3, 2, 1	2, 3, 1	No(1)	No(3)	No(2)	No(2)	Yes	No(1)
Prob. of Complete fairness					2/3	10/27	0	17/27	1	8/27
Avg. # of blocking pairs					1/3	7/9	4/3	4/9	0	19/27

[11] Note the penalty of playing truth-telling for player 2 compared to playing equilibrium is only 1.67, a relatively small fraction of total possible payoffs. The correct expected payoff for student 2 to choose the equilibrium strategy (B, A, C) is 65/3=21.67, and the correct expected payoff of deviation to choose (A, B, C) is 20.
[12] Note that in BOS-before, student 1's equilibrium strategy does not preclude truth-telling.
[13] Wu and Zhong (2012), find that students admitted into a top college under the BOS-before mechanism have no higher college performance than admitted under other mechanisms. If we interpret college performance as a good proxy for students' internal ability, their findings through field data are consistent with our experimental results.

Hypothesis 1: Under the above-mentioned ability-wise design, the BOS-before mechanism will implement (in its Nash equilibrium) more ex-ante fair matching than the other three mechanisms (BOS-after, SD-before and SD-after), although it will implement a less ex-post fair matching.

2.1.2 Preference-wise Design

We now turn to our experimental settings designed to test Hypothesis 2 regarding efficiency. Under the preference-wise design, all student roles have the same expected scores as well as the same score distribution. They have the same ordinal preferences over schools, but their cardinal preferences differ. We specifically consider the case where student 3's valuation of school A is less than that of Students 1 and 2, but our hypothesis also holds for the case where student 3 (or any single student)'s valuation of school A is higher than that of the other students. Their payoffs from being admitted to each school are shown in Table 4 below:

Table 4: Score distributions, Preference-wise Design

Slot received at school	A	B	C
Payoff of student 1	31	22	18
Payoff of student 2	31	22	18
Payoff of student 3	25	22	18

We again consider equilibrium under each of the four mechanisms: BOS-before, BOS-after, SD-before, SD-after.

BOS-before Mechanism

It is easily found that under the BOS-before mechanism, in equilibrium, students 1 and 2, who value school A more than student 3, submit their preference ordering as (A, B, C), while student 3 submits (B, *,*). Again, we use "*" to represent any school not yet listed by that student. Student 1 and 2 then have an equal probability of getting into schools A and C, while student 3 gets into school B. (See Appendix 2 for details.)

Other Mechanisms

Similar to the ability-wise design, the other three mechanisms can be considered separately from the BOS-before mechanism.

Under BOS-after mechanism, scores have already been realized when preference orderings are submitted. So the student with the highest score submits (A, *,*) and gets into school A. The student with the second highest score submits a list of (B,*,*) and gets into school B. The student with the lowest score can submit any list and gets into school C. Note that all the three students face equal probabilities of being the student with highest, second highest and lowest score, so each student has the same probability of getting into each of the three schools.

Under the SD-before and SD-after mechanisms, as mentioned above, truth-telling is the dominant strategy for all students. So under this dominant strategy equilibrium, the matching result is identical to the BOS-after mechanism. As in the ability-wise design, BOS-before mechanism is less ex-post fair than the other three mechanisms. Note also that all the possible matching results are equally ex-ante fair since all the students have the same expected score.

Efficiency Measures

We consider two possible measures of efficiency: Pareto dominance, and maximizing the sum of payoffs across students.

In the case of ex-post efficiency, since all students have the same ordinal preference, no matching result can be *Pareto* dominated by any other matching result (every mechanism implements an ex-post Pareto efficient matching outcome). Thus for the ex-post case, we can only use the sum of realized payoffs as the efficiency criterion. The BOS-before mechanism implements the allocation which maximizes the sum of payoffs across students with certainty, since it prevents student 3, the student with the lowest value on school A, from getting into this school. All the other mechanisms only implement this result with probability less than 1, since student 3 still has a chance to get into school A.

In the case of ex-ante efficiency, we can consider both measures. For the criterion of maximizing total expected payoffs, BOS-before is superior to the other mechanisms since it in fact always implements the total payoff maximizing result. Furthermore, by the Pareto efficiency criterion, BOS-before is *still* more ex-ante efficient than other mechanisms. As seen in Table 5, the BOS-before mechanism Pareto dominates the other mechanisms in expectation by giving each student a strictly higher expected payoff.

Table 5 shows students' expected payoffs under different mechanisms, according to our equilibrium of interest:

Table 5: Expected Payoffs (efficiency measures)

Expected payoff	BOS-before mechanism	Other mechanisms
Student 1	(31+18)/2=24.5	(31+22+18)/3=23.67
Student 2	24.5	23.67
Student 3	22	(25+22+18)/3=21.67
Total	71	69

Hypothesis 2: Under the above-mentioned preference-wise design, the BOS-before mechanism will implement (in its Nash equilibrium) a more ex-ante (and ex-post) efficient matching than the other three mechanisms (BOS-after, SD-before and SD-after).[14]

2.2 Experimental Setup

We conducted 2(designs)*4(mechanisms) = 8 different treatments as described in the previous section. Within each experimental session, subjects played both the pre-exam score preference submission game and the post-exam score preference submission game for the same mechanism. We alternated the sequence of preference submission timing conditions across sessions to account for

[14] Note however that in the preference-wise design, BOS-before is (as in the ability-wise design) less ex-post fair than the other mechanisms.

any potential systematic biases due to ordering effects. Thus subjects need to submit their preferences under both timing scenarios, allowing us to know the effect of submission timing within subject.

For each treatment, groups of three are formed and students are asked to play each of the three possible student roles (Student 1, Student 2, Student 3) in a randomly assigned order. Participants are anonymous within groups, and groups were randomly re-formed after each round so as to avoid reputation building within groups. Each subject makes 6 school choice decisions in total.

At the end of each session subjects complete an incentivized risk attitude test (Tanaka, Camerer and Nguyen, 2010).[15] We use Tanaka, Camerer and Nguyen (2010) because it provides a richer set of parameter estimates than Holt and Laury (1994), including a measure of loss aversion.

In the procedure where submission occurs before the exam (either under BOS or SD mechanism), students only know about score distributions of each student role but not students' realized scores. In the procedure where preference submission occurs after the exam, students are notified of the score outcomes of all the students in his or her group before making the submission. In the ability-wise design, score distributions are designed so that each student will have different scores by random draws from the distribution. In the preference-wise design, we avoid equal scores by random draw without replacement from the same distribution for all the students. Both procedures give us a strict score ranking over students.

Students were paid according to the sum of payoffs from all rounds, after converting experimental currency units (ECU) to Chinese Yuan. Subjects were only told their total earnings after completing all of their decisions, so that learning effects due to performance feedback from previous rounds are ruled out.

We recruited subjects from among the pool of undergraduate students at Tsinghua University using the ORSEE online recruiting system. We conducted all 8 sessions on May 27th (2 sessions) and on June 3th (6 sessions) of 2012. Each session had between 33 and 42 subjects, depending on the show-up rate, and each session lasted approximately an hour. The average payoff to each subject was about 80 yuan YMB, including the show-up fee (10 yuan). The minimum payoff was 60 yuan and the maximum payoff was 95 yuan.

All sessions were conducted in Tsinghua University, School of Economics and Management's Experimental Economics laboratory (ESPEL) and students completed the experiments on computer terminals.[16] The experiments were implemented using Z-tree. Details of each of the sessions are shown in Table 6.

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[15] Since risk attitudes were a factor we wished to control for, but were not the main purpose of our study, we incentivized the Tanaka, Camerer, Nguyen test on a randomly selected subject in each session as follows: Subjects filled out the risk attitude form shown in the Appendix, and we informed subjects ahead of time that one randomly selected subject from each session would be chosen to have the risk attitude test implemented according to their answers. Once a subject had been randomly chosen in each session, we randomly drew a row number and implemented the lottery from that row. Then selected subject was paid according to his stated preference in the risk attitude form.

[16] http://espel.sem.tsinghua.edu.cn/intro.htm

Table 6: Experimental Sessions[17]

Session Name	Design	Mechanism	Timing(1st procedure/2nd procedure)	# of Subjects
B-a-1	Ability-wise	BOS	before/after	36
B-a-2	Ability-wise	BOS	after/before	39
S-a-1	Ability-wise	SD	before/after	39
S-a-2	Ability-wise	SD	after/before	36
B-p-1	Preference-wise	BOS	before/after	36
B-p-2	Preference-wise	BOS	after/before	36
S-p-1	Preference-wise	SD	before/after	33
S-p-2	Preference-wise	SD	after/before	42

3. Results: Efficiency, Fairness and Strategy-Proofness

In this section we present our experimental results. Overall, our experiments supported our efficiency hypothesis (Hypothesis 2) more strongly than our fairness hypothesis (Hypothesis 1). Nevertheless, Hypothesis 1 is also *not rejected* by the data. We hypothesize that the ambiguity regarding Hypothesis 1 in our data may be due to subjects' behavioral response to certain features of our experimental design, and we explore the causes of these issues further in Section 4.

We first present our efficiency results which are relatively straightforward. We then turn to a more detailed discussion of our fairness results. Since empirical strategy-proofness affects the degree of adherence to our hypotheses about efficiency and fairness, we discuss the strategy-proofness of each mechanism prior to discussing the main efficiency or fairness results.

3.1 Efficiency Results (Preference-wise Design)

3.1.1 Strategy-Proofness in the Preference-wise Design

Table 13 (see also figure 3(b)) shows truth-telling as an empirical measure of strategy-proofness, for each of the four mechanisms under the preference-wise design. As predicted by previous theory, the two SD mechanisms are substantially more strategy-proof than the other two BOS mechanisms. However, submission timing still matters. Within each mechanism type, BOS or SD, the submission before exam procedure induces more truth-telling than submission after the exam. Student 1 and 2, having the same ex-ante expected scores, are often both willing to compete for school A when submitting preferences before exam, but are no longer incentivized do so once score rankings are realized in the submission after exam procedure.

[17] The complete instruction manual of session "B-a-1" is in the Appendix. Instruction manuals of session "S-a-1", "B-p-1" are also briefed in appendix, showing how they differ from session "B-a-1". Instructions of sessions "B-a-2", "S-a-2" and "B-p-2" are not reported, since they only differ from the corresponding session with number "1" in title in sequences of conducting "submitting before score known" and "submitting after score known" procedure. Instruction manual of session "S-p-1/2" is a combination of "S-a-1/2" and "B-p-1/2" in an easily understandable way.

Table 13: Strategy-proofness in Preference-wise Design

panel A: proportions of truth-telling under different mechanisms			
BOS-before	BOS-after	SD-before	SD-after
0.690	0.426	0.933	0.858
panel B: differences in proportions and p-values of significance tests			
before-after	BOSb-BOSa	BOSb-SDb	BOSb-SDa
0.168	0.264	-0.244	-0.168
(0.000)	(0.000)	(0.000)	(0.000)

Note: p-values are derived from running probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the subject level.

3.1.2 Ex-ante Efficiency

We examine ex-ante efficiency of each the four mechanisms by two methods: the *sum of expected payoffs (displayed as average expected payoffs)* obtained across student-school matches, and whether average payoffs by student type in some mechanisms *Pareto dominate* other mechanisms. Total expected payoffs are simply the sum of all the three student types by matching group. These are ex-ante measures in the sense that the calculation was done conditional on other subjects' strategy choices, but prior to the realization of scores. Given our sample size, there should be enough realizations of scores such that the empirical average of payoffs reflects expected total payoffs under each mechanism.

Table 11 (and Figure 4) shows average ex-ante total payoffs under each of the four mechanisms. The average ex-ante total payoff is significantly (at the 95% level) larger under the BOS-before mechanism than under the other mechanisms, and the gap is very close in magnitude compared to the theoretical prediction shown in Table 5. Thus we find strong support for Hypothesis 2 using the ex-ante total payoff criteria.

Figure 4: Ex-ante Efficiency under Preference-wise Design
(Means and 95% confidential intervals are shown)

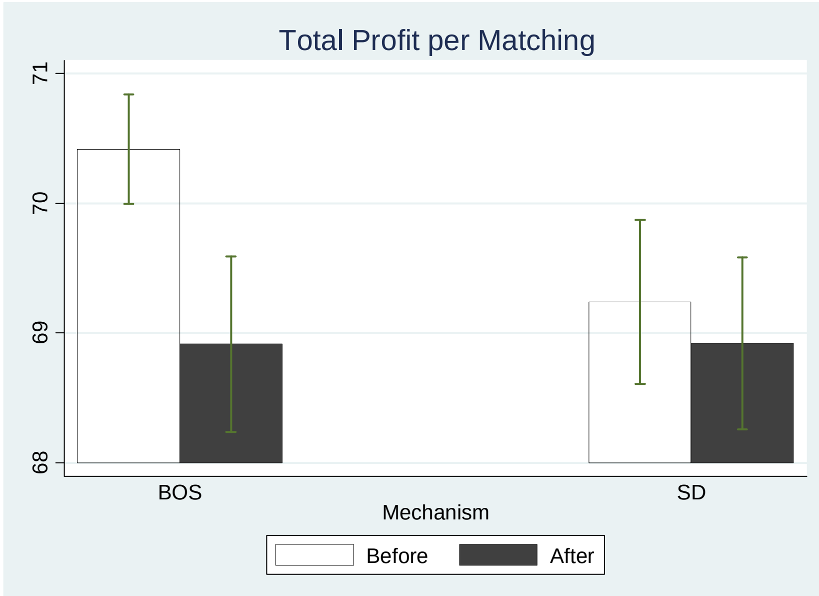

Table 11: Total Expected Payoffs in Preference-wise Treatment

panel A: total ex-ante expected payoffs under different mechanisms			
BOS-before	BOS-after	SD-before	SD-after
70.417	68.917	69.240	68.920
panel B: differences in total payoffs and p-values of significance tests			
before-after	BOSb-BOSa	BOSb-SDb	BOSb-SDa
0.898	1.500	1.177	1.497
(0.061)	(0.023)	(0.096)	(0.023)

Note: p-values are derived from running OLS regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the session level.

Next, we look at average expected payoffs *within* each specific student role (Student 1, 2, and 3) for each mechanism, to explore the prediction that BOS-before Pareto dominates others from the ex-ante standpoint.

Table A3 describes Hypothesis 2's success using the Pareto dominance criteria. Panel A shows each player type's average ex-ante expected payoff, given the preference submission choices of other subjects in that player's group. Students 1 and 2 (whose payoff possibilities are identical), receive significantly higher expected payoffs under BOS-before than under the BOS-after mechanism. The ex-ante expected payoffs for students 1 and 2 are higher under BOS-before than under the SD-before mechanism on average, but not significantly so. Student 3's payoff under the BOS-before mechanism is not significantly different from that under other mechanisms. Thus support for the Pareto dominance hypothesis is found for students 1 and 2, while for student 3 the evidence is weaker although not strictly contrary to the hypothesis.

Table A3: Ex-ante Pareto Dominance in Preference-wise Design

panel A: Profits under different mechanisms				
student type	BOS-before	BOS-after	SD-before	SD-after
type 1&2	24.507	23.521	23.767	23.580
type 3	21.403	21.875	21.707	21.760
panel B: differences in profits and p-values of significance tests				
student type	before-after	BOSb-BOSa	BOSb-SDb	BOSb-SDa
type 1&2	0.578	0.986	0.740	0.927
	(0.091)	(0.047)	(0.191)	(0.057)
type 3	-0.259	-0.472	-0.304	-0.357
	(0.264)	(0.192)	(0.494)	(0.278)

Note: p-values are derived from running OLS regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the session level.

3.1.3 Ex-post Efficiency

We cross-check the results in the previous ex-ante efficiency section using the sum of realized payoffs conditional on student score ranking outcomes, as our ex-post efficiency measure. Recall that in the case of ex-post efficiency, no mechanism Pareto dominates another mechanism – hence our only relevant measure in the ex-post case is the sum of realized payoffs. We expect the results to be largely consistent with the ex-ante measures in Table 11, since the two only differ by actual score ranking outcomes realized.

Table 12 shows a measure of ex-post efficiency for each of the four mechanisms, in terms of the sum of realized payoffs. We condition the payoff results on the realized score ranking among students 1, 2 and 3 (leftmost column) to reflect the ex-post nature of the measure. BOS-before performs marginally better in this regard, having slightly higher average payoff totals than the other mechanisms in the cases where student 3's score is ranked first. Table A5 in the Appendix shows the statistical significance of the differences between the mechanisms shown in Table 12.

Table 12: Ex-post Efficiency: Total Payoffs (conditional on realized scores)

realized score ranking	total payoffs under different mechanisms			
	BOS-before	BOS-after	SD-before	SD-after
(1,2,3)	71.000	71.000	71.000	71.000
(1,3,2)	71.000	71.000	70.625	71.000
(2,1,3)	71.000	71.000	71.000	71.000
(2,3,1)	71.000	71.000	71.000	71.000
(3,1,2)	69.500	65.000	65.000	65.462
(3,2,1)	68.692	65.500	65.750	65.000

3.2 Fairness Results (Ability-wise Design)

3.2.1 Strategy-proofness in the Ability-wise Design

Table 10 (and Figure 3(a)) shows how strategy-proofness empirically holds up under each of the four mechanisms under the ability-wise design. The two SD mechanisms induce truth-telling behavior with a proportion of more than 70% in our experiments, either under the submission-before-exam or after-exam procedure. Truth-telling behaviors are far less prevalent (as expected) under the two BOS mechanisms, with a proportion of just 40% to 50%. However, the prevalence of truth-telling in the data generally still exceeds the rate predicted by the theory, particularly in the case of BOS-before.

The reason might be as follows: Under the BOS-after mechanism, all the students know their score and its ranking. For the second-ranked student, it no longer makes sense to compete for the best school (school A) with the top-ranked student. But under the BOS-before mechanism, the ex-ante second-ranked student (student 2) may take the risk of competing for admission at school A with the best student, rather than listing school B as her first choice as our framework predicts. Such behavior by student 2 can weaken the implicit ex-ante sorting mechanism offered by BOS-before, and reduce adherence of the data to Hypothesis 1. We explore this deviation from our equilibrium prediction in greater detail in Section 4.

Table 10: Truth-telling in Ability-wise Design

panel A: proportions of truth-telling under different mechanisms			
BOS-before	BOS-after	SD-before	SD-after
0.516	0.391	0.778	0.720
panel B: differences in proportions and p-values of significance tests			
before-after	BOSb-BOSa	BOSb-SDb	BOSb-SDa
0.091	-0.124	-0.262	-0.204
(0.001)	(0.009)	(0.000)	(0.000)

Note: p-values are derived from running probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the subject level.

3.2.2 Ex-ante Fairness

Table 7 (see also Figure 1) shows the ex-ante fairness property of matching results under each of the four mechanisms. Proportions of completely ex-ante fair matching are not significantly different among all the four mechanisms at the 95% level. The BOS-before mechanism has the second-highest proportion of ex-ante fair matching, only slightly less than that of SD-before mechanism. Thus our Hypothesis 1, that the BOS-before mechanism should be *more* ex-ante fair than the other three mechanisms, does not gain strong support in the aggregate data. Table A1 in the Appendix shows the average number of blocking pairs for each of the mechanisms, with similar results.

Figure 1: Complete Ex-ante Fairness under Ability-wise Design

(Means and 95% confidential intervals are shown)

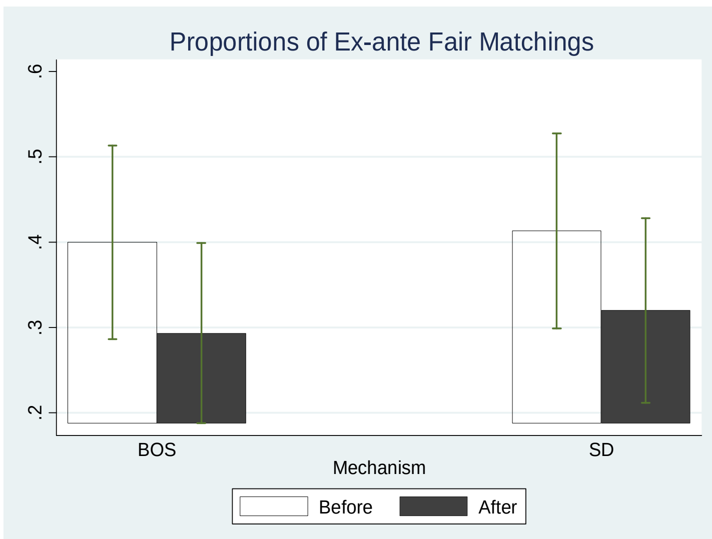

Table 7: Ex-ante Fairness in Ability-wise Designs

panel A: proportions of completely ex-ante fair matches under different mechanisms			
BOS-before	BOS-after	SD-before	SD-after
0.400	0.293	0.413	0.320
panel B: differences in proportions and p-values of significance tests			
before-after	BOSb-BOSa	BOSb-SDb	BOSb-SDa
0.100	0.107	-0.013	0.080
(0.075)	(0.187)	(0.756)	(0.318)

Note: p-values are derived from running probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the session level.

Our results show that preference submission timing as a whole appears to matter, although it does not differ significantly within a given mechanism (BOS or SD). In fact, when we test the effect of timing across the BOS and SD mechanisms, the difference is significant at the 90% level (p-value=0.075, not reported in the table). By contrast, mechanism specific effects across different timings were insignificant (p-value=0.763, not reported in the table). Thus, the ex-ante fairness results confirm that submission timing indeed plays a significant role in terms of fairness outcomes.

Table 8 categorizes ex-ante fairness results within the BOS-before mechanism separately for cases where student 2 plays the equilibrium strategy and where student 2 plays the truth-telling strategy. The difference in ex-ante fairness is large. When student 2 plays the equilibrium strategy, as we predict, the matching outcome is substantially more likely to be completely ex-ante fair than when student 2 chooses truth-telling. This confirms that student 2's behavior is indeed critical. However, it is also notable that the outcome in the case of equilibrium play of student 2 is also substantially more likely to be completely ex-ante fair compared to any of the other mechanisms (see Table 7). This provides some indirect evidence for Hypothesis 1, but also shows that the aggregate result is quite sensitive to subjects' propensity to play equilibrium.

Table 8: Ex-ante Fairness in BOS-before, Ability-wise Design, by Strategy of Student 2

mechanism	proportions of completely ex-ante fair matches for student 2's different behaviors		differences in proportions and p-values of significance tests
	equilibrium strategy	truth-telling	
BOS-before	0.634	0.118	0.516 (0.000)

Note: p-values are derived from running probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters at the session level.

3.2.3 Ex-post Fairness

Table 9 (see also Figure 2) shows the ex-post fairness property of each of the mechanisms, measured by proportions of completely ex-post fair matches. Similar results for the measure using number of blocking pairs are shown in Table A2 in the Appendix.

Consistent with Hypothesis 1, the BOS-before mechanism is less ex-post fair than all the other mechanisms. Only 40% of all the matching results under the BOS-before mechanism are completely ex-post fair, compared with around 90% of all the other mechanisms. This can be compared to our theoretical prediction in Table 2, in which BOS-before yields 63% complete fairness, while other mechanisms yield 100% complete fairness. In fact, the empirical gap between the ex-post fairness of BOS-before and other mechanisms is nominally larger than the theoretical gap.

Furthermore, the SD-after and BOS-after mechanisms are empirically significantly more ex-post fair than the SD-before mechanism. This is reasonable because in theory ex-post fair matching might be only one of many equilibrium outcomes under the SD-before mechanism, but under the SD-after and BOS-after mechanisms, it is the unique equilibrium outcome.[18] The result again highlights the importance of submission timing, either under the BOS or SD mechanism.

Figure 2: Ex-post Fairness under Ability-wise Design

(Means and 95% confidential intervals are shown)

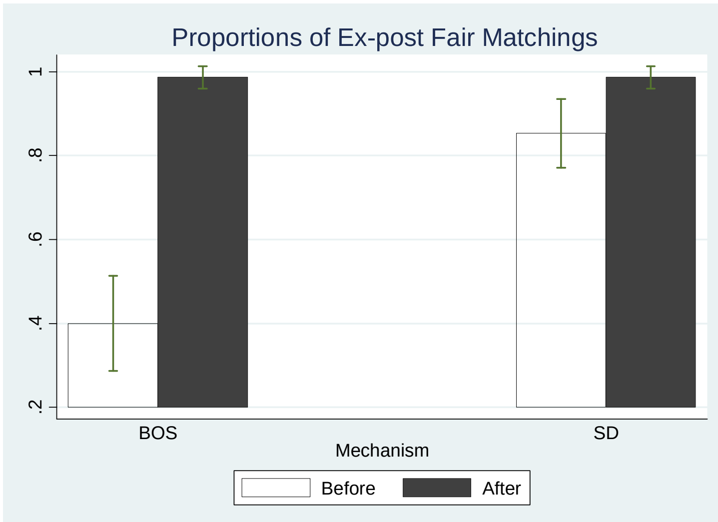

Table 9: Ex-post Fairness In Ability-wise Design

panel A: proportions of completely ex-post fair matches under different mechanisms			
BOS-before	BOS-after	SD-before	SD-after
0.400	0.987	0.853	0.987
panel B: differences in proportions and p-values of significance tests			
before-after	BOSb-BOSa	BOSb-SDb	BOSb-SDa
-0.360	-0.587	-0.453	-0.587
(0.000)	(0.000)	(0.000)	(0.000)

Note: p-values are derived from running probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the session level.

4. Explaining truth-telling behaviors

How closely the data confirm or refute our hypotheses about fairness and efficiency clearly hinges upon how well subjects adhere to our equilibrium strategies of interest. There could be a

[18] For the uniqueness of equilibrium outcome under the SD(-after) mechanism, an additional condition on school priorities called acyclicity is required. For details, see Haeringer and Klijn (2009).

number of reasons for them to deviate from submitting preferences that match our specified prediction. Such reasons may include risk attitudes, beliefs about what other subjects will submit, desire to compete, and others. Appendix 5 provides detailed summary statistics about tendency to truth-tell in our experiment by student type in each design. Readers interested in a detailed analysis and discussion of truth-telling behavior, are directed to Appendix 5. In this section we focus on whether truth-telling may be linked to risk preference as measured in our risk attitude test, personal experience, or other demographic variables.

We restrict our analysis to non-dominated strategies by omitting all the samples where dominated strategies were played, and analyze behavior at the level of each decision made in the experiment.[19] During the experiments, we collected several personal characteristics of our subjects via an end-of-session survey, including age, years of schooling completed, gender and major. We also collect information on their college entrance exam experience, including whether they took the exam, when and where. If they did not attend the exam, we instead ask them to provide when and where they graduated from the high school. From the time and location of the exam reported, we can derive the particular school choice mechanism they experienced when they were applying to colleges. We also test subjects' risk and loss attitude by using a recently developed test by Tanaka, Camerer and Nguyen (2010).

Using Tanaka, Camerer and Nguyen's (2010) methodology, three parameters can be derived for each subject: θ, α and λ. θ reflects the subject's risk aversion via a power function, where higher θ implies a lower risk aversion. α reflects how the subjects value likelihood of events with small vs. large probability. When α is small, subjects tend to overvalue small probability events but undervalue large ones. λ is the parameter of loss aversion, where larger λ means a higher loss aversion.[20] The table of summary statistics for those three parameters in each treatment is shown in the Table A9. Our parameter estimates are quite similar to those found by Tanaka, Camerer and Nguyen (2010) in Vietnamese villages, and are statistically indistinguishable across sessions.

Table A9: Summary Statistics of Risk Attitude Parameters

Ability-wise design					
Variable	Obs	Mean	Std. Dev.	Min	Max
θ	150	0.709	0.319	0.05	1.5
α	150	0.774	0.274	0.15	1.45
λ	150	2.689	2.453	0.07	9.78
Preference-wise design					
Variable	Obs	Mean	Std. Dev.	Min	Max
θ	147	0.761	0.303	0.05	1.5
α	147	0.789	0.274	0.05	1.45
λ	147	2.462	2.316	0.07	9.67

Note that individual risk attitude parameters may correlate with variables such as gender, age, or

[19] In all the sessions, non-dominated strategies account for over 90% percent of subjects' behaviors. Subjects may choose to play a dominated strategy when they are (at least in equilibrium) indifferent with non-dominated ones. Here we do not tend to explain dominated vs. non-dominated strategies.
[20] See Tanaka, Camerer, and Nguyen (2010) for details.

major. We run regressions of truth-telling behaviors on risk attitude variables with and without control of others. Since our primary interest lies in whether the risk parameters explain strategy choices in the matching results, we simply include those demographic variables as controls in the regression.

Table 14 reports how truth-telling is explained by factors we observe, including mechanisms, design, student types and personal attributes (risk attitude, demographics, etc.) using a probit model. We find that while mechanism and student role are significant factors (as previously discussed), personal attributes do not play a very significant role. Estimated risk attitude parameters are in fact individually and jointly insignificant in predicting truth-telling. Within demographics, female students tend to be slightly less truth-telling under the preference-wise design than males. Age and year in college are significant under the ability-wise design at a 10% level. Real life CEE experiences are also largely insignificant, except that whether students have CEE experience at all is negatively associated with truth-telling behavior under the ability-wise design. The impact of real life admission mechanisms experienced on their behaviors is also small: only timing has a significant effect at 10% level under preference-wise design.

Table 14: Determinants of Truth-telling: Probit Model

explanatory variables	explained var.: truth-telling			
	ability-wise design		preference-wise design	
BOS (vs. SD)	-0.405***	-0.424***	-0.343***	-0.361***
	(0.0506)	(0.0516)	(0.0439)	(0.0428)
Before (vs. After)	0.0131	0.0189	0.103**	0.0921*
	(0.0452)	(0.0455)	(0.0492)	(0.0497)
BOS*before	0.0876	0.0887	0.0620	0.0719
	(0.0623)	(0.0622)	(0.0492)	(0.0492)
Type 1 student (vs. type 3 student)	0.410***	0.410***	0.115***	0.110***
	(0.0321)	(0.0319)	(0.0266)	(0.0268)
Type 2 student (vs. type 3 student)	0.194***	0.193***	0.145***	0.138***
	(0.0320)	(0.0329)	(0.0257)	(0.0257)
θ	0.0756	0.108	-0.0297	-0.00913
	(0.0692)	(0.0659)	(0.0503)	(0.0527)
α	0.0368	0.0566	0.0845	0.0924
	(0.0969)	(0.0952)	(0.0612)	(0.0607)
λ	0.00517	0.00215	0.00530	0.0108
	(0.00871)	(0.00802)	(0.00640)	(0.00734)
joint sig. of risk parameters (prob.>F)	0.521	0.245	0.504	0.225
female		0.0372		-0.0901**
		(0.0463)		(0.0363)
age		0.0560*		-0.00793
		(0.0337)		(0.0202)
grade		-0.0865*		0.0139
		(0.0444)		(0.0285)

exam taken?		-0.136***		0.0360
		(0.0505)		(0.0391)
partial parallel		0.0561		0.0415
		(0.0624)		(0.0517)
complete parallel		-0.0998		0.0390
		(0.0620)		(0.0577)
submit before exam		-0.0903		0.0559
		(0.0775)		(0.0375)
submit after exam but		-0.0674		-0.0966*
before score known		(0.0617)		(0.0587)
major	No	Yes	No	Yes
Observations	828	828	826	797

Note: Standard errors (in parentheses) are corrected for subject-level clustering effects, *** p<0.01, ** p<0.05, * p<0.1. Coefficients report marginal effects at the mean levels.

Table 14 does not consider potential heterogeneous effects of personal attributes on behaviors. For this, we focus on two cases we are most interested in: student 2 under the ability-wise design and student 3 under the preference-wise design, both under the BOS-before mechanism. Table 15 reports these results for these critical students of interest. Once again, almost all the variables are insignificant including most of the risk attitude variables, demographic variables and college entrance experience variables. Only age and CEE participation variable are significant under the preference-wise design, and λ is significant in one regression under ability-wise design.

Table 15: Determinants of truth-telling of critical players under BOS-before Mechanism: Probit Model

explanatory variables	explained var.: truth-telling			
	student 2 under ability-wise design		student 3 under preference-wise design	
θ	-0.117	-0.187	-0.0238	0.00468
	(0.184)	(0.198)	(0.217)	(0.209)
α	-0.0415	-0.00560	0.182	0.160
	(0.236)	(0.260)	(0.244)	(0.266)
λ	0.0308	0.0442*	-0.00586	0.00781
	(0.0215)	(0.0235)	(0.0235)	(0.0259)
joint sig. of risk parameters (prob.>F)	0.435	0.188	0.863	0.924
female		0.173		-0.0704
		(0.155)		(0.162)
age		-0.121		-0.139*
		(0.0909)		(0.0814)
grade		0.0582		0.115

		(0.130)		(0.112)
exam taken?		-0.186		0.312**
		(0.164)		(0.132)
partial parallel		-0.253		0.0850
		(0.248)		(0.258)
complete parallel		-0.363		0.194
		(0.233)		(0.238)
submit before exam		-0.159		0.0106
		(0.184)		(0.231)
submit after exam but before score known		-0.132 (0.219)		-0.223 (0.185)
major	No	Yes	No	Yes
Observations	75	75	64	62

Note: Standard errors (in parentheses) are corrected for subject-level clustering effects, *** p<0.01, ** p<0.05, * p<0.1. Coefficients report marginal effects at the mean levels.

So why might subjects not play the Nash equilibrium strategy? One of the reasons not included in our regression is the player's calculation of expected payoffs based on objective score and ranking distributions. Subjects may attempt to follow the expected payoff formula, but given the short time period for decision making, they cannot calculate precisely these distributions and derive the equilibrium. So among the two non-dominated strategies available to them, they may make mistakes. Another possible explanation for non-equilibrium play is different levels of strategic sophistication among subjects (see Camerer, Ho and Chong, 2004; Crawford, Costa-Gomes, Iriberri, forthcoming), wherein subjects may assume that other subjects are less sophisticated than they are with some probability.[21]

5. Conclusions

In this paper we conduct a series of laboratory experiments on the Boston and Serial Dictatorship mechanisms which vary by the timing of students' required preference submissions over schools. Our focus on preference submission timing is inspired by the heterogeneity in matching mechanisms implemented in China's college admission system over years of reform. We are further motivated by the insight that the Boston mechanism with preference submission timing before the realization of an 'exam' score, may have superior ex-ante fairness and efficiency properties over the frequently theoretically preferred Serial Dictatorship mechanism.

Our experiments confirm that students' behavior is indeed affected by the incentives introduced by preference submission timing variation, thus influencing efficiency and fairness results. Overall,

[21] For example, in the case of BOS before, student 2 may believe that student 3 lists school C as her first choice, due to having the lowest ex-ante expected score, even though student 3 has no incentive to do so. In this case, student 2 may choose to gamble with student 1 for school A, believing that her fallback option is school B in a later round, after student 3 is matched successfully to school C.

our experiments confirmed our prediction more strongly in the case of ex-ante efficiency compared to ex-ante fairness. A detailed examination of our data reveals that the fairness result was especially sensitive to the conformity of the second highest ranked student to equilibrium play. When this student chose to 'compete' with the top ranked student over the top school by revealing her true preference over schools, the likelihood of a completely ex-ante fair matching was just 12 percent, as compared to 63 percent in the case of equilibrium play.

Surprisingly, risk attitudes did not have any significant predictive power in explaining subjects' propensity to truth-tell. We find little evidence that risk aversion, demographic characteristics or prior personal experience with school choice matching play a significant role in students' strategy choices. More work is needed in order to pin down the determinants of equilibrium and truth-telling play, and this may indeed have policy consequences for the fairness viability of BOS-before as an ex-ante screening mechanism in school choice settings.

Another direction for future research is a formal theoretical model to determine more generally when existing school choice mechanisms of interest are superior or inferior once preference submission timing as a design characteristic is introduced. Our current experiment specified a fixed set of payoffs, and checked whether subjects behaved as predicted by risk neutral valuation of these payoffs. A more rigorous model could reveal not only what payoff structures support higher efficiency and fairness, but also analyze a more general matching environment than the 3-school, 3 student environment we consider here.

Finally, we would like to mention some policy implications about our results in the context of China's college admission system. A prevalent criticism of the current system is that it places too much weight on a single exam's result, which not only places substantial pressures on high school students, but also requires teachers to spend non-trivial amounts of time 'teaching to the test'. The benefit of the test-based admissions system however, is its objective rewarding of academic merit, as measured by ability and effort on the exam and preparations leading up to it. This incentive system may be crucial for families' relatively high regard for education in China.

Since the exam-based system indeed has its benefits as well as its drawbacks, it may be less realistic to consider drastic reforms toward the CEE-based system, and more realistic to consider the effects of relatively small changes in mechanism design such as the preference submission timing we have considered here.

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Appendix 1: Equilibrium Calculation for BOS-before mechanism under ability-wise design

Given the score distribution of all the three students (uniformly distributed over high, normal and low scores), the score-rank distribution is the following:

Ranking of students by score	Probability of occurrence
(1, 2, 3)	10/27
(1, 3, 2)	7/27
(2, 1, 3)	7/27
(2, 3, 1)	1/27
(3, 1, 2)	1/27
(3, 2, 1)	1/27

Consider the first choice school of each of the three students. Note that in equilibrium each of the students must be admitted to one of the three schools. We show that all Nash equilibria of the game must have student 1 listing A as her first choice and students 2 and 3 listing B as their first choice.

Claim 1: There in no equilibrium where some student chooses school C as her first choice.

Proof: Note that every student has a positive probability of being ranked first. Thus, by listing C as her first choice, is strictly dominated in expectation, compared to listing either B or A as her first choice.

Claim 2: There is no equilibrium where all three students choose school A as their first choice.

Proof: Suppose that there is an equilibrium where students 1, 2 and 3, each choose school A as their first choice. All students will then have incentive to choose school B, instead of C, as their second choice, in order to maximize their expected payoffs. Consider the expected payoff of student 3 in this case: 30*2/27+ 25*8/27+15*17/27 = 515/27, whereas by choosing B as her first choice, her expected payoff is 25 with certainty, which is greater than 515/27.

Claim 3: In any equilibrium, at least one student chooses school A as her first choice.

Proof: Suppose there is an equilibrium where no students choose school A as their first choice. Then for student i (i=1,2,3), her payoff would be 30 for sure if she choose school A as her first choice instead of playing the equilibrium strategy, which yields an expected payoff strictly less than 30.

Claim 4: In any equilibrium, student 1 chooses school A as her first choice.

Proof: Suppose there is an equilibrium where student 1 does not choose school A as her first choice. Then by Claim 1, she must choose school B as her first choice. By Claim 3, there are in total three cases.

Case 1. Both of the other two students choose school A as their first choice. Then student 1 will get 25 by choosing school B as her first choice. But if she chooses school A as her first choice and school B as her second choice, she will get in expectation: 30*17/27+25*8/27+15*2/27=740/27>25.

Case 2. Student 2 chooses school A as her first choice while student 3 chooses school B as her first choice. Then by choosing school B as her first choice, student 1's expected payoff is: 25*24/27+15*3/27=215/9. By choosing school A as her first choice, student 1's expected payoff is: 30*18/27+15*9/27=25>215/9.

Case 3. Student 3 chooses school A as her first choice, while student 2 chooses school B as her first choice. Then by choosing school B as her first choice, student 1's expected payoff is: 25*18/27+15*9/27=65/3. By choosing school A as her first choice, student 1's expected payoff is: 30*24/27+15*3/27=85/3>65/3.

So in any of the three possible cases, student 1 prefers choosing school A as her first choice.

Claim 5: In any equilibrium, student 2 chooses school B as her first choice.

Proof: Suppose there is an equilibrium where student 2 chooses school A as her first choice.

Then in equilibrium, student 3 must choose school B as her first choice by Claim 3 and Claim 4. Then student 2's expected payoff is: 30*9/27+15*18/27=20. But if student 2 chooses school B as her first choice, her expected payoff is 25*18/27+15*9/27=65/3, which is greater than 20.

Claim 6: In any equilibrium, student 3 chooses school B as her first choice.

Proof: By Claims 4 and 5, in equilibrium student 1 chooses school A as her first choice, and student 2 chooses school B as her first choice. Given this, if student 3 chooses school A as her first choice, her payoff is: 30*3/27+15*24/27=50/3. If she chooses school B as her first choice, her payoff is: 25*9/27+15*18/27=55/3>50/3.

Given the first choices of all the three students in equilibrium, the resulting outcome is that student 1 is admitted to school A, student 2 is admitted to either school B or C, depending on her score relative to student 3. Student 3 goes to the remaining school. Their second or third choices do not affect the matching result, so those choices can be arbitrary. It is easy to verify that such choice profiles constitute a Nash equilibrium.

Appendix 2. Equilibrium Calculation for BOS-before mechanism under preference-wise design

As we assume, each student has the same ability. Thus each of them has the same score distribution which implies an equal probability of getting into each of the three schools.

Claim 7: There is no equilibrium where all three students choose school A as their first choice.

Proof: Suppose that there is an equilibrium where students 1, 2 and 3, each choose school A as their first choice. All students will then have incentive to choose school B, instead of C, as their second choice, in order to maximize their expected payoffs. Consider the expected payoff of student 3 in this case: 25*1/3+ 22*1/3+18*1/3= 65/3, whereas by choosing B as her first choice, her expected payoff is 22 with certainty, which is greater than 65/3.

Claim 8: In any equilibrium, at least one student chooses school A as her first choice.

Proof: Suppose there is an equilibrium where no students choose school A as their first choice. Then for student i (i=1,2,3), her payoff would be u*(i)=31 (i=1,2) or u*(i)=25 (i=3) for sure if she choose school A as her first choice instead of playing the equilibrium strategy, which yields an expected payoff strictly less than u*(i).

Claim 9: In any equilibrium, both students 1 and 2 choose school A as their first choice.

Proof: Consider student i, i=1,2. Suppose there exists an equilibrium where student i does not choose school A as her top choice. Then by Claim 8, at least one of the other two students would choose school A as their first choice, so student i's highest possible payoff will be 22. If she deviates by choosing school A as her first choice, her expected payoff will be at least 31*(1/3)+18*(2/3)=67/3, which is greater than 22. So such an equilibrium cannot exist.

Claim 10: In any equilibrium, student 3 chooses school B as her first choice.

Proof: By Claim 7 and Claim 9, in equilibrium student 3's first choice must be either school B or school C. In either case student 3 will be admitted to her first choice school with certainty. Comparing the payoffs (22 v.s. 18), student 3 must choose school B as her first choice.

Claim 11: In any equilibrium, both students 1 and 2 choose school B as their second choice.

Proof: Consider student i, i=1,2. Suppose there exists an equilibrium where student i does not choose school B as her second choice. Then by Claim 9 and Claim 10, it must be the following case: student i's strategy is (A,C,B); student 3's first choice is school B; the other student (denoted by j)'s first choice is school A. Thus student 3's payoff is 22. However, if student 3 deviates by playing (A,B,C), her expected payoff will be either 25*1/3+22*1/2+18*1/6=67/3 (when student j's strategy is (A,B,C)) or 25*1/3+22*2/3=23 (when student j's strategy is (A,C,B)). In either case, her payoff will be greater than 22. So such an equilibrium cannot exist.

Therefore students 1 and 2's equilibrium strategy is (A, B, C). Given this, student 3's second choice and third choice do not matter. That is, student 3's strategy is (B, *, *), where "*" represents any school not yet listed. It is easy to verify such choice profiles form a Nash equilibrium. In equilibrium, both student 1 and 2 have an equal probability of getting into school A and C. Student 3 will get into school B for sure.

Appendix 3. Experimental Instruction Manual

Instruction-Mechanism B-a-1

Thank you for participating in this experiment on decision making. From now until the end of the session any communication with other participants is forbidden. If you have any question, feel free to ask at any point of the experiment. Please do so by raising your hand and one of us will come to your desk to answer your question. The experiment will be conducted in two phases. We will only explain phase 1 now. After we finish phase 1, we will explain phase 2.

In this experiment we simulate two procedures to allocate students to schools. For each procedure, there are 3 independent rounds of games to play with. So the whole experiment will have totally 6 rounds. In each round, we will form groups of three participants, so that you will be grouped with 2 other participants, whose identity you will not know. You will play one of three roles of students, namely student 1, 2 or 3, and the other 2 players will play the remained roles respectively. You will play all the three roles of student 1, 2 and 3 one by one in the 3 consecutive rounds for each procedure. The sequence is assigned randomly. Note that groups will be reformed after each round.

In each round, all the participants have to indicate a preference ordering over schools. There are three schools (A, B, and C) and every school has one slot available. Each slot will be allocated to a participant, based on the preference ordering submitted by the 3 participants of the group, and also a score ranking assigned to each of the 3 participants. Schools differ in quality, and the desirability of schools in terms of quality is summarized in the amounts shown in the payoff table (see Decision Sheets), which contains the payoff amounts in experimental currency units (ECU) corresponding to each participant and school slot. This matrix is known by all the participants.

Submitted school ranking. In each round during the experiment, you will be asked to complete the Decision Sheet by indicating the preference ordering over schools you wish to submit. You have to rank every school.

Score Assignment and ranking. Schools build a priority ordering when offering slots where all candidates are ranked. The rankings are solely determined by score rankings of all candidates. All the three schools give the student with the highest score rank the highest priority, the second highest score the second highest priority, and the third highest (or the lowest) score the third highest (or lowest) priority. Score rankings are determined by score numbers all the participants have. The rules of score assignment and ranking are described below:

Each student will have a score number. Score numbers of all the participants will determine score rankings. Students who have the highest score will be ranked no. 1, the second highest no. 2, and the third highest (or the lowest) no. 3.

Each student will have an equal probability of getting three types of scores (namely high, normal, and low), where 100 represents full marks. However, those three scores are different for each of the three participants. The following table contains the score distribution of each student (this is known by all participants):

Score number	Score 1 (high)	Score 2 (normal)	Score 3 (low)	Avg. score
Probability	1/3	1/3	1/3	
Student 1	95	90	85	90
Student 2	91	86	81	86

Student 3	87	82	77	82

It can be seen from the table above that student 1 has an average score higher than 2, and 2 higher than 3. However, when student 1 has a normal score and 2 has a high score, 2 will have a higher score than 1 thus rank ahead of 1. The similar event happens between student 2 and 3. Furthermore, if student 1 has a low score and student 3 has a high score, even student 3 will surpass 1.

Every student's exact score number will be drawn randomly and independently from the distribution stated in the table above. Their score rankings are determined by their *exact* scores.

Payoffs. During the session you can earn money. You will receive 20 ECU for your participation, in addition to the amount you earn in the experiment. The amount for each student in each round is displayed in the payoff matrix, corresponding to the slot you hold at the end of each round. Note that the slot you hold at the end of each round depends on your submitted ordering and the submitted ordering of the other participants of your group (which you will not know at the moment of submitting your order).

The total payoff you earn is the sum of payoffs you earn in each of the 6 rounds, plus the 20 ECU participation fee. Once the whole experiment has finished and all the 6 allocations (corresponding to the 6 games) of the participants are determined, each participant will get paid her total payoff in YMB. One ECU equals to 0.5 yuan YMB.

Allocation Procedures. You will experience two different procedures of allocating students to schools in this experiment. With each of those two procedures and in each round, each participant is assigned a slot at the best possible school reported in her Decision Sheet that is consistent with the priority ordering of schools, the ordering being solely determined by score rankings among all the participants. The two procedures you will experience, however, differ in one aspect: whether you only know the distribution of score numbers of all the students, or you know their exact score numbers of all the students when you submit your preference over schools. The detailed process of each procedure is the following:

Procedure 1 (pre-score submission):

Step 1 and 2 concerns preference submission and score assignment and ranking:

- Step 1. Each student will submit their preferences over all the 3 schools in the Decision Sheet.
- Step 2. Each student will be assigned a score number and all the scores will be ranked.

Step 3-6 is the process used to allocate students to schools:

- Step 3. An application to the first ranked school in the Decision sheet is sent for each participant.
- Step 4. Each school accepts the applicant with the highest score ranking. The applicant and her position is removed from the system. All the other applicants (if any) are rejected by the schools.
- Step 5. The applicants remaining in the system have their applicants sent to their second ranked slot in the Decision Sheet. If a school's slot is still available, then it accepts the applicant with the highest score ranking. The remaining applications are rejects.
- Step 6. Each remaining participant is assigned a slot at her last choice.

An example. We will go through a simple example to illustrate how this allocation procedure works.

Step 1. Submitted school ranking: Suppose the submitted school rankings of each participant are the following.

	Student 1	Student 2	Student 3
1st choice	A	A	A
2nd choice	B	B	B
3rd choice	C	C	C

Step 2. Score assignment and ranking: Suppose after three lotteries being drawn randomly and independently for each participant, students have scores and therefore ranks as:

Student/Applicant	1	2	3
Score	95	91	87
Rank	1	2	3

Step 3-6. Allocation. The allocation procedure consists of the following steps:

Step 3: Each applicant applies to her first choice:

- Applicant 1, 2, 3 apply all to school A.

Step 4: Each school accepts the applicant with the highest score ranking and rejects others:

- School A retains applicant 1 and reject applicant 2 and 3.
- Applicant 1 and school A are removed from the subsequent process.

Step 5: Each applicant who is rejected in round 1 applies to her second choice:

- Applicants 2 and 3 apply to school B.
- School B accepts applicant 2 and rejects applicant 3.
- Applicant 2 and school B are removed from the subsequent process.

Step 6: Each remaining participant is assigned her last choice.

- Applicant 3 gets the remaining slot in school C.

Here the process finishes; and the final allocations are the following.

Student/Applicant	1	2	3
School	A	B	C

Procedure 2 (post-score submission):

- Step 1. Each student will be assigned a score number and all the sores will be ranked.
- Step 2. Each student will submit their preferences over all the 3 schools in the Decision Sheet.
- Step 3-6. All these steps are the same as in procedure 1.

Note that the only difference between procedure 1 and 2 is that the sequence of preference submission and score assignment (steps 1 and 2) are reversed.

Now you can go over the instructions at your place. Then we will go through 3 rounds of decisions of procedure 1, in which you will play the role of student 1, 2 and 3 in turn. We will end decisions of procedure 1 in 20-25 minutes. Then we will turn uniformly to 3 rounds of decision of procedure 2. The whole phase 1 of the experiment will end in 30-35 minutes, then we move to phase 2. Your total payoff will be informed at the end of the whole experiment.

Are there any questions?

Decision Sheet – Mechanism B-a-1

(Procedure 1: submission before score is known)

Recall: You will submit your preference ordering *without* knowing the exact score but only its distribution. Note that all the other participants know the distribution, meaning that every student knows every student's distribution of possible scores.

The score distribution of all the students is as the table below:

Score number	Score 1 (high)	Score 2 (normal)	Score 3 (low)
Probability	1/3	1/3	1/3
Student 1	95	90	85
Student 2	91	86	81
Student 3	87	82	77

Your payoff amount for each role you play in each procedure depends on the school slot you hold at the end of it. Your possible payoff amounts in each round are shown in the following table.

Slot received at school	A	B	C
Your payoff(ECU)	30	25	15

This means, that if at the end of one game you hold a slot:

– at school A, you will be paid 30 ECU for this round;
– at school B, you will be paid 25 ECU for this round;
– at school C, you will be paid 15 ECU for this round.

Recall: There is only one slot opening at each school.

Recall: You will be asked to play the role of student 1, 2, 3 alternately. The sequence of role play will be determine by lottery.

Decision 1

You are playing the role of student _ (1, 2, or 3 - will be shown on your screen) in this pre-score submission game. Please submit your ranking of the schools (A through C) from your first choice to your last choice. Please be sure to rank EVERY school!

1st choice	2nd choice	3rd choice

Decision 2

You are playing the role of student _ (1, 2, or 3; will be shown on your screen) in this pre-score submission game. Please submit your ranking of the schools (A through C) from your first choice to your last choice. Please be sure to rank EVERY school!

1st choice	2nd choice	3rd choice

Decision 3

You are playing the role of student _ (1, 2, or 3; will be shown on your screen) in this pre-score submission game. Please submit your ranking of the schools (A through C) from your first choice to your last choice. Please be sure to rank EVERY school!

1st choice	2nd choice	3rd choice

Decision Sheet – Mechanism B-a-1

(Procedure 2: submission after score is known)

Recall: You will submit your preference ordering *after* you know not only your own exact score, but all the others' scores.

Your payoff amount for each role you play in each procedure depends on the school slot you hold at the end of it. Your possible payoff amounts in each round are shown in the following table.

Slot received at school	A	B	C
Your payoff(ECU)	30	25	15

This means, that if at the end of one game you hold a slot:

– at school A, you will be paid 30 ECU for this round;
– at school B, you will be paid 25 ECU for this round;
– at school C, you will be paid 15 ECU for this round.

Recall: There is only one slot opening at each school.

Recall: You will be asked to play the role of student 1, 2, 3 alternately. The sequence of role play will be determine by lottery.

Decision 4

Now you play the role of student _ (1, 2, or 3; will be shown on your screen).

Every student's exact score is assigned as:

– Student 1: __ (95/90/85 - will be shown on your screen)
– Student 2: __ (91/86/81 - will be shown on your screen)
– Student 3: __ (87/82/77 - will be show on your screen)

Please submit your ranking of the schools (A through C) from your first choice to your last choice. Please be sure to rank EVERY school!

1st choice	2nd choice	3rd choice

Decision 5

Now you play the role of student _ (1, 2, or 3; will be shown on your screen).

Every student's exact score is assigned as:

– Student 1: __ (95/90/85 - will be shown on your screen)
– Student 2: __ (91/86/81 - will be shown on your screen)

– Student 3: __ (87/82/77 - will be show on your screen)

Please submit your ranking of the schools (A through C) from your first choice to your last choice. Please be sure to rank EVERY school!

1st choice	2nd choice	3rd choice

Decision 6

Now you play the role of student _ (1, 2, or 3; will be shown on your screen).

Every student’s exact score is assigned as:

– Student 1: __ (95/90/85 - will be shown on your screen)

– Student 2: __ (91/86/81 - will be shown on your screen)

– Student 3: __ (87/82/77 - will be show on your screen)

Please submit your ranking of the schools (A through C) from your first choice to your last choice. Please be sure to rank EVERY school!

1st choice	2nd choice	3rd choice

This is the end of phase 1 of the experiment. Please remain sitting in your seat until all the other participants finish. Then we will explain and conduct phase 2 of the experiment.

Personal Background and Risk-Attitude Test Form

1. Your name is: ______; student ID is: _____; subject number is: ______.
2. Your gender is ______ (F/M).
3. Your age is ______.
4. You major is _____________________.
5. Have you ever taken college entrance exam? (Y/N)_____. If so, in what province and which year? ________________. If not, please indicate the province your high school is in, and the year you graduate from high school.__________.
6. The following is a risk attitude test form. Please continue.

NOTE: To pay for doing this risk attitude test form, We will randomly choose one participant in each experimental session. Then for the chosen participant we will randomly choose one row among all the 35 rows in three tables below. The chosen participant would be paid according to her lottery chosen at that row. The lottery would be drawn publicly on the spot. 1ECU=0.5 yuan RMB. Good Luck!

You are going to choose from two lotteries, A and B, whose outcome (amounts in ECU you would win) will be determined by a random draw of 10 balls in a cage, with the balls being numbered 1, 2, 3,....10. For Table 1, at which row of lottery pairs would you begin to accept the Lottery B over Lottery A?

Table 1

Row	Lottery A		Lottery B	
	Ball 1-3	Ball 4-10	Ball 1	Ball 2-10
1	40	10	68	5
2	40	10	75	5
3	40	10	83	5
4	40	10	93	5
5	40	10	106	5
6	40	10	125	5
7	40	10	150	5
8	40	10	185	5
9	40	10	220	5
10	40	10	300	5
11	40	10	400	5
12	40	10	600	5
13	40	10	1,000	5
14	40	10	1,700	5

Your answer is in table 1:

I choose Lottery A for Row 1 to ____, and Lottery B for Row ____ to 14.

Now consider another pair of Lotteries, C and D. Now for Table 2, at which row of lottery pairs would you begin to accept the Lottery D over Lottery C?

Table 2

Row	Lottery C		Lottery D	
	Ball 1-9	Ball 10	Ball 1-7	Ball 8-10
1	40	30	54	5
2	40	30	56	5
3	40	30	58	5

4	40	30	60	5
5	40	30	62	5
6	40	30	65	5
7	40	30	68	5
8	40	30	72	5
9	40	30	77	5
10	40	30	83	5
11	40	30	90	5
12	40	30	100	5
13	40	30	110	5
14	40	30	130	5

Your answer is in table 2:

I choose Lottery C for Row 1 to ____, and Lottery D for Row ____ to 14.

Consider the final pair of Lotteries, E and F. Now for Table 3, at which row of lottery pairs would you begin to accept the Lottery F over Lottery E? (Note: Negative income implies money you are going to lose.)

Table 3

Row	Lottery E		Lottery F	
	Ball 1-5	Ball 6-10	Ball 1-5	Ball 6-10
1	25	-4	30	-21
2	4	-4	30	-21
3	1	-4	30	-21
4	1	-4	30	-16
5	1	-8	30	-16
6	1	-8	30	-14
7	1	-8	30	-11

Your answer is in table 3:

I choose Lottery E for Row 1 to ____, and Lottery F for Row ____ to 14.

Instruction-Mechanism S-a-1

……

Allocation Procedures.……

Procedure 1 (post-score submission):

……

Step 3-5 is the process used to allocate students to schools:

- Step 3. The student with the highest score among all the three has its application sent to her first ranked school in the Decision sheet. She will be accepted by the school, and the applicant and her position is removed from the system.
- Step 4. The student with the second highest score has its application sent to her first ranked school in the Decision sheet.
  - ✓ If the school's slot is still available, it accepts the applicant. The applicant and her position is removed from the system.
  - ✓ If the school's slot is not available, the student is rejected by the school and its application is sent to her second ranked school. She will be accepted by the school, and the applicant and her position is removed from the system.
- Step 5. The applicant with the lowest score has its applicant sent to her first ranked school in the Decision sheet.
  - ✓ If the school's slot is still available, it accepts the applicant.
  - ✓ If the school's slot is not available, the student is rejected by the school and its application is sent to her second ranked school.
    - If the school's slot is still available, it accepts the applicant.
    - If the school's slot is not available, the student is rejected by the school and its application is sent to her third ranked school. She will be accepted by the school.

An example. ……

……

Step 3. The student with the highest score among all the three has its application sent to her first ranked school in the Decision sheet.

- Student 1 applies for school A.
- School A retains student 1. Student 1 and school A are removed from the subsequent process.

Step 4. The student with the second highest score has its application sent to her first ranked school (and second ranked school, and so on…… if needed) in the Decision sheet.

- Student 2 applies to school A.
- School A has no slots available thus rejects student 2. Student 2's application is sent to her second ranked school, school B.
- School B retains student 2. Student 2 and school B are removed from the system.

Step 5. The applicant with the lowest score has its applicant sent to her first ranked school in the Decision sheet.

- Student 3 applies to school A.
- School A has no slots available thus rejects student 3. Student 3's application is sent to her second ranked school, school B.
- School B has no slots available thus rejects student 3. Student 3's application is sent to her third ranked school, school C.

- School C retains student 3.

Here the process finishes; and the final allocations are the following.

Student/Applicant	1	2	3
School	A	B	C

……

Instruction-Mechanism B-p-1

……

In each round, all the participants have to indicate a preference ordering over schools.……Schools differ in quality, and students differ in their eagerness for different schools. So the desirability of schools for students in terms of quality and eagerness is summarized in the amounts shown in the payoff table (see Decision Sheets), which contains the payoff amounts in experimental currency units (ECU) corresponding to each participant and school slot. ……

……

Score Assignment and ranking.……

……

Each student will have an equal probability of getting three types of scores (namely high, normal, and low), where 100 represents full marks. Those three scores are the same for each of the three participants, so every student has the same average score. The following table contains the score distribution of each student (this is known by all participants):

Score number	Score 1 (high)	Score 2 (normal)	Score 3 (low)	Avg. score
Probability	1/3	1/3	1/3	
Student 1	95	90	85	90
Student 2	95	90	85	90
Student 3	95	90	85	90

Every student's exact score number will be drawn through the following procedure: First, one number is randomly picked from three numbers, 95, 90 and 85 and assigned as the score for a randomly chosen student from student 1, 2, 3. Then Another number is picked from the remaining two numbers for another randomly chosen student. And the single remaining student will be assigned the single remaining number. Note that through this procedure no two students have the same score.

……

Decision Sheet – Mechanism B-p-1

(Procedure 1: submission before score is known)

Recall: You will submit your preference ordering *without* knowing the exact score but only its distribution. Note that all the other participants know the distribution, meaning that every student knows every student's distribution of possible scores.

The score distribution of all the students is as the table below:

Score number	Score 1	Score 2	Score 3

	(high)	(normal)	(low)
Probability	1/3	1/3	1/3
Student 1	95	90	85
Student 2	95	90	85
Student 3	95	90	85

Students' exact scores will be drawn randomly without repetition from the above distribution.

Your payoff amount for each role you play in each procedure depends on the school slot you hold at the end of it. Your possible payoff amounts in each round are shown in the following table.

Slot received at school	A	B	C
Payoff of student 1 (ECU)	31	22	18
Payoff of student 2 (ECU)	31	22	18
Payoff of student 3 (ECU)	25	22	18

This means that, as student 1 and 2, if at the end of one round you hold a slot:

– at school A, you will be paid 31 ECU for this round;
– at school B, you will be paid 22 ECU for this round;
– at school C, you will be paid 18 ECU for this round.

And as student 3, if at the end of one round you hold a slot:

– at school A, you will be paid 25 ECU for this round;
– at school B, you will be paid 22 ECU for this round;
– at school C, you will be paid 18 ECU for this round.

Recall: There is only one slot opening at each school.

Recall: You will be asked to play the role of student 1, 2, 3 alternately. The sequence of role play will be determine by lottery.

……

Appendix 4: Supplementary Tables

Table A1: Ex-ante Blocking Pairs in Ability-wise Design

panel A: Average number of blocking-pairs under different mechanisms			
BOS-before	BOS-after	SD-before	SD-after
0.827	0.947	0.720	0.773
panel B: differences in numbers and p-values of significance tests			
before-after	BOSb-BOSa	BOSb-SDb	BOSb-SDa
-0.087	-0.120	0.107	0.053
(0.365)	(0.449)	(0.069)	(0.518)

Note: p-values are derived from running OLS regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the session level.

Table A2: Ex-post Blocking Pairs in Ability-wise Design

panel A: Average number of blocking-pairs under different mechanisms			
BOS-before	BOS-after	SD-before	SD-after
0.613	0.027	0.147	0.013
panel B: differences in numbers and p-values of significance tests			
before-after	BOSb-BOSa	BOSb-SDb	BOSb-SDa
0.360	0.587	0.467	0.600
(0.032)	(0.013)	(0.029)	(0.012)

Note: p-values are derived from running OLS regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the session level.

Table A4: Ex-post Blocking Pairs in Preference-wise Design

panel A: Average number of blocking-pairs under different mechanisms			
BOS-before	BOS-after	SD-before	SD-after
0.458	0.069	0.027	0.013

panel B: differences in numbers and p-values of significance tests			
BOSb-BOSa	SDb-SDa	BOSb-SDb	BOSa-SDa
0.389	0.013	0.432	0.056
(0.000)	(0.365)	(0.000)	(0.044)

Note: p-values are derived from running OLS regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the session level.

Table A5: Ex-Post Efficiency: differences in total profits and p-values of significance tests

BOSb-BOSa	BOSb-SDb	BOSb-SDa	before-after
0.000	0.000	0.000	0.000
(1.000)	(1.000)	(1.000)	(1.000)
0.000	0.375	0.000	-0.214
(1.000)	(0.364)	(1.000)	(0.323)
0.000	0.000	0.000	0.000
(1.000)	(1.000)	(1.000)	(1.000)
0.000	0.000	0.000	0.000
(1.000)	(1.000)	(1.000)	(1.000)
4.500	4.500	4.039	1.414
(0.064)	(0.064)	(0.089)	(0.331)
3.192	2.942	3.692	2.341
(0.015)	(0.088)	(0.003)	(0.072)

Appendix 5: Truth-Telling in Detail

Table A5 shows proportions of truth-telling behavior for each student role in the four mechanisms under the ability-wise design (fairness test). For all the students, truth-telling is relatively high under the two SD mechanisms between 60% and 90%. In the BOS mechanisms, for student 1, truth-telling is very high (96%) under the BOS-before mechanism but decreases to only 52% under the BOS-after mechanism. This is natural since for student 1, its ex-post score has a probability of 17/27=63% of being ranked first. This is the only case where she should tell the truth. In the case of student 2, under the BOS-before mechanism, almost half of subjects (45%) try to compete with student 1 by truth-telling, rather than listing school B first. This accounts for why our aggregate ex-ante fairness result does not strongly support hypothesis 1. The propensity to truth-tell is approximately the same as when student 2 submits after exam (under BOS-after), where she has a probability of 8/27=30% to be ranked first. For student 3, truth-telling is relatively low, particularly in BOS-before - likely because subjects acknowledge the strategic disadvantage of doing so.

Table A5: Truth-telling under Ability-wise Design

panel A: proportions of truth-telling under different mechanisms				
student type	BOS-before	BOS-after	SD-before	SD-after
type 1	0.960	0.520	0.960	0.893
type 2	0.453	0.453	0.773	0.680
type 3	0.133	0.200	0.600	0.587
panel B: differences in proportions and p-values of significance tests				
student type	BOSb-BOSa	SDb-SDa	BOSb-SDb	BOSa-SDa
type 1	0.440	0.067	0.000	-0.373
	(0.000)	(0.096)	(1.000)	(0.000)
type 2	0.000	0.093	-0.320	-0.227
	(1.000)	(0.143)	(0.000)	(0.005)
type 3	-0.067	0.013	-0.467	-0.387
	(0.252)	(0.820)	(0.000)	(0.000)

Note: p-values are derived from running probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism Standard errors are corrected for clusters on the subject level.

Table A6 shows proportions of truth-telling behavior for each student role under preference-wise design (efficiency test). As in the ability-wise design, for all types of students, truth-telling is higher under the two SD mechanisms. Under the BOS-before mechanism, students 1 and 2 have a high proportion of truth-telling which is close to that under SD mechanisms. Since probability of being ranked first for each type of student is 1/3, it is easy to understand that under the BOS-after mechanism, each type has a proportion of truth-telling close to this probability (here around 40%). We are especially interested in the truth-telling behavior of student 3 under BOS-before mechanism. Although in theory, student 3 should not submit school A as their first choice, in the experiment 32% of subjects do so.

Table A6: Truth-telling under Preference-wise Design

panel A: proportions of truth-telling under different mechanisms				
student type	BOS-before	BOS-after	SD-before	SD-after
type 1&2	0.875	0.410	0.960	0.860
type 3	0.319	0.458	0.880	0.853
panel B: differences in proportions and p-values of significance tests				
student type	BOSb-BOSa	SDb-SDa	BOSb-SDb	BOSa-SDa
type 1&2	0.465	0.100	-0.085	-0.450
	(0.000)	(0.001)	(0.007)	(0.000)
type 3	-0.139	0.027	-0.561	-0.395
	(0.076)	(0.619)	(0.000)	(0.000)

Note: p-values are derived from running probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the subject level.

Under the submission-after-exam mechanisms, rational students should base their submission only on their ex-post type, i.e., rankings of their realized scores. So we are interested in behaviors of different ex-post type of students under such mechanisms.

Table A7 summarizes truth-telling behaviors of students with different realized scores under ability-wise designs. Notably, the student with the second highest score is even less likely to list the best school as its first choice than student with the lowest score. One reason is that the student with the lowest score is indifferent between her two non-dominated strategies. But for student with the second highest score, it is critical to list the second best school as her first choice to avoid getting assigned to her last choice. Yet this explanation is only valid for BOS-after mechanism. But even under SD-after mechanism, when truth-telling is the dominant strategy, almost half of students with the second highest score still refuse to do so. Note that in the equilibrium it is still indifferent for this student to play the two non-dominated strategies. So students with a slight inclination toward fairness may lean toward choosing the second best school as her first choice.

Table A7: Truth-telling of students with different realized scores under submission-after-exam mechanisms: Ability-wise Design

panel A: proportions of truth-telling under BOS/SD-after mechanisms		
student type	BOS	SD
high-score	0.987	1.000
medium-score	0.013	0.493
low-score	0.173	0.667
panel B: differences in proportions and p-values of significance tests		
student type	BOS-SD	
high-score	-0.013	
	(0.316)	
medium-score	-0.480	

	(0.000)
low-score	-0.493
	(0.000)

Note: p-values are derived from running OLS/probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the subject level.

Table A8 examines the same issue under the preference-wise design. The finding is similar except that student with the second highest score now chooses truth-telling more frequently than under the ability-wise design. This may also be attributed to potential predispositions of fairness. In this case, the three students have the same expected scores, so the one who turns out to have a lower realized score may still feel she should submit as though her rights are equal to the others'.

Table A8: Truth-telling of students with different realized scores under submission-after-exam mechanisms: Preference-wise Design

panel A: proportions of truth-telling under BOS/SD-after mechanisms		
student type	BOS	SD
high-score	0.958	0.987
medium-score	0.083	0.827
low score	0.236	0.760

panel B: differences in proportions and p-values of significance tests	
student type	BOS-SD
high-score	-0.028
	(0.398)
medium-score	-0.743
	(0.000)
low-score	-0.524
	(0.000)

Note: p-values are derived from running OLS/probit regression of truth-telling dummies on mechanism/timing dummies within timing/mechanism. Standard errors are corrected for clusters on the subject level.

Appendix 6: Robustness Checks for Order Effects

Recall that for each mechanism under each treatment, we conducted two sub-sessions, one with pre-score preference submission and one with post-score preference submission, with the sequence altered in two different sessions.

Table A10 shows the between-session effects for major indicators we are concerned about. For most of those indicators, between-session effects are insignificant. There are only a few variables which significantly differ between sessions and they are scattered into different mechanisms and treatments, meaning that on average no single mechanism or treatment shows any consistent difference. For those which are significant, our qualitative conclusions still remain. We conclude that our results are robust to treatment order effects.

Table A10: Between Session Effects

design	mechanism	session 1	session 2	dif	p-value	sig. level
			panel A: truth-telling			
abi-wise	BOS-before	0.481	0.547	0.066	0.328	
	BOS-after	0.343	0.436	0.093	0.153	
	SD-before	0.778	0.778	0.000	1.000	
	SD-after	0.735	0.704	-0.031	0.603	
pref-wise	BOS-before	0.667	0.713	-0.046	0.464	
	BOS-after	0.463	0.389	0.074	0.273	
	SD-before	0.899	0.960	-0.061	0.068	*
	SD-after	0.838	0.873	0.035	0.463	
			Panel B: ex-ante fair			
abi-wise	BOS-before	0.417	0.385	0.032	0.781	
	BOS-after	0.389	0.205	0.184	0.083	*
	SD-before	0.462	0.361	0.100	0.384	
	SD-after	0.231	0.417	-0.186	0.087	*
			Panel C: ex-ante efficiency(total payoff)			
pref-wise	BOS-before	70.833	70.000	0.833	0.047	**
	BOS-after	68.833	69.000	-0.167	0.808	
	SD-before	69.727	68.857	0.870	0.175	
	SD-after	69.000	68.857	0.143	0.833	
			Panel D: ex-post fair			
abi-wise	BOS-before	0.278	0.513	-0.235	0.038	**
	BOS-after	0.972	1.000	-0.028	0.301	
	SD-before	0.795	0.917	-0.122	0.140	
	SD-after	1.000	0.972	0.028	0.301	
pref-wise	BOS-before	0.583	0.500	0.083	0.485	
	BOS-after	0.917	0.944	-0.028	0.649	
	SD-before	0.970	0.976	-0.006	0.865	
	SD-after	0.970	1.000	-0.030	0.262	

Note: ***=sig. at 1% level, **=sig. at 5% level, *=sig. at 10% level.

Appendix 7: Supplementary Figures:

Figure 3(a): Truth-telling under Ability-wise Design

(Means and 95% confidential intervals are shown)

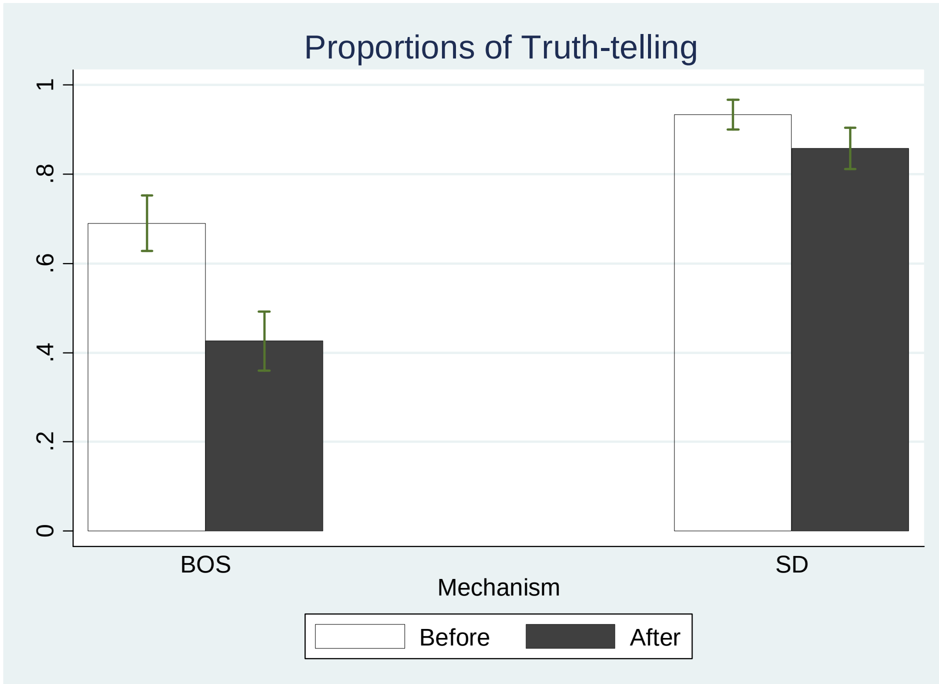

Figure 3(b): Truth-telling under Preference-wise Design

(Means and 95% confidential intervals are shown)

Figure 5: Ex-post Fairness under Preference-wise Design

(Means and 95% confidential intervals are shown)