Affirmative Action through Minority Reserves: An Experimental Study on School Choice

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Abstract

Minority reserves are an affirmative action policy proposed by Hafalir et al. [19] in the context of school choice. We study in the laboratory the effect of minority reserves on the outcomes of two prominent matching mechanisms, the Gale-Shapley and the Top Trading Cycles mechanisms. Our first experimental result is that the introduction of minority reserves enhances truth-telling of some minority students under the Gale-Shapley but not under the Top Trading Cycles mechanism. Secondly, for the Gale-Shapley mechanism we also find that the stable matchings that are more beneficial to students are obtained more often relative to the other stable matchings when minority reserves are introduced. Finally, the overall expected payoff increases under the Gale-Shapley but decreases under the Top Trading Cycles mechanism if minority reserves are introduced. However, the minority group benefits and the majority group is harmed under both mechanisms.

Keywords: affirmative action, minority reserves, school choice, deferred acceptance, top trading cycles, truth-telling, stability, efficiency.

JEL–Numbers: C78, C91, C92, D78, I20.

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1 Introduction

The concern for diversity has lead many school districts in the U.S. to take affirmative action in promoting equal access for those groups that have been traditionally excluded, thus becoming more representative of their surrounding community. As such, school choice programs give students the opportunity to express their preferences over schools and thus provide choice to students, but the final assignment is also shaped by admission policies that aim at maintaining racial, ethnic, or socioeconomic balance.\(^1\)

In the last decade, matching theory and mechanism design have been employed to accommodate affirmative action in school choice. For instance, Abdulkadiroğlu and Sönmez [2] and Abdulkadiroğlu [1] consider a cap or maximum quota on the number of students from the same group that a school can admit. Kojima [23] shows that affirmative action policies based on maximum quotas can be detrimental to the very minorities they are supposed to help. More precisely, for the widely studied Gale-Shapley (GS) and Top Trading Cycles (TTC) mechanisms there are environments in which every minority student is hurt by the introduction of maximum quotas. The intuition behind this result is as follows. If there is a school that is mostly wanted by majority students, it may end up with unfilled seats and unassigned majority students may create competition for seats at other schools, thus hurting minority students.

To overcome this problematic feature of placing bounds on the number of seats for majority students, Hafalir et al. [19] propose an affirmative action policy by reserving seats for minority students. Here, schools give higher priority to minority students up to the point when minorities fill the reserves, so that a school may assign some of its reserved seats to majority students provided that no minority student prefers that school to her assigned school. Hafalir et al. [19] adapt GS and TTC to minority reserves and explore the properties of the resulting mechanisms. They show that the GS and TTC mechanisms with minority reserves preserve the property of strategy-proofness, i.e., no student can ever benefit by misrepresenting her preferences. Moreover, when all students tell the truth there is a clear sense in which minority reserves present an improvement over majority quotas. Indeed, the GS with minority reserves (weakly) Pareto dominates the GS with majority quotas and, considering minority students only, is not strictly Pareto dominated by the standard GS. As for TTC, the advantage is less clear, but it is still the case that, for minority students, the TTC with minority reserves is not strictly Pareto dominated by the standard TTC.

Still, the theoretical results may easily break down in practice. It is well documented in the experimental literature on school choice that agents do not always realize it is in their best interest to reveal their true preferences when confronted with strategy-proof mechanisms.\(^2\) Two strategy-proof mechanisms may therefore be perceived differently and give rise to very different types and levels of non-truthful behavior. Therefore, whether or not affirmative action policies actually benefit minority students may well depend on how agents perceive the different mechanisms.

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\(^1\) See, for instance, Abdulkadiroğlu and Sönmez [2].

\(^2\) See, for instance, Calsamiglia et al. [6], Chen and Kesten [7], Chen and Sönmez [8], Featherstone and Niederle [14], Klijn et al. [22], Pais and Pintér [25].
This provided the motivation for our experimental study. We consider four mechanisms: the standard GS, the standard TTC, and the two counterparts proposed in Hafalir et al. [19], i.e., GS with minority reserves and TTC with minority reserves. We present a stylized environment where six students —four majority and two minority— are to be assigned to three schools with two positions each. When minority reserves are present, each school reserves exactly one seat for minority students. Preferences of students over schools are such that it is possible to assign each student to the school she ranks first. This is the student-optimal stable matching and the unique Pareto-efficient outcome, which is obtained under any of the four mechanisms when all students tell the truth. Schools’ priorities over students are such that there is a strong opposition of interests between the two sides of the school choice problem. As a result, under the standard mechanisms, the Pareto-efficient outcome can only be reached when exactly all students coordinate and rank their most preferred school first.

In this environment, higher truth-telling rates increase the frequency of the Pareto-efficient outcome. At the same time, minority reserves may have a positive effect on truth-telling. In fact, minorities may feel protected when minority reserves are used and thus compelled to tell the truth more often. Given the coordination element in this setup, as minority students tell the truth more often, the easier it is for other students to recognize truth-telling as the best possible strategy. It follows that spillovers on the truth-telling rates of majority students may occur.

Our results show that truth-telling by minority students increases when minority reserves are introduced in GS, but not in TTC (Result 1). We might expect that increased truth-telling by minority students would positively affect the truth-telling rates of majority students, but this is not observed in the data. In what the final outcome is concerned, the proportion of stable matchings does not necessarily increase when minority reserves are introduced; however, under GS, the stable matchings that are more beneficial to students are obtained more often with respect to the other stable matchings when minority reserves are added. In fact, the probability distribution over stable matchings under GS with minority reserves first-order stochastically dominates the distribution obtained under the standard GS mechanism, but the converse holds for TTC (Result 2). Finally, we have the following findings on efficiency. Despite the simplicity of the environment and the strong coordination element of the setup, expected payoffs do not necessarily increase with the introduction of minority reserves. In fact, the introduction of minority reserves in both GS and TTC harms majority students, even though it benefits minority students inasmuch as the expected payoff of minority students as a group increases (Result 3). This efficiency advantage is actually very clear for minority students in GS as the distribution of a minority student’s payoffs under GS with minority reserves first-order stochastically dominates her payoff distribution under the standard GS (Result 3). Instead, the distribution of several majority students’ payoffs under the standard TTC first-order stochastically dominates that under the TTC with minority reserves.

Motivated by the theoretical findings of Hafalir et al. [19], we focus on affirmative action through

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3A matching is stable if, for any student, all the schools she prefers to the one she is assigned to have exhausted their capacity with students that have higher priority. The student-optimal stable matching is the stable matching that is unanimously preferred by the students to all other stable matchings.
minority reserves. However, other types of affirmative action in school choice are studied in the literature as well. Kominers and Sönmez [24] generalize Hafalir et al. [19] to allow for slot-specific priorities. Westkamp [27] studies the German university admissions system, where priorities may also vary across slots, and Braun et al. [4] and Braun et al. [5] complement his analysis by conducting a field experiment and a laboratory experiment, respectively. The laboratory experiment confirms the result in Westkamp [27] that the mechanism that is currently used for university admissions in Germany, designed to give top-grade students an advantage, actually harms them. Kamada and Kojima [21] study entry-level medical markets in Japan, where regional caps are used to overcome the shortage of doctors in rural areas. Moreover, Ehlers et al. [12], Fragiadakis et al. [16], and Fragiadakis and Troyan [17] combine lower and upper bounds on the number of students of each type. Finally, Echenique and Yenmez [11] and Erdil and Kumano [13] study generalizations of schools’ priorities over sets of students with the aim of capturing diversity.

The remainder of the paper is organized as follows. We describe the stylized school choice problem and the mechanisms in Section 2. In Section 3, we present our experimental hypotheses and, in Section 4, we describe the obtained experimental results. Section 5 concludes.

2 The experiment

2.1 The school choice problem

Our experiment aims at analyzing the effect of minority reserves on the functioning of the Gale-Shapley and the Top Trading Cycles mechanisms in school choice. We consider throughout the problem described in Table 1, which we explain next.

<table>
<thead>
<tr>
<th>Preferences</th>
<th>Priorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>$M_1$</td>
<td>$s_1$</td>
</tr>
<tr>
<td>$M_2$</td>
<td>$s_2$</td>
</tr>
<tr>
<td>$M_3$</td>
<td>$s_3$</td>
</tr>
<tr>
<td>$M_4$</td>
<td>$s_4$</td>
</tr>
<tr>
<td>$m_1$</td>
<td>$s_5$</td>
</tr>
<tr>
<td>$m_2$</td>
<td>$s_6$</td>
</tr>
</tbody>
</table>

Table 1: Preferences of students over schools (left) and priority orderings of schools over students (right).

Six students look for a seat at one of three schools. Four students —indicated by $M_1$, $M_2$, $M_3$, and $M_4$— belong to the majority group, and two students —$m_1$ and $m_2$— form the minority group. The three schools are denoted by $s_1$, $s_2$, and $s_3$. Each school offers exactly two seats.

Table 1 shows that the students can be divided into three groups according to their preferences. Students $M_1$ and $M_2$ like $s_1$ most and $s_3$ least, students $M_3$ and $M_4$ like $s_3$ most and $s_2$ least, and students $m_1$ and $m_2$ like $s_2$ most and $s_1$ least. Since all schools offer two seats, it is feasible
to assign all students to their most preferred school, which is therefore the unique Pareto-efficient outcome.¹ The priority orderings of the schools are such that students $M_1$, $M_3$, and $m_1$ are ranked fifth in their most preferred, fourth in their second most preferred, and first in their least preferred school. Similarly, students $M_2$, $M_4$, and $m_2$ are ranked last in their most preferred, third in their second most preferred, and second in their least preferred school. We chose this particular problem for two main reasons. First, the structure of the priority orderings puts some tension on obtaining the Pareto-efficient outcome as, by looking at the priority orderings only, it seems “easier” for a student to get a seat at less desirable schools. Still, if all students report their true preferences, each student will be admitted to her top school, so that there is a strong coordination element in this setup. Second, in the absence of any positive discrimination in favor of the minority students, $m_1$ is in exactly the same situation as $M_1$ and $M_3$ (and $m_2$ faces exactly the same decision problem as $M_2$ and $M_4$). This symmetry helps us to evaluate the effect of the minority reserves on the two mechanisms in a clear-cut way.

During the experiment, subjects assume the role of students that seek to find a seat at one of the schools. Schools are not strategic players. Given the information in Table 1, the subjects’ task is to submit a ranking over schools (not necessarily the true preferences) to be used by a central clearinghouse to assign students to schools. They receive 12 experimental currency units (ECU) in case they end up in their most preferred school, 9 ECU if they get a seat in their second most preferred school, and 6 ECU if they study in their least preferred school.

We consider four different matching mechanisms. Our two baseline mechanisms that treat all students equally are the standard Gale-Shapley student proposing deferred acceptance mechanism (GSs) and the standard Top Trading Cycles mechanism (TTCs). Following Hafalir et al. [19], the corresponding two modified mechanisms, denoted by GSm and TTCm, favor the minority group by obliging each school to reserve one seat to students from this group in case it is demanded; that is, each school has a minority reserve of 1. For the particular school choice problem at hand, the four mechanisms are as follows:

**Gale-Shapley mechanisms (GSs and GSm)**

**Step 1.** Each student sends an application to the school she ranked first.

**Step 2.** Each school that receives at least one application acts as follows.

*(GSs)* It temporarily accepts the applicant with the highest priority. It also temporarily accepts the applicant with the highest priority among all remaining applicants (if any). The rest of the applicants (if any) are rejected.

*(GSm)* If the school receives no application from minority students, proceed as in Step 2 of GSs. If the school receives at least one application from minority students, then it temporarily accepts the minority applicant with the highest priority; it also temporarily accepts

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¹Schools are considered mere objects and are thus not taken into account for welfare evaluation.
the applicant with the highest priority among all remaining (majority or minority) applicants (if any); the rest of the applicants (if any) are rejected.

Step 3. Whenever a student is rejected by a school, she applies to the next highest ranked school.

Step 4. Each school that receives at least one new application acts as follows.

\( GSs \) Among all new and retained applications, the school temporarily accepts the applicant with the highest priority. Among the remaining (new and retained) applications (if any), it also temporarily accepts the applicant with the highest priority (if any). The rest of the applicants (if any) are rejected.

\( GSm \) The school considers the new and the retained applications. If none of these applications is from a minority student, proceed as in Step 4 of \( GSs \). If there is at least one application from a minority student, the school temporarily accepts the minority applicant with the highest priority; it also temporarily accepts the applicant with the highest priority among all remaining (majority or minority) applicants (if any); the rest of the applicants (if any) are rejected.

Step 5. Steps 3 and 4 are repeated until no more students are rejected, and the assignment is finalized. Each student is matched to the school that holds her application at the end of the process.

\[ \text{Top Trading Cycles mechanisms (TTCs and TTCm)} \]

Step 1. Each student points to the school she ranked first.

\( TTCs \) Each school points to the student with the highest priority.

\( TTCm \) Each school points to the minority student with the highest priority.

There is at least one cycle of students and schools. Each student in any of the cycles is matched to the school she is pointing to and the school’s number of available seats is reduced by one.

Step 2. Each unmatched student points to the school she ranks highest among all schools that still have available seats.

\( TTCs \) Each school with at least one available seat points to the student with the highest priority among all remaining students.

\( TTCm \) A school that was not matched to a minority student before points to

- the unmatched minority student if there is one,\(^5\) and otherwise points to
- the majority student with the highest priority among all remaining students.

\(^5\)Since in Step 1 all schools point to minority students and since there is at least one cycle, at least one minority student is matched in Step 1. Hence, in Step 2 there is at most one minority student.
A school that was already matched to a minority student points to the student (minority or majority) with the highest priority among all remaining students.

There is at least one cycle of students and schools. Each student in any of the cycles is matched to the school she is pointing to and the school’s number of available seats is reduced by one.

Step 3. Repeat Step 2 until all students are matched.

### 2.2 Procedures

The experiment was programmed within the z–Tree toolbox provided by Fischbacher [15] and carried out in the computer laboratory at a local university. We used the ORSEE registration system by Greiner [18] to invite students from a wide range of faculties. In total, 175 undergraduates from various disciplines participated in the experiment.

We considered two matching mechanisms in each session. At the beginning of the session, subjects were anonymously matched into groups of six. Each subject received instructions for one of the four mechanisms together with an official payment receipt and was told that she would play two games under this mechanism: once in her true and once in a fictitious role.\(^6\)

Subjects could study the instructions at their own pace and any doubts were privately clarified. Participants were also informed that after this first phase of two games they would take part in a second phase with a different matching mechanism. Subjects knew that their decisions in the first phase would not affect their payoffs in the second phase (to avoid possible hedging across phases) and that they would not receive any information regarding the decisions of any other player (so that they could not condition their actions in the second phase on the behavior of other participants under the first matching mechanism). Also, no feedback whatsoever was provided during the entire experiment. In theory, therefore, the two phases are independent from each other.

After completing the two games under the first mechanism, subjects received instructions for the second mechanism. The group assignment did not change and subjects took decisions in the same roles (neither the true nor the fictitious role changed). To prevent income effects, either the first or the second mechanism in the true roles was payoff relevant, which was randomly determined by the central computer at the end of the experiment. The whole procedure was known by the subjects from the beginning.

We ran a total of eight sessions in such a way that each mechanism was played four times.

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\(^6\)This procedure allows us to collect the same number of observations for both minority and majority students. Since subjects did not know which of their roles was true and which was fictitious, incentives are not affected. The true (fictitious) role of the six subjects in a group were: \(M_1 \, (m_1)\) for the first, \(M_2 \, (m_2)\) for the second, \(M_3 \, (m_1)\) for the third, \(M_4 \, (m_2)\) for the fourth, \(m_1 \, (M_1)\) for the fifth, and \(m_2 \, (M_2)\) for the sixth subject. We distinguish between true and fictitious roles in the instructions because it is not possible to calculate the outcome when subjects act in their fictitious roles as there are four subjects who play the game in the role of a minority student and two subjects in the role of a majority student. So, the actions in the fictitious roles cannot be used for payment.
Subjects received 1 Euro per ECU earned during the experiment. A typical session lasted about 75 minutes and subjects earned on average 12 Euro (including a 3 Euro show-up fee) for their participation.

3 Hypotheses

We derive the null hypothesis of the experiment by analyzing the economic incentives of the students. It is well-known that in the setting without minority reserves, the Gale-Shapley and the Top Trading Cycles mechanisms are strategy-proof (see Dubins and Freedman [10], Roth [26], and Abdulkadiroğlu and Sönmez [2]); that is, no student can gain from misrepresenting her preferences. Strategy-proofness of the corresponding mechanisms with minority reserves is established in Hafalir et al. [19]. If students indeed report their preferences truthfully, all four mechanisms assign all students to their most preferred school. It follows that the resulting matching is the student-optimal stable matching and the unique Pareto-efficient outcome.

**Null Hypothesis:** In all four mechanisms, preferences are revealed truthfully. Hence, all four mechanisms generate the student-optimal stable matching and are Pareto-efficient.

The construction of the alternative hypotheses starts from the general experimental observation that not all subjects reveal preferences truthfully when the standard mechanisms are employed; see, for instance, Calsamiglia et al. [6], Chen and Kesten [7], Chen and Sönmez [8], Featherstone and Niederle [14], Klijn et al. [22], and Pais and Pintér [25]. To say it differently, we presume that there is a considerable number of subjects who do not realize that it is in their best interest to report their true preferences under GSs and TTCs. Then, since $M_1$, $M_3$, and $m_1$ (and similarly, $M_2$, $M_4$, and $m_2$) all face the same situation when there are no minority reserves and the mechanisms do not distinguish between majority and minority students, it is natural to hypothesize that the level of truthfully reported preferences is the same for these students.

**Alternative Hypothesis 1:** In the absence of minority reserves, that is for both GSs and TTCs, there is no difference in the level of truthfully reported preferences between $M_1$, $M_3$, and $m_1$. Similarly, the degree of truth-telling among $M_2$, $M_4$, and $m_2$ is the same.

On the other hand, the introduction of minority reserves has the potential to positively affect the level of truth-telling among minority students, now facing reduced competition for their top

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7The combinations of mechanisms in the eight sessions were as follows: session 1 = GSs − GSm, session 2 = GSm − GSs, session 3 = GSm − TTCm, session 4 = TTCm − GSm, session 5 = TTCm − TTCs, session 6 = TTCs − TTCm, session 7 = TTCs − GSs, and session 8 = GSs − TTCs. In total, we have 92 observations for GSs, 83 observations for GSm, 92 observations for TTCs, and 82 observations for TTCm.

8We focus on truth-telling, as it is interesting on its own right. Nevertheless, to be precise, having all students ranking their preferred school first is sufficient for such an assignment to be obtained.
schools. This effect is clear in the case of student $m_1$. In the presence of minority reserves, $m_1$ will be assigned to her most preferred school, $s_2$, in case she puts that school on the top of her reported preferences \textit{independently of the behavior of the other students}. Having realized this, rationality implies that $m_1$ puts $s_2$ on the top of her list. Furthermore, as there is no reason why $m_1$ would invert the true order of the other schools on her list, ultimately we may expect her to tell the truth. So, even though $m_1$ may not be aware of the strategy-proofness of $GSm$ and $TTCm$, she may be tempted to reveal her true preferences because minority reserves render the strategic uncertainty of this student irrelevant.\footnote{A player has strategic uncertainty if she is unsure about the actions or beliefs (or beliefs of beliefs, etc.) of others; see Brandenburger [3] for a formal definition and Heinemann \textit{et al.} [20] for an experimental application to coordination games.}

The case for $m_2$ is less obvious, as she still faces competition from $m_1$ for her top school, but nonetheless strategic uncertainty for $m_2$ is reduced by the introduction of minority reserves as she should have a better idea about the behavior of $m_1$ and still holds an advantage over majority students. This reduction in strategic uncertainty should help $m_2$ to make better decisions; that is, manipulate less often in the presence than in the absence of minority reserves and less often than the corresponding majority students when there are minority reserves.

**Alternative Hypothesis 2:** Minority students report preferences truthfully more often in the presence than in the absence of minority reserves. In both $GSm$ and $TTCm$, the level of truth-telling of student $m_1$ is higher than the level of truth-telling of $M_1$ and $M_3$ and the level of truth-telling of student $m_2$ is higher than the level of truth-telling of $M_2$ and $M_4$.

Given the strong coordination element in our setup, the higher level of truth-telling for minority students might be foreseen by the other students, who, as a consequence, see their own strategic uncertainty reduced and are therefore also more inclined to report preferences truthfully in the presence of minority reserves.

**Alternative Hypothesis 3:** The mechanisms with minority reserves generate more truth-telling among all students than the corresponding mechanisms without minority reserves.

So far, we have discussed how minority reserves might affect the level of truth-telling. Next, we analyze the implications of these hypotheses on the likelihood that stable matchings are obtained. In our school choice problem, there are a total of five stable matchings (see Table 2), which, as is explained next, the students unanimously rank from worst to best. In the stable matching that is least attractive to the students, denoted by $\mu_1$, each student is assigned to her worst school. So, the expected payoff from this matching (including the show-up fee of 3 ECU) is equal to 9 ECU. In the stable matching $\mu_2$, three students ($M_2$, $M_4$, and $m_2$) are assigned to their second best school and the other three students ($M_1$, $M_3$, and $m_1$) are at their worst school. The expected payoff of $\mu_2$ is thus 10.5 ECU. The stable matching $\mu_3$ assigns all students to their second best school,
which leads to an expected payoff of 12 ECU. In the stable matching $\mu_4$, the students $M_1$, $M_3$, and $m_1$ are assigned to their best and the students $M_2$, $M_4$, and $m_2$ to their second best school. Hence, the expected payoff of $\mu_4$ is 13.5 ECU. Finally, all students get a seat at their best school in the student-optimal stable matching $\mu_5$. Therefore, this matching is Pareto-efficient (and the expected payoff per student is 15 ECU).

<table>
<thead>
<tr>
<th>Student</th>
<th>Stable matching</th>
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<tbody>
<tr>
<td></td>
<td>$\mu_1$</td>
</tr>
<tr>
<td>$M_1$</td>
<td>$s_3$</td>
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<tr>
<td>$M_2$</td>
<td>$s_3$</td>
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<tr>
<td>$M_3$</td>
<td>$s_2$</td>
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<td>$M_4$</td>
<td>$s_2$</td>
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<tr>
<td>$m_1$</td>
<td>$s_1$</td>
</tr>
<tr>
<td>$m_2$</td>
<td>$s_1$</td>
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</tbody>
</table>

Expected payoff (in ECU) $\begin{bmatrix} 9 & 10.5 & 12 & 13.5 & 15 \end{bmatrix}$

Table 2: Stable matchings.

Under Alternative Hypothesis 2, minority students are more likely to report preferences truthfully when the mechanisms with minority reserves are employed. For $m_1$, this implies that she directly obtains a seat at her top school $s_2$. In terms of the stable matchings, $m_1$ is assigned to $s_2$ only in $\mu_4$ and $\mu_5$, so that if stability is obtained when minority reserves are introduced, we should expect the matchings $\mu_4$ and $\mu_5$ to be reached more often.

For $m_2$ the effects are less clear, since even though this student sees her strategic uncertainty reduced, her final assignment when telling the truth still depends on the behavior of majority students. Moreover, it is clear that their behavior will affect the stability of the final outcome, so that we are not able to derive implications from Alternative Hypothesis 2 on how the proportion of stable matchings changes when minority reserves are introduced. This leads to the following alternative hypothesis.

**Alternative Hypothesis 4:** The probability of obtaining $\mu_4$ or $\mu_5$ relative to the other three stable matchings is higher in the presence than in the absence of minority reserves.

The affirmative action targets the minority group, and we have already seen that the mechanisms with minority reserve help (one of) these students to insure herself a seat at their most preferred school in an easy way. So, in order to evaluate the success of the discriminatory policy, one definitively demands that the payoff to the minority students as a group is higher when minority reserves are present. In our particular school choice problem, the effect of the minority reserves on the expected payoff of the majority group could be positive as well. Indeed, if the other students see their own strategic uncertainty reduced and become more likely to reveal
their true preferences (Alternative Hypothesis 3), then their own payoffs should increase as well.

**Alternative Hypothesis 5:** No student is harmed by the presence of minority reserves.

Note that in our particular environment, if all students tell the truth, the same outcome is obtained under the four mechanisms, whereas in other, more general contexts, this is not the case. In particular, in some settings, the effects of affirmative action on efficiency may actually be quite disappointing under full truth-telling.\(^{10}\)

## 4 Results

We now present the aggregate results of our experiment. We are interested in how the different mechanisms perform in terms of truth-telling (Section 4.1). Afterwards, we study the implications of individual behavior on stability (Section 4.2) and payoffs (Section 4.3).

### 4.1 Truth-telling

Table 3 shows the probabilities with which each of the six possible strategies is played. We use the notation \((2,3,1)\) for the ranking where a student lists her second most preferred school first, her least preferred school second, and her most preferred school last. The other five strategies \((1,2,3), (1,3,2), (2,1,3), (3,1,2),\) and \((3,2,1)\) have similar interpretations.

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Submitted ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1,2,3)</td>
</tr>
<tr>
<td>Gale–Shapley standard (GSs)</td>
<td>0.39</td>
</tr>
<tr>
<td>Gale–Shapley with minority reserves (GSm)</td>
<td>0.39</td>
</tr>
<tr>
<td>Top Trading Cycles standard (TTCs)</td>
<td>0.48</td>
</tr>
<tr>
<td>Top Trading Cycles with minority reserves (TTCm)</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Table 3: Probability distribution of submitted rankings (aggregated over all six roles).

It can be seen from the second column that truth-telling is the most prominent strategy in all four mechanisms —ranging from 34% in treatment \(TTCm\) to 48% in treatment \(TTCs\)—, in line with many experimental studies on matching,\(^{11}\) yet considerably lower than what is predicted by theory (the Null Hypothesis). Consequently, there are many subjects who do not realize that it

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\(^{10}\)In fact, it can only be guaranteed that if the affirmative action benefits no minority student, then at least one minority student is not worse off (see Hafalir et al. [19]). Moreover, when no minority student benefits from affirmative action, then also no majority student benefits (see Doğan [9]).

\(^{11}\)See the examples mentioned in Section 3.
is in their best interest to report preferences truthfully. The effects the different mechanisms and roles have on truth-telling can be identified with the help of Table 4.

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Student</th>
<th>$M_1$</th>
<th>$M_2$</th>
<th>$M_3$</th>
<th>$M_4$</th>
<th>$m_1$</th>
<th>$m_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gale-Shapley standard ($GS_s$)</td>
<td></td>
<td>0.47</td>
<td>0.37</td>
<td>0.37</td>
<td>0.27</td>
<td>0.44</td>
<td>0.37</td>
</tr>
<tr>
<td>Gale-Shapley with minority reserves ($GS_{m}$)</td>
<td></td>
<td>0.25</td>
<td>0.30</td>
<td>0.43</td>
<td>0.14</td>
<td>0.76</td>
<td>0.44</td>
</tr>
<tr>
<td>Top Trading Cycle standard ($TTC_s$)</td>
<td></td>
<td>0.53</td>
<td>0.55</td>
<td>0.50</td>
<td>0.33</td>
<td>0.58</td>
<td>0.39</td>
</tr>
<tr>
<td>Top Trading Cycle with minority reserves ($TTC_{m}$)</td>
<td></td>
<td>0.50</td>
<td>0.42</td>
<td>0.21</td>
<td>0.07</td>
<td>0.55</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Table 4: Probability of truth-telling.

First, we know from Table 1 that students $M_1$, $M_3$, and $m_1$ face the same situation: they are ranked fifth in their most preferred school, fourth in their second most preferred school, and first in their least preferred school. A similar kind of symmetry holds true for students $M_2$, $M_4$, and $m_2$. Consequently, one would expect that the proportion of truth-telling of the minority students is the same as that of their majority counterparts in the absence of minority reserves when there is no positive discrimination and the matching mechanisms treat subjects equally (Alternative Hypothesis 1). Mann-Whitney U tests confirm this intuition in all cases.\(^{12}\)

Second, the introduction of minority reserves has one important effect. Independently of the behavior of the other students, $m_1$ can now directly grab a seat in her most preferred school by ranking this school first and $m_2$ faces reduced competition as minority reserves give her an advantage over majority students. Hence, Alternative Hypothesis 2 stated that minority students tell the truth more often than their majority counterparts in the presence of minority reserves and increase their own level of truth-telling with respect to the situation when there are no minority reserves. In fact, we find that student $m_1$ tells the truth more often than both $M_1$ and $M_3$ in $GS_{m}$ and more often than $M_3$ in $TTC_{m}$.\(^{13}\) Student $m_1$ also tells the truth more frequently in $GS_{m}$ than in $GS_s$ (two-sided $p=0.0019$). Since $m_1$ tells the truth more often in $TTC_s$ than in $TTC_{m}$, it is clear that minority reserves do not effect the level of truth-telling of this student positively under $TTC$. This interpretation is further strengthened when one compares the behavior of this student in $GS_{m}$ with that in $TTC_{m}$. The level of truth-telling reaches 76% in $GS_{m}$ but “only” 55% in $TTC_{m}$ (two-sided $p=0.0406$).\(^{14}\) Furthermore, there is no statistical difference between $m_2$ and $M_2$ or $M_4$ and no evidence that $m_2$ tells the truth more often when minority reserves are introduced.\(^{15}\)

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\(^{12}\)The two-sided $p$-values under $GS_s$ are 0.4840 for the comparison between $m_1$ and $M_1$, 0.3458 for $m_1$ and $M_3$, 0.4840 for $m_2$ and $M_2$, and 0.3458 for $m_2$ and $M_4$. The two-sided $p$-value under $TTC_s$ are 0.4840 for the comparison between $m_1$ and $M_1$, 0.7728 for $m_1$ and $M_3$, 0.5653 for $m_2$ and $M_2$, and 0.4237 for $m_2$ and $M_4$.

\(^{13}\)The two $p$-values of the Mann Whitney U tests are 0.0015 (0.0107) for the comparison with $M_1$ ($M_3$) in $GS_{m}$ and 0.0368 for the comparison with $M_3$ in $TTC_{m}$.

\(^{14}\)And this occurs while it follows from Table 4 that the baseline level of truth-telling for $m_1$ in the absence of minority reserves is higher for the Top Trading Cycles than for the Gale-Shapley mechanism (58% vs. 44%).

\(^{15}\)The two-sided $p$-values of the Mann Whitney U tests range from 0.1294 (when comparing $m_2$ with $M_4$ under
Finally, we would also like to know whether the possible higher level of truth-telling of minority students in the presence of minority reserves is anticipated by the other participants, and whether this change in their beliefs induces them to tell the truth more often as well (Alternative Hypothesis 3). However, we do not find any significant spillover effect of this kind.\footnote{The two-sided $p$-values of the Mann Whitney U tests range from 0.0835 to 0.8173.} So, either the other subjects are not aware of the different situation of the minority students or they do not respond to this change in their beliefs. We summarize as follows.

**Result 1.** There is a positive effect of minority reserves on the level of truth-telling of $m_1$ under the Gale-Shapley mechanism. There are no spillover effects on other students.

### 4.2 Stability

We now analyze the effects of the minority reserves on the probability of stable matchings.

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Overall</th>
<th>Breakdown by stable matching</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\mu_1$</td>
<td>$\mu_2$</td>
</tr>
<tr>
<td>Gale–Shapley standard ($GSs$)</td>
<td>0.3452</td>
<td>0.0125</td>
</tr>
<tr>
<td>Gale–Shapley with minority reserves ($GSm$)</td>
<td>0.1318</td>
<td>0.0099</td>
</tr>
<tr>
<td>Top Trading Cycles standard ($TTCs$)</td>
<td>0.0460</td>
<td>0.0152</td>
</tr>
<tr>
<td>Top Trading Cycles with minority reserves ($TTCm$)</td>
<td>0.1157</td>
<td>0.0320</td>
</tr>
</tbody>
</table>

*Table 5: Probability of stable matchings.*

Our first observation is that under Gale-Shapley the probability of obtaining a stable matching is significantly reduced when minority reserves are introduced. It seems that many students do not tell the truth under $GSs$, but instead rank their second best school first, implying that the stable matching $\mu_3$, where each student is assigned to her second best school, is reached in almost 60% of the times a stable matching is obtained. However, under $GSm$, the fact that $m_1$ tells the truth significantly more, resulting in her immediate assignment to her top school, prevents the outcome from being $\mu_3$. This combined with the fact that there are no spillovers on truth-telling, leads to reaching $\mu_4$ alone more often. It follows that, under $GSm$, $\mu_4$ is the most frequent stable outcome, representing 81% of the stable outcomes obtained and ensuring that Alternative Hypothesis 4 cannot be rejected.\footnote{Due to the very large number of recombinant combinations, all pairwise comparisons are significant at $p = 0.01$. This is also true for the analysis that follows in the remainder of this subsection and the next subsection on payoffs.} But the numbers in Table 5 allow us to go further as a closer inspection unveils a sharper result: the probability distribution of stable matchings obtained under $GSm$ first-order stochastically dominates the one obtained under $GSs$. It is clearly the case that, conditional $GSm$ to 0.5297 (for the comparison with $M_2$ under $TTCm$). The two-sided $p$-values associated to the introduction of minority reserves are 0.8798 for $GS$ and 0.4116 for $TTC$.\footnote{The two-sided $p$-values of the Mann Whitney U tests range from 0.0835 to 0.8173.}
upon stability, introducing minority reserves in Gale-Shapley actually shifts the probability mass over matchings towards those that are more beneficial to students.

In contrast, introducing minority reserves under Top Trading Cycles increases the chances of reaching stability, but the probability of obtaining the matchings $\mu_4$ and $\mu_5$ within the set of stable matchings actually decreases from roughly 93% to 57% (and Alternative Hypothesis 4 can be rejected). As noted above, there is no increase in $m_1$’s truth-telling rate when minority reserves are introduced. However, there is a slight increase in the number of times $m_1$ ranks her worst school first, as well as an increase in the number of times $m_2$ ranks her second best school first, resulting in outcomes where minority students are matched to these schools more often.\textsuperscript{18}

Even though not significant statistically, these differences in behavior actually have an impact on outcomes, rendering $\mu_2$ more frequent and $\mu_5$ less frequent. This happens to such an extent that the distribution over stable matchings under $TTCs$ first-order stochastically dominates the distribution under $TTCm$.

**Result 2.** The probability distribution over stable matchings obtained under $GSm$ first-order stochastically dominates the one obtained under $GSs$. Conversely, the probability distribution over stable matchings under $TTCs$ first-order stochastically dominates the one obtained under $TTCm$.

### 4.3 Expected payoffs

Next, we turn our attention to the expected payoff. To evaluate the success of the introduction of minority reserves, one definitively demands that minority students are not harmed as a group. In our particular setup, we could additionally expect majority students not to be worse off with the introduction of minority reserves (Alternative Hypothesis 5).

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Overall</th>
<th>Students</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M_1$</td>
<td>$M_2$</td>
</tr>
<tr>
<td>Gale–Shapley standard ($GSs$)</td>
<td>12.06</td>
<td>12.33</td>
</tr>
<tr>
<td>Gale–Shapley with minority reserves ($GSm$)</td>
<td>12.27</td>
<td>11.97</td>
</tr>
<tr>
<td>Top Trading Cycles with minority reserves ($TTCm$)</td>
<td>12.25</td>
<td>12.29</td>
</tr>
</tbody>
</table>

**Table 6:** Expected payoffs. In parenthesis, we present the variances.

\textsuperscript{18}Minority student $m_1$ ranks her third school first only 6% of the times under $TTCs$, but 19% of the times under $TTCm$; $m_2$ ranks her second school first 48% of the times under $TTCs$, but 60% of the times under $TTCm$. The two-sided $p$-values of the corresponding Mann-Whitney U tests are 0.0669 and 0.2651, respectively.
The numbers in first column in Table 6 indicate that, on average, expected payoffs are lower under $TTC_m$ than under $TTC_s$ and, even though they are slightly higher under $GS_m$ than under $GS_s$, the corresponding variances indicate that there are instances in which $GS_m$ delivers considerably lower expected payoffs than $GS_s$. The rejection of Alternative Hypothesis 5 is due to the change in payoffs of majority students. In fact, a closer inspection of the above table reveals that all majority students (except $M_3$ when we compare $GS_m$ with $GS_s$) obtain lower expected payoffs once minority reserves are introduced. On the contrary, when we focus on minority students, they appear to benefit from the introduction of minority reserves. In fact, expected individual payoffs are higher under the mechanisms with minority reserves than under the corresponding standard mechanisms in most of the instances. There is one exception: the minority student $m_1$ obtains a slightly lower payoff under $TTC_m$ than under $TTC_s$. Despite this fact, when we consider minority students as a group (i.e., focus on the joint distribution of their payoffs), we clearly see that expected rewards increase and risk is reduced when minority reserves are added to each of the two standard mechanisms.

![Figure 1: Cumulative distributions of payoffs in treatment $GS_s$ (solid gray) and $GS_m$ (dashed black).](image)

Even though, on average, minority students benefit from the introduction of minority reserves, there is one fundamental difference between the two standard mechanisms. In fact, the comparison of the full distributions of individual payoffs reveals that while introducing minority reserves in $GS_s$ benefits one minority student in a very clear-cut way, without harming the other minority
student, this does not happen under TTCs. In fact, in Figure 1 we can see that the distribution of minority student $m_1$’s payoffs under GS$m$ has first-order stochastic dominance over his payoff distribution under GS$s$. The same conclusion cannot be drawn for Top Trading Cycles. As Figure 2 shows, there is no first-order stochastic dominance of TTC$m$ over TTCs with respect to any individual student. Instead, the distribution of payoffs under TTCs dominates the distribution under TTC$m$ for $M_1$, $M_2$, and $M_3$.

Figure 2: Cumulative distributions of payoffs in treatment TTCs (solid gray) and TTC$m$ (dashed black).

We summarize these findings in Result 3.

**Result 3.** Minority reserves harm majority students, but benefit minority students inasmuch as the average payoff of this group increases. Moreover, the payoff distribution of $m_1$ under GS$m$ first-order stochastically dominates her payoff distribution under GS$s$, whereas the payoff distribution under TTC$s$ first-order stochastically dominates the distribution under TTC$m$ for several majority students.

## 5 Conclusion

We have analyzed in this experimental paper the effects of minority reserves on the Gale-Shapley and the Top Trading Cycles mechanisms in a school choice problem. Our main experimental
finding highlights that adding minority reserves increases the level of truth-telling of some of the minority students when the Gale-Shapley mechanism is employed but not when the Top Trading Cycles mechanism is used. This result deserves some more detailed discussion.

Strategy-proofness of the four mechanisms implies that it is in the best interest of all students to reveal their preferences truthfully. Since we find that subjects tell the truth in the standard setting without minority reserves in about 39% of the cases under the Gale-Shapley and with 48% under the Top Trading Cycles mechanism, it is clear that many subjects are not aware of the strategy-proofness property. The corresponding percentages for the mechanisms with minority reserves are 39% for the Gale-Shapley and 34% for the Top Trading Cycles mechanism. This suggests that adding minority reserves increases the difficulty to understand the induced game when the Top Trading Cycles mechanism is employed (in fact, truth-telling decreases for all six types of students under this mechanism). The picture for the Gale-Shapley mechanism is more positive. In particular, we find that the minority student $m_1$ who can insure herself a seat at her most preferred school independently of the behavior of the others increases her level of truth-telling from 44% for the mechanism without minority reserves to 76% for the mechanism with minority reserves. Yet, the affirmative action policy does not affect the level of truth-telling of the other students.

The discussion above suggests that in our particular school choice problem, the Gale-Shapley mechanism performs better than the Top Trading Cycles mechanism when minority reserves are present. This intuition is confirmed when one looks at the stable matchings and the expected payoffs. While there is almost no difference in the overall efficiency between the two mechanisms with minority reserves, the Gale-Shapley mechanism tends to be more stable than the Top Trading Cycles mechanism independently of whether minority reserves are employed or not. And when we restrict attention to the obtained stable matchings, the better (stable) matchings are reached more often under the Gale-Shapley mechanism than under the Top Trading Cycles mechanism.

Nevertheless, two facts should be taken into account when evaluating the introduction of minority reserves. First, even if the Gale-Shapley mechanism appears to deliver better results than the Top Trading Cycles, the numbers obtained reveal that there may be a price to pay, as stability is actually affected by introducing minority reserves in Gale-Shapley: the proportion of stable matchings obtained decreases from 35% to 13% of all matchings. Second, these results were obtained using a simple experimental setup with the flavor of a coordination game that puts pressure on the level of truth-telling but where minimum reserves could actually bring a clear improvement for all students in terms of efficiency. Yet, we observed that several majority students were still harmed by this policy when the Gale-Shapley mechanism was applied.

References


Instructions (translated from Spanish)

Welcome

Thank you for participating in the experiment. The objective of this session is to study how individuals make decisions in a particular situation. The session is going to last about 2 hours. In addition to the 3 Euros show up fee you receive for your participation, you can earn additional money depending on the decisions made during the experiment. In order to ensure that the experiment takes place in an optimal environment, we ask you to respect the following rules:

1. Do not speak with other participants.
2. Turn off your mobile phone.
3. If you have a question, raise your hand.

If you do not follow these rules, it is impossible for us to make use of the data, and we have to exclude you from the session. In that case, you will not receive any compensation. During the experiment, payoffs are expressed in ECU (experimental currency units). You will receive 1 Euro for each ECU gained during the experiment. Since your final payoff depends on your decisions, it is of utmost importance that you read the instructions very carefully. If you are not sure to fully understand the functioning of the experiment at any point in time, please, do not hesitate to raise your hand and ask.

Procedures

In this session, you are going to make decisions in an economic environment. In this environment, there are a total of six different roles. At the beginning of the experiment, the central computer divides all participants into groups of six. Within each group of six participants, each participant is assigned to TWO of the six roles. One of the assigned roles is the TRUE role, the other is FICTITIOUS. You will only learn your true role at the end of the experiment. Hence, you will have to make decisions in both roles you get assigned.

We are going to consider two variations of the basic environment. Thus, you will have to make a total of four decisions (2 roles × 2 variations) in this experiment. At the end of the experiment, the central computer randomly selects one of the two variations. The outcome of the randomly selected variation (together with the true roles of all group participants) is going to determine your final payoff.

It is important to note that the group assignment does not change during the experiment. Neither you nor the other participants in your group know or are going to learn the identity of the group participants. Moreover, your are not going to receive any information regarding the behavior of the other participants or the possible monetary implications of your own decisions until the end of the experiment.

The decision environment

The basic decision environment in the experiment is as follows: There are six students (the six roles) —let us call them $M_1$, $M_2$, $M_3$, $M_4$, $m_1$, and $m_2$— to be assigned to a school. The students
and $m_2$ are called minority students. The students $M_1$, $M_2$, $M_3$, and $M_4$ are called majority students. There are three schools—denoted $s_1$, $s_2$, and $s_3$—and every school has two available seats. Since the schools differ in their location and quality, students have different opinions of which school they want to attend. The desirability of schools in terms of location and quality is expressed in the following table:

<table>
<thead>
<tr>
<th>Most preferred school</th>
<th>$M_1$</th>
<th>$M_2$</th>
<th>$M_3$</th>
<th>$M_4$</th>
<th>$m_1$</th>
<th>$m_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second most preferred school</td>
<td>$s_1$</td>
<td>$s_1$</td>
<td>$s_3$</td>
<td>$s_3$</td>
<td>$s_2$</td>
<td>$s_2$</td>
</tr>
<tr>
<td>Least preferred school</td>
<td>$s_3$</td>
<td>$s_3$</td>
<td>$s_2$</td>
<td>$s_2$</td>
<td>$s_1$</td>
<td>$s_1$</td>
</tr>
</tbody>
</table>

Table 7: Preferences of students over schools

Schools have a priority ordering that is predetermined independently for each school and that, among other things, depends on the distance from the student to the school and whether a sibling already attends the school. The following table summarizes the priority ordering of each school.

<table>
<thead>
<tr>
<th>School $s_1$</th>
<th>School $s_2$</th>
<th>School $s_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best candidate</td>
<td>$m_1$</td>
<td>$M_3$</td>
</tr>
<tr>
<td>Second best candidate</td>
<td>$m_2$</td>
<td>$M_4$</td>
</tr>
<tr>
<td>Third best candidate</td>
<td>$M_4$</td>
<td>$M_2$</td>
</tr>
<tr>
<td>Fourth best candidate</td>
<td>$M_3$</td>
<td>$M_1$</td>
</tr>
<tr>
<td>Fifth best candidate</td>
<td>$M_1$</td>
<td>$m_1$</td>
</tr>
<tr>
<td>Worst candidate</td>
<td>$M_2$</td>
<td>$m_2$</td>
</tr>
</tbody>
</table>

Table 8: Priority orderings of schools over students

To decide which students are assigned to which school, each student is asked to submit a ranking over schools; that is, each student has to order the three schools (the decision you have to make during the experiment). Observe that students can submit whatever ranking they like, it does not have to coincide with the actual preferences. In other words, each students has to select (and hand in) one of the following six lists (each column represents a possible ranking):

<table>
<thead>
<tr>
<th>Ranking 1</th>
<th>Ranking 2</th>
<th>Ranking 3</th>
<th>Ranking 4</th>
<th>Ranking 5</th>
<th>Ranking 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt; position</td>
<td>$s_1$</td>
<td>$s_1$</td>
<td>$s_2$</td>
<td>$s_2$</td>
<td>$s_3$</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; position</td>
<td>$s_2$</td>
<td>$s_3$</td>
<td>$s_1$</td>
<td>$s_3$</td>
<td>$s_1$</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt; position</td>
<td>$s_3$</td>
<td>$s_2$</td>
<td>$s_3$</td>
<td>$s_1$</td>
<td>$s_2$</td>
</tr>
</tbody>
</table>

Table 9: Each student has to select one of the six rankings.

Given the submitted rankings of the six students, the final assignment of the students to the schools is determined by a procedure in the central computer. We remind you that there are
two variations of this procedure. The first procedure is as follows. We will present the second variation once the first variation is completed.

The first variation

[The participants receive one of the following four instructions depending on the session. The names of the mechanisms are not included in the instructions.]

Mechanism 1: Gale-Shapley standard (GSs)

Step 1 Every student applies to the school she ranked first.

Step 2 Every school that receives at least one application acts as follows.

- It temporarily accepts the applicant with highest priority.
- It also temporarily accepts the applicant with highest priority among all remaining applicants (if any).
- The rest of the applicants are rejected (if any).

Step 3 Whenever a student is rejected by a school, she applies to the next highest ranked school.

Step 4 Every school that receives at least one new application mixes the retained and the new applications. These applications are then processed as follows:

- It temporarily accepts the applicant with highest priority.
- It also temporarily accepts the applicant with highest priority among all remaining applicants (if any).
- The rest of the applicants are rejected (if any).

Step 5 Steps 3 and 4 are repeated until all students are matched, and the assignment is completed. Each student is assigned to the school that holds her application at the end of the process.
Mechanism 2: Gale-Shapley with minority reserves \((GSm)\)

**Step 1** Every student applies to the school she ranked first.

**Step 2** Every school that receives at least one application acts as follows.

- If the school receives one or more applications from minority students, then it temporarily accepts the minority applicant with highest priority.
  It also temporarily accepts the applicant with highest priority among all remaining (majority or minority) applicants (if any).
  The rest of the applicants are rejected (if any).
- If the school receives no applications from minority students, then it temporarily accepts the majority applicant with highest priority.
  It also temporarily accepts the applicant with highest priority among all remaining majority applicants (if any).
  The rest of the applicants are rejected (if any).

**Step 3** Whenever a student is rejected by a school, she applies to the next highest ranked school.

**Step 4** Every school that receives at least one new application mixes the retained and the new applications. These applications are then processed as follows:

- If there are one or more applications from minority students, then it temporarily accepts the minority applicant with highest priority.
  It also temporarily accepts the applicant with highest priority among all its remaining (majority or minority) applicants (if any).
  The rest of the applicants are rejected (if any).
- If there is no application from minority students, then it temporarily accepts the majority applicant with highest priority.
  It also temporarily accepts the applicant with highest priority among all its remaining majority applicants (if any).
  The rest of the applicants are rejected (if any).

**Step 5** Steps 3 and 4 are repeated until all students are matched, and the assignment is completed. Each student is assigned to the school that holds her application at the end of the process.
Mechanism 3: Top Trading Cycles standard (TTCs)

Step 1  Each student points (with her index finger) to the school she ranked first.

Each school points (with its index finger) to the student with highest priority.

There always is some cycle of students and schools. In each cycle each element (i.e., student or school) points to the next element and the last element points to the first element.

For example, it can happen that some submitted rankings are such that the cycle (Ana, Santa Fé, Jorge, Los Pinos) forms in the first step (it is possible to have cycles with more or less students and schools):

![Diagram of cycles](image)

Each student in any of the cycles is matched to the school she is pointing to and that school’s number of available seats is reduced by one. Each student in any cycle is sent home with a letter that confirms her obtained seat.

In the example, Ana obtains a seat at “Santa Fé” and Jorge obtains a seat at “Los Pinos”. The two schools forming part of the cycle reduce their number of seats by 1.

Step 2  Each student that still has no school seat points to the school she ranked highest among all schools that still have available seats.

Each school with available seats points to the student with highest priority among all remaining students.

There always is some cycle of students and schools. In each cycle each element (i.e., student or school) points to the next element and the last element points to the first element.

Each student in any of the cycles is matched to the school she is pointing to and that school’s number of available seats is reduced by one. Each student in any cycle is sent home with a letter that confirms her obtained seat.

Step 3  Step 2 is repeated until all students are matched.
Mechanism 4: Top Trading Cycles with minority reserves (TTCm)

**Step 1** Each minority student points (with her index finger) to the school she ranked first.
Each school points (with its index finger) to the minority student with highest priority.
There always is some cycle of minority students and schools. In each cycle each element (i.e., minority student or school) points to the next element and the last element points to the first element.

*For example, it can happen that some submitted rankings are such that the cycle (Pedro, La Fuente) forms in the first step (it is possible to have cycles with more students and schools):*

![Diagram showing a cycle between Pedro and La Fuente]

Each student in any of the cycles is matched to the school she is pointing to and that school’s number of available seats is reduced by one. Each student in any cycle is sent home with a letter that confirms her obtained seat.

*In the example, Pedro obtains a seat at “La Fuente”. The school “La Fuente” reduces its number of seats by 1.*

**Step 2** All students (minority or majority) that still have no school seat point to the highest ranked school (according to the submitted ranking) that still has at least one seat available.
Each school with available seats acts as follows.

- A school that was **not matched** to a minority student in Step 1 points to the unmatched minority student (if any). In case all minority students are already matched, it points to the majority student with highest priority.
- A school that was **matched** to a minority student in Step 1 points to the (minority or majority) student with highest priority.

There always its some cycle of students and schools. In each cycle each element (i.e., student or school) points to the next element and the last element points to the first element.

*For example, it can happen that some submitted rankings are such that the cycle (Pablo, Cielo Azul, María, La Fuente, Juan, Dos Torres) forms in the second step (it is possible to have cycles with less students and schools):*
Each student in any of the cycles is matched to the school she is pointing to and that school’s number of available seats is reduced by one. Each student in any cycle is sent home with a letter that confirms her obtained seat.

In the example, Pablo obtains a seat at “Cielo Azul”, María obtains a set at “La Fuente”, and Juan obtains a seat at “Dos Torres”. Each school of the cycle reduces its number of seats by 1.

Step 3 Step 2 is repeated until all students are matched.

Procedures - continuation

You are going to play the two variations with the following monetary payoffs. You will receive 12 ECU in case you end up in your most preferred school, 9 ECU if you manage to get a seat in your second most preferred school, and 6 ECU if you study in your least preferred school.

The second variation

[Depending on the session, the subjects get the instructions for a different mechanism once the first variation is completed.]