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University Admissions Mechanism: Theoretical Analysis with Application to Russian Universities

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The Russian university admissions mechanism which is based upon a combination of the university proposing deferred acceptance algorithm and serial dictatorship is shown to generate unstable and manipulable allocations. To improve on the mechanism, we propose a sequenced student proposing deferred acceptance (DA) algorithm with a serial dictatorship which is followed after every cycle of the student-proposing DA, allocating state-funded placements and offering the opportunity to decommit and be allocated to tuition placements based on the hybrid STB-MTB tie-breaking rules (Single Tie Breaking – Multiple Tie Breaking rules). The proposed algorithm will satisfy both stability and strategyproofness assuming the Russian higher education system is defined as a large market and universities cannot manipulate their preferences. In addition, this paper deals with the possibility of students taking a risk of preference misrepresentation to improve their allocation despite the fact the mechanism is strategy-proof and chances of success are low. We identify that the profitability of preference misrepresentation depends on the size of the market (the number of universities participating in the algorithm), preference list size, and existence of a recommendation mechanism. The paper also reviews how truth-telling can be promoted specifically in the form of recommendation mechanisms being applied in the university admissions systems.

Key words: University admissions, Deferred acceptance algorithm, Serial dictatorship, tie-breaking rules, Stability, Strategyproofness.

JEL Classification: D47.

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1. Introduction

In the 2020/2021 academic year, more than 1 million high school graduates have entered the Russian higher education system [Gokhberg et al., 2021], joining one of approximately 26 thousand Bachelor programs and 3.4 thousand Postgraduate programs offered by 497 state universities and 213 private institutions. About 42.5 percent of those enrolled have received a state-funded placement (e.g., scholarship) in their respective programs [Bondarenko et al., 2021]. In contrast, tuition seats cost on average 73 and 53 thousand rubbles per semester in public universities and private institutes respectively, while the average Russian salary per month at the start of 2022 is only 55.7 thousand rubbles. For many, the hardship of paying for higher education has created a high demand for state-funded seats, requiring additional effort and adoption of different mechanism-related strategies, such as misrepresentation of preferences to enter the desired programs.

After graduating high school, each student can enter a given program in a university by completing Unified State Exams (USE) in different subjects required by the program the student wants to pursue. For example, to enter an economics program, a student must complete exams in math, Russian, and social sciences. In addition, some programs replace different subjects of the state exams with internal examinations which students must complete in the university itself. After completing those requirements, the students receive a cumulative overall grade which ranks them compared to other applicants for that program and offers students the opportunity to apply to universities based on grade requirements published by the programs for each type of placement (state-funded and tuition).

To allocate students to these programs, the Russian Ministry of Education has implemented the University Admission System, which is the country's first centralized system [Eliseeva, 2020] and has been in place since 2009. This system allocates both state-funded and tuition places through a separate technique for each of the two allocation types. With that said, some of the properties of the given system create room for unfair behavior and manipulation by the students to improve their allocation based on the flaws of the Russian1 mechanism, which we believe can be improved upon the manipulable outcomes witnessed in the existing design.

In this paper, we will start by providing a literature review discussing previous mechanism designs used, their properties, and the comparison between them, as well as the important assumptions they are based upon which will be implemented in the proposed design. Following the literature review, we will explain the framework of the applied mechanism in the Russian university admission system and show some of its flaws based on the properties seen in the outcomes. It is necessary to acknowledge here that the applied mechanism is imperfect, and its comparison with the proposed design is a theoretical exercise rather than a direct linkage to the Russian system. Therefore, while our critique aims to be constructive, it is recommended to

[1] In this paper, the representation of Russian university admission mechanism procedures is based upon the system implemented in the early 2010s which has seen numerous shifts since then.

temper the degree of uncompromising in our analysis. It's worth noting that real-life applications may vary, and this discussion primarily focuses on a theoretical context. Afterwards, we will propose an improved mechanism and show that it is overall at least as good as the Russian mechanism when it comes to outcomes while also displaying the desired properties of stability and strategy-proofness which the Russian mechanism lacks. In addition, we will discuss a real-world version of the improved mechanism which involves tie-breaking between students competing for a limited number of quotas and universities being indifferent between those competing students. Penultimately, we will discuss the profitability of student risk taking in the case when students decide to improve their allocation outcomes through preference misrepresentation even when a desired outcome is not guaranteed due to randomization in the tie-breaking rules and how to incentivize truth-telling.

2. Literature review

Mechanism design of college admission and school choices have been some of the most widespread and debated education policies of the last two decades [Chen, Kesten, 2017]. One such mechanism change was the replacement of the Boston mechanism by the student proposing deferred acceptance mechanism in Boston in July of 2005 [Pathak et al., 2006].

The Boston mechanism had theoretical and experimental evidence of vulnerability towards preference misrepresentation [Chen, Sonmez 2003; Abdulkadiroglu, Sonmez 2003], as such the mechanism is not strategy-proof (or manipulable) meaning it is not immune to preference manipulation (assuming that all preferences are strict) done by the students providing untruthful preferences to improve the outcome of the mechanism's allocation. In contrast, the student proposing deferred acceptance mechanism does provide strategy-proofness (for the students) [Roth, 1982] in addition to stability [Gale, Shapley, 1962]. Stability is a very desired property comprised of individual rationality, meaning the student prefers to enroll in any university compared to not enrolling at all, while universities prefer to have any eligible student instead of an empty seat. No blocking pairs meaning that no pair comprised of a student and a university prefer each other compared to the allocation given to them by the mechanism. Since we are also discussing a many-to-one problem (several students enrolling into each university) we require the matching to be non-wasteful meaning a student won't be allocated to a university only if all the quotas are already taken.

The student proposing deferred acceptance mechanism was also compared to its counterpart, the university proposing deferred acceptance mechanism [Balinski, Sonmez, 1999]. Assuming that university preferences are government regulated (or based only upon the grades of the students) and having no ability to manipulate, in this case, it was shown that a university proposing DA is the worst stable matching for students, while also being manipulable and pareto inefficient meaning at least one student could have been given a better outcome without harming other students. This contrasts with the student proposing DA providing the best stable matching for students in addition to strategy-proofness and pareto domination of the university proposing DA.

Following this, another mechanism that exists in the mechanism design literature and is used in school choice and university admission (among other subjects such as house allocation) is the serial dictatorship mechanism. This mechanism lets the students apply to their desired universities based on priority order given by categories such as age, background, grades etc., the mechanism offers the properties of strategy-proofness and pareto efficiency [Svensson, 1999] which cannot be achieved together by the student proposing DA, university proposing DA or the Boston mechanism.

Separately from known mechanisms which provide students with only one offer from a university, there is expanding literature researching mechanisms which provide students with multiple offers. These mechanisms are based on the idea that full information on a student's preferences may not be held in practice [Grenet, Kubler, 2022], as such we can improve on a student's welfare by using a mechanism that allows students to hold multiple offers before ranking universities. In multi-offer mechanisms, early offers inform students of their admission chances, thus allowing them to learn about programs more efficiently.

In addition to the mechanism discussed above, it is important to understand the relation and trade-offs between the properties of stability, efficiency and strategy-proofness, specifically when it comes to indifferent preferences. In the case when a university is indifferent between certain students we require a tie-breaking rule to avoid unstable and manipulable outcomes [Abdulkadiroglu et al., 2009]. In current literature there is ongoing debate on which tie-breaking rule provides the most desirable properties [Erdil, Ergin, 2008; Kesten, 2012]. Relevant to this paper is specifically the standing debate between the single tie-breaking rule (STB) and the multiple tie-breaking rule (MTB) [Ashlagi, Nikzad, 2020]. Although both approaches are strategy-proof, STB provides a singular tiebreaker of students for all universities. The rule's fairness is questioned when a student is given a bad draw throughout all the universities compared to having the possibility of having a better draw in some universities compared to others given the MTB approach. With that said, it was shown that STB allocates more students to their top choices than MTB, but MTB allocates less students to their lower-rank choices and fewer students unassigned [Abdulkadiroglu et al., 2009]. In this paper we will use a hybrid tie-breaking rule of STB and MTB which was discussed in Ashlagi and Nikzad (2020) based on the concept of university popularity.

In certain cases, students might decide to improve outcomes through preference misrepresentation even if an improved outcome is not guaranteed. To mitigate unnecessary risk-taking, opportunities for strategic manipulation are limited [Roth, Peranson, 1999] when we increase the market size of students and universities and increase preference correlation while decreasing the preference list student can submit to the admissions system have been found to discourage students from risky preference misrepresentation [Ankile et al., 2022].

After discussing the existing mechanism designs, the properties they possess and lack, the assumptions that the mechanisms are based upon, and the relation between the properties and tie-breaking, following the latest literature related to comparing mechanisms in countries based on their properties [Chen, Kesten, 2017] and possible improvements [Pathak et al., 2006; Balinski, Sonmez, 1999]. We will explain the framework of the Russian university admission mechanism used in Russia, based on existing framework provide the needed assumptions, the mechanism's properties, and show an example of its property's failures. Following this, we will explain the framework of the proposed mechanism and show how it keeps the properties that the existing design fails to maintain.

3. The Russian university admission system mechanism

The Russian admission system allows the students to apply to a fixed number of programs and choose between a state-funded or tuition placement or both, while the student must have at least the minimum required cumulative grade to apply to each program. The mechanism is divided into 2 parts based on the type of allocation (state funded or tuition). To provide the frameworks, it is important to present several assumptions based on previous literature, anticipated behavior, and university requirements. These assumptions will help breakdown the overall mechanism used and display the existing properties:

Assumption 1: All students and universities are agents with bounded rationality, and universities cannot manipulate their preferences.

The concept of bounded rationality proposes that individuals are intendedly rational, but their rationality is bounded due to several constraints [Simon, 1985]. For students, limited information about the university programs or limited time to make a decision and personal biases contribute to their rationally bounded decision-making. For universities, as agents, the ranking of students is based upon grades, awards, participation in national and international tournaments, etc. making direct comparisons between students challenging and increasing the complexity of ranking the applicants. In addition, university rationality is also bounded by government/higher education council regulations which denies preference manipulation from education providers.

Assumption 2.1: For both state funded and tuition placements, all students and universities have weak preferences over each other, but universities prefer having any student to an empty seat. Weak preferences relate to the case where an individual either strictly prefers one allocation over another or is indifferent between the two options.

Assumption 2.2: As a special case of the student preferences, all students **strictly** prefer a state funded placement compared to a tuition placement in the same program.

Assumption 3: The universities admission market is large.

The allocation of state funded placements is separated into two rounds with a fixed number of quotas in each one, where the in-round allocations are done by a university proposing DA mechanism. In this mechanism the universities propose to potential students a placement into their university until the student substitutes the offering university for a strictly preferred university based on the rankings submitted by the student (in case of indifference between a few universities, students assign rankings to those universities at random). If no other preferred universities propose a placement the current program is taken. Between the first and the second round the student can choose to leave the matching with the given allocation or drop the allocation and try to receive an improved placement from the quotas left. Students will prefer to drop their first-round allocation if a preferred placement is available in the second round, and students cannot apply to the same program they dropped/denied again. For all quotas that haven't been allocated in the first round will be moved to the second round. The mechanism finishes when for all students, each one got either allocated or have dropped a program, or for all quotas each was either filled or dropped.

Separately from the university proposing DA, tuition placements are given on a "first-come-first serve" principle. This principle will be defined by a serial dictatorship mechanism with a priority order based on the timing of the application, every student will apply into a program if there are quotas left when his turn comes. Otherwise, the student will apply to the next program on his preference list with open quotas. The mechanism finishes when all students are allocated to programs, or all the quotas have been filled out. Finally, after both mechanisms have allocated the students. If a student has a tuition slot and a state funded slot the higher ranked slot is taken while the lower ranked one becomes free. This overall mechanism's matchings are unstable and manipulable by the students as we will in the following example.

In this set up, we have 3 universities and 5 students.

University A offers both state-funded (SF) and tuition (T) placements, with 1 quota for SF in the first round and 1 quota in the second round. In addition, it offers 1 quota for T.

University B also offers both state-funded (SF) and tuition (T) placements, with 1 quota for SF in the first round and 1 quota in the second round. In addition, it offers 1 quota for T.

University C which offers only tuition (T) placements, with 1 quota for T.

Universities A and B have the following preferences (C has no preferences because it is not in the DA mechanism):

Table 1.

University/Rank	University A	University B
1	Student 1	Student 1
2	Student 3	Student 2
3	Student 2	Student 4
4	Student 4	Student 3
5	Student 5	Student 5

Students have the following preferences (Table 2).

Table 2.

Student/Rank	Student 1	Student 2	Student 3	Student 4	Student 5
1	University A (SF)	University A (SF)	University A (SF)	University A (SF)	University C (T)
2	University A (T)	University B (SF)	University B (SF)	University C (T)	University B (SF)
3	University C (T)	University B (T)	University B (T)	University A (T)	University B (T)
4	University B (SF)	University A (T)	University C (T)	University B (SF)	University A (SF)
5	University B (T)	University C (T)	University A (T)	University B (T)	University A (T)

The students have applied for tuition placements in the following order: 4, 3, 2, 1, 5.

For state funded placements.

In Round 1:

Table 3.

Round	Student 1	Student 2	Student 3	Student 4	Student 5
1	A, ~~B~~				
2		B			
Allocation	A	B	–	–	–

- Student 1 got his top preference so he leaves the matching with University A.
- Student 2 prefers the open spot in University A, so he drops his spot in University B and continues to the second round. Now University B has 2 quotas in Round 2.

Round 2:

Table 4.

Round	Student 1	Student 2	Student 3	Student 4	Student 5
1			A, ~~B~~	B	
2					B
Allocation	–	–	A	B	B
Final Allocation	A(SF)	–	A(SF)	B(SF)	B(SF)

For tuition placements:
Student 4 starts and chooses University C (T);
Next Student 3 chooses University B (T);
Next Student 2 chooses University A (T);
Next is Student 1 but he is left with no options.
Next is Student 5 but he is also left with no options.
Following this the students choose their preferred allocation:

- Student 1 prefers his state funded allocation and chooses University A (SF);
- Student 2 prefers his tuition allocation and chooses University A (T);
- Student 3 prefers his state funded allocation and chooses University A (SF);
- Student 4 prefers his tuition allocation and chooses University C (T);
- Student 5 prefers his state funded allocation and chooses University B (SF).

Overall mechanism allocation (Table 5).

Table 5.

Student/ Rank	Student 1	Student 2	Student 3	Student 4	Student 5
1	University A (SF)*	University A (SF)	University A (SF)*	University A (SF)	University C (T)
2	University A (T)	University B (SF)	University B (SF)	University C (T)*	University B (SF)*
3	University C (T)	University B (T)	University B (T)	University A (T)	University B (T)
4	University B (SF)	University A (T)*	University C (T)	University B (SF)	University A (SF)
5	University B (T)	University C (T)	University A (T)	University B (T)	University A (T)

* The university each student was allocated.

The mechanism is unstable because Student 2 prefers University B (SF) to his allocation and the university has an unassigned quota, meaning the allocation is wasteful.

The mechanism is also manipulable by Student 2 which can submit University B (SF) as his top choice and receive a better allocation.

4. The proposed mechanism

To improve on the unstable and manipulable mechanism we propose several changes to the Russian university admissions system. The first adjustment is removing the 2-round system in place and setting up only one round which allocates all state funded seats the university offers. This is done to avoid students misjudging their capabilities by dropping the allocation they were given after the first round and failing to get a better allocation. With a one round only system students will be competing for all seats available and thus will not drop an allocation that might be a regretful decision in the future. Secondly, we will be substituting the university proposing DA mechanism with a student proposing DA. The student proposing DA offers the student optimal allocation, which is the best stable matching for students. In addition, the mechanism provides strategy-proofness and pareto domination of the university proposing DA [Balinski, Sonmez, 1999]. Although we assumed universities are agents, they also provide their rankings based on government regulations and cannot manipulate their preferences meaning the only strategy-proofness that is of interest in this case, is that of the students and the student proposing DA promotes truth-telling by providing better outcomes to those students who submit true preferences. The third change is sequencing the two mechanisms of state funded and tuition placements. To do this, first we would like to provide 2 new definitions:

"Cycle": A cycle will be defined as one matching process completed by the student proposing DA. A cycle is not the same as a round. In rounds, each university allocates a fixed number of seats not necessarily equal to all seats available. In addition, rounds themselves are also fixed in their count (for example the Russian admission system has exactly 2 rounds). In comparison, every cycle offers all available seats a university has to offer, and the number of cycles depends on the number of seats to be allocated, meaning the more seats there are to allocate the more cycles it will require to match a student to a university. In other words, all cycles will finish only when all seats are allocated or there are no more students to allocate seats to. Cycles are an important addition to this mechanism because they provide the opportunity to allocate all seats to the most suitable students without creating wastefulness and blocking pairs when a certain seat is not allocated properly (to the best suiter or remaining empty).

"(De)Commitment": After a cycle is completed, a student will choose between committing to the SF program he was allocated to and leave the mechanism or decommit and proceed to the serial dictatorship mechanism. With that said, only students who have received their top available SF placement have the choice of staying in the SF placement or decommiting. This is done so students can have a chance to compete for their top available choice without risking losing their current placement for a less favorable one.

Given the definitions above, the overall matching process will start with the student proposing DA for state funded seats. After a cycle finishes and all students are allocated to SF programs, or all SF quotas have been filled out, students who prefer to decommit will be placed in serial dictatorship for tuition placements. Students will prefer to decommit only if there are quotas left in a tuition placement which is preferred to their given SF allocation. The serial dictatorship priority continues to be based on timing of application, but now the timing of application depends on the cycle after which a student has decommited. After all decommited students are allocated to a tuition spot (or all tuition spots are taken) and all students who received their top available SF choice (those who committed to their SF placement) leave the mechanism, a new cycle starts with those who haven't received their top available SF spot, competing for the remaining available spots. If all SF placements have been allocated, those who are left without a placement move to the serial dictatorship mechanism. The overall mechanism finishes when all students are allocated to their top available SF or tuition spots, or all quotas are taken.

In case of a tie of multiple students competing for the same tuition placements after a cycle, a tie breaking rule will be implemented to decide which students will be decommiting (and will be allocated to their tuition spot) and which students will be staying in their allocated SF placement. If none of the student's preferred tuition placements are available (placements which are above the committed SF spot) when his turn in the tiebreaker comes up, the student commits to his SF spot. Before explaining the rules which the tiebreakers will follow, I would like to illustrate how the proposed mechanism works through the following example:

In this example, we will use the same set up as before but now the Serial Dictatorship is based on the cycle of decommitment. In addition, there are no rounds, all quotas are given from the start. Universities A and B have 2 quotas to give.

Table 6.

Round	University A	University B
1	1,~~2~~,3,~~4~~	~~5~~
2		2,4
Allocation	1,3	2,4

Student 1 gets top choice overall and leaves the mechanism;

Student 3 gets top choice overall and leaves the mechanism;

Student 2 gets his second-best choice, but he has no tuition placements above his current match and top SF isn't available anymore, which makes this allocation his top available SF.

Student 4 is matched with his top available SF placement, but he has University A (T) and University C (T) still available, thus he decommits and goes for tuition placement since he is first in the series, he chooses his first preference which is University C (T).

Student 5 isn't allocated.

Since Student 4 decommited the mechanism runs again without students who got their top available SF choice and those who decommited (only with leftover placements).

Table 7.

Round	University A	University B
1		5
Allocation	–	5

Student 5 gets his top available SF placement, but his top overall choice University C (T) is already taken by Student 4 thus Student 5 commits to University B (SF).

Overall mechanism allocation (Table 8).

Table 8.

Student/Rank	Student 1	Student 2	Student 3	Student 4	Student 5
1	University A (SF)**	University A (SF)	University A (SF)**	University A (SF)	University C (T)
2	University A (T)	University B (SF)**	University B (SF)	University C (T)**	University B (SF)**
3	University C (T)	University B (T)	University B (T)	University A (T)	University B (T)
4	University B (SF)	University A (T)	University C (T)	University B (SF)	University A (SF)
5	University B (T)	University C (T)	University A (T)	University B (T)	University A (T)

** The university each student was allocated.

As can be seen in the allocations above, this mechanism provides better outcomes compared to the Russian mechanism with Student 2 being improved without harming other students. In addition, this mechanism provides stable and strategy-proof allocations. Since we assumed rationality and there are no blocking pairs and wastefulness due to the stability property of the student-proposing DA mechanism incorporated into the overall mechanism. This means the stability property is also kept in the overall mechanism since the serial dictatorship only improves upon a student's choice while the free position becomes reallocated to the next best fitting student. In the next chapter we will be discussing and explaining the strategyproofness property of this mechanism and its relation to the tie-breaking rules which will also be defined in the following chapter.

5. Strategyproofness and tie-breaking rules

When discussing real-world university admissions mechanisms with large amounts of students and universities such as in the case of Russia. It is plausible to assume we are discussing a large market which might allow students to improve their allocation outcomes through preference misrepresentation. Let us imagine the following case: Student X is in a very large market with many universities and even more students. The student has the following true preferences and rankings in a reputable university A and mediocre university B (among others).

Table 9.

University/Rank	University A (Prestigious)	University B (Mediocre)
1	Many other students	Student X
2	Many other students	Many other students
……	Student X	Many other students

Table 10.

Student/Rank	Student X (True Preferences)
1	University A (SF)
2	University A (T)
3	Many other universities
…..	University B (SF)
……	Many other universities

Student X is considered a top choice student for mediocre University B but a very unlikely candidate for University A. By following his true preferences Student X has a higher chance ending up at University B compared to University A. On the other hand, if student X decides to misrepresent his preferences in the following manner:

Table 11.

Student/Rank	Student X (False Preferences)
1	University A (SF)
2	University A (T)
3	University B (SF)
…..	Many other universities
……	Many other universities

Student X can easily manipulate his preferences and improve his outcome. Just by placing the less reputable university B high on the list, get allocated there in an early cycle, decommit and choose a tuition placement in the reputable university A.

So why is this mechanism strategy-proof? Uncertainty! Since we have many students competing for limited spots a student's manipulation won't provide the desired outcome with certainty. After each cycle there will be multiple students wanting to decommit for a tuition spot but not as many spots as the cycles go on.

To deal with this uncertainty we will provide a set of tie-breaking rules based on Ashlagi and Nikzad (2020). The tie-breaker rule is the hybrid STB-MTB (HTB) model. STB or Single Tie Breaking rule requires all universities to follow the same randomized breaking list. For example, if Student X is 5th on the tie-breaking list for University A, he will also be 5th on the list for all other universities. In comparison, the MTB or Multiple Tie Breaking rule allows all universities to have their own randomized breaking list. For the same example, Student X can be 5th on the tie-breaking list for University A but 2nd for University B and 15th for University C. With that said, there exists a tradeoff between the STB and MTB rules. STB assigns more students to their top choices than MTB does, but MTB assigns fewer students to their lower-rank choices and leaves fewer students unassigned. Ashlagi and Nikzad (2020) found that it is preferable to use the STB rule to assign students to popular universities while non-popular universities should follow the MTB rule. To use the hybrid STB-MTB model we first need to define popularity and which universities are considered popular.

Popularity of a school will be defined as the ratio between the number of students that rank the school as their first choice and the capacity of the school. A popular school is defined as a school with popularity above a certain threshold. We will define this by the following formula:

$$a_c = \frac{p_{\#1}(c)}{q_c} \geq n \tag{1}$$

a_c is the school's popularity, $p_{\#1}(c)$ is the number of times the school has been selected as top choice, q_c is the number of seats the school has (both tuition and state-funded), and *n* is the threshold. Thus, a school with popularity above the threshold will follow STB while a school below the threshold will follow MTB. The benefit of using the hybrid STB-MTB rule is the ability of this system to provide the beneficial properties of STB and MTB as separate systems which enables students both the opportunity to receive their top choices but also the assurance that with high probability, they won't be unassigned or receive their worst preference.

With that said, even with a defined system with strategy-proofness and randomized breaking lists, students might decide to take the risk of misrepresenting their preferences even with uncertainty of outcome improvement. In the next chapter, we will discuss student risk taking and how it can be mitigated based on the proposed mechanism.

6. Student risk taking

The strategy-proofness of the proposed mechanism might not turn away students from taking a risk to improve the allocation outcome through preference misrepresentation due to the possible profitability of the action. This will be especially applicable for students who are expected to be allocated to a mediocre university with high utility improvement if the misrepresentation succeeds and the student receives an allocation to a reputable university. This is compared to a small change in utility if the misrepresentation fails and the student receives an allocation to a worse yet similar mediocre university.

The profitability of preference misrepresentation will depend on several factors specific to an admission system [Ankile et al., 2022]. The first factor is the size of the market, Ankile et al. (2022) found that a larger market with many universities and even more students (the example in the paper was male-female marriage) which follows the student-proposing DA will approach complete strategy-proofness when the size of the market is above 100 universities. Secondly, preference correlation between the rankings students submit about universities also affects strategy-proofness. A higher preference correlation, which means more students ranking each university in the same respective ranking slot increases strategy-proofness. To raise preference correlation, it is suggested that truth-telling will be promoted when students submit their preferences. The proposed way of promoting truth-telling is a recommendation system which advises students to rank their preferences based on their true desire and avoid strategic behavior to improve outcomes. The final factor is the size of the preference list, Ankile et al. (2022) have found that a smaller list size will significantly diminish the ability of students to misrepresent their preferences due to less opportunities to deviate and thus approach complete strategy-proofness.

To show how those parameters are currently implemented. We will illustrate how the Russian admissions system compares to different admission systems (with publicly available information) around the world based on preference list size, university admission market size, and the existence of a recommendation system which improves preference correlation (assuming the system promotes truth-telling).

Table 12.

Country	Preference list size	Recommendation system	Market size (type of universities in the allocation mechanism)	Source
France	36	No	~70 (Universities, preparatory schools for grandes écoles and technical high schools)	[Frys, Staat, 2016]
Australia	5	Yes	~43 (All universities)	[Guillen et al., 2022]
Italy	Unlimited	No	~60 (Only public universities)	[Merlino, Nicolo, 2012]
Belgium	Unlimited	Yes	~12 (Only public universities)	[Cantillon, Koen, 2012]
Hungary	3*	Yes	~65 (Most public universities, some universities run by Churches and a small number of private universities)	[Biro, 2012]
Russia	15	No	~710 (All universities)	[Eliseeva, 2020]
Ireland	10	Yes	~22 (Most public universities)	[Chen, 2012]
Ukraine	5	No	~100 (Most public universities)	[Kiselgof, 2011]
UK	5	Yes	~130 (Most public universities)	[Chen, 2012]
Germany	10	Yes	~300 (Most public, a few private universities)	[Kubler, 2019]

* There is no restriction, but the applicants are charged for every item in their lists after the third one.

Source: Summarized by the author.

This illustration shows that the university market size varies across countries and not all have a large market size (understandable from the size difference of the countries), the use of recommendation systems and preference list sizes do not inherently follow the optimal list size and/or do not follow truth-telling guidelines in the recommendation system. In addition, we can see that in comparison to other countries, Russia lacks a recommendation system, and has a relatively large preference list size but on the other hand, has achieved an optimal market size (above 100).

7. Incentivizing truth-telling

To improve our mechanism by raising preference correlation, we are going to implement and discuss how a recommendation system can promote truth-telling from students and by doing so increase preference correlation. In previous research by Rees-Jones and Skowronek (2018) it was found that even when a mechanism has complete strategy-proofness students continue to misrepresent their preferences even if such practice may worsen their allocation outcome since the DA mechanism is designed to offer students their "true" best allocation.

It has been explained that possible reasoning for such behavior includes cognitive ability, strategic positioning, overconfidence, expectations, advice, and trust [Rees-Jones, Skowronek, 2018]. When discussing strategic positioning and cognitive ability, there is a distinction between students with high and low grades. Students with low grades are at a strategic disadvantage getting their desired allocations. This can result in attempts to misrepresent preferences in order to compensate, or they might choose not to include desirable programs on their list due to the belief that they cannot attain them. In addition, certain students might also have comparatively low cognitive ability, which increases the probability of incorrectly identifying the optimal strategy. Overconfidence is another characteristic noticed in student decision making to misrepresent preferences. Rees-Jones and Skowronek (2018) defined overconfident students as those whose forecasted performance exceeded their actual percentile rank (in their case it was in the MCAT exam).

This overconfidence also connects to the student's desire to rank their expected outcome higher. If students derive satisfaction from the prospect of being matched to a program they highly prioritize, or if they anticipate disappointment from being matched to a program they did not rank highly, they may be inclined to submit preference orderings that do not accurately reflect their true preferences, aiming to manage these expectations. In this scenario, the act of misrepresentation does not necessarily stem from irrationality. With the presence of utility functions influenced by these beliefs, the DA algorithm lacks strategy-proofness.

In numerous systems, a specific course of action, such as telling the truth, may be considered the best strategy only if all other participants in the market also adopt optimal behavior. This is not the case with the deferred acceptance algorithm since telling the truth remains the optimal choice regardless of the actions taken by other participants. However, if participants fail to understand this distinction or hold mistrust towards other participants, which leads them to doubt the credibility of the matching agency, it is possible for suboptimal behavior to emerge.

Finally, when the mechanism is sufficiently difficult to understand, students might be significantly influenced by advice. This advice might come from different third parties such as friends, family, universities [Guillen, Hing, 2014; Guillen, Hakimov, 2018], and the centralized admissions system which may offer students mixed advice which makes them misjudge their capabilities and thus misrepresent their preferences. Guillen et al. (2022) found that preference misrepresentation and expected outcome biases are more prevalent with universities and combined advice (university and centralized admission system) compared to when advice is only offered by the centralized admission system.

To confront those issues of strategic positioning, expected outcomes bias, mistrust and mixed advice we propose the implementation of a recommendation system which follows certain guidelines. These guidelines include universities not giving advice to students due to possible manipulation which may worsen allocation outcomes for the students, the only official third-party advice provider should be the centralized admissions system. This will be implemented to minimize the effect of mixed advice on the student's preferences. Secondly, an easy-to-understand explanation of the mechanism involved should be provided to the students. This will improve both the understanding and decision-making of students, reducing the expected outcome bias while also promoting trust in the algorithm.

The recommendation system should explicitly promote truth-telling in student preferences submission. In addition to explicitly stating that student outcomes are optimal when true preferences are submitted the system should also illustrate how extreme preference misrepresentations can drastically weaken the allocation given to a student. This can be illustrated by providing previous laboratory and university experiments showing how an improved outcome could have been achieved if the students have followed the advice of truth-telling. By doing so the recommendation system will limit unnecessary strategic positioning and mistrust. Overall, we believe that the given guidelines for a recommendation system will limit unwanted characteristics while also promoting truth telling and increasing preference correlation which improves strategy-proofness by approaching its completeness.

8. Conclusion

This paper has introduced the admission system algorithm implemented in Russian universities which is a combination of a university-proposing DA and a serial dictatorship allocating state-funded and tuition placements. We have shown how this algorithm operates and have discussed the manipulability and unstable allocations this mechanism provides. Following this, we have implemented an improved mechanism which sequences the allocations based on placement type, starting with state-funded placements which are allocated by a student-proposing DA after which students competing for tuition placements are allocated by a serial dictatorship based on cycle of decommitment. We have shown how the improved algorithm operates and how the desired properties of stability and strategy-proofness are achieved.

In addition, the proposed mechanism has implemented tie-breaking rules to allocate multiple students competing for limited number of tuition placements without worsening their outcome from trying to improve their allocation. These tie-breaking rules have been separated based on the popularity of a university with the purpose of providing both high and low achieving students with the opportunity to receive an allocation while minimizing the possibility of being unassigned. After this, we have discussed how although the mechanism is strategy-proof, students might decide to take the risk of improving their outcomes through the randomness of the tie-breaking rules which does not guarantee a successful outcome improvement.

We have discussed how student risk-taking can be minimized through reducing the preference list size, increasing the size of the university admissions market while also increasing preference correlation between students through the truth-telling behavior and submission of true preferences. To incentivize truth-telling, we have explained different traits found in the literature which hinder the effectiveness of the DA mechanism overall and ours individually as a strategy proof mechanism. These traits which include strategic positioning, expected outcome bias, mixed advice and mistrust in the mechanism can be minimized with an optimal recommendation system which limits the number of official third-party agents who can offer advice, provide easy-to-understand explanation of the mechanism while explicitly promoting truth-telling by stating that student outcomes are optimal when true preferences are submitted the system while also illustrating how extreme preference misrepresentations can drastically weaken the allocation given to a student.

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