How does Major Adjustment Affect Chinese College Admissions?

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Abstract

During the annual college application season, popular college majors often attract a large number of applicants, while less popular majors rarely receive many applications. To fulfill the government's enrollment targets, Chinese colleges may accept additional applicants through the major adjustment process and place them in majors with vacancies. This poses a dilemma for applicants: should they allow colleges to place them in an adjusted major? In this paper, we examine the impact of the adjustment process on Chinese college admissions from the perspective of mechanism design. Based on the Application-Rejection mechanisms, we introduce the Major-Adjusted Parallel Mechanisms. The latter considers both the regular admissions process and the adjustment process. We find that, under the same conditions, the Major-Adjusted Parallel Mechanisms allocate at least as many college seats as the Application-Rejection Mechanisms, implying that the major adjustment process can boost enrollment. Furthermore, we show that truth-telling is a weakly dominant strategy for every student with a preference ordering that can be recognized by the system. However, there is no weakly dominant strategy for other students.

Contents

1 Introduction

School choice and admissions mechanisms have been widely debated in various countries for the past few years, and China is no exception. Every year, over 10 million Chinese high school seniors take the National College Entrance Examination (NCEE, or *Gaokao* in Mandarin), competing for 4 million four-year college seats. Based on candidates' NCEE scores and rank-ordered lists, the centralized admissions system in each province allocates them to colleges across the country. Prior to 2000, the immediate acceptance (IA, or Boston) mechanism was implemented in the Chinese college admission system. However, the Chinese college admissions system has undergone a series of reforms during the past two decades, and most of the provinces have transitioned from the IA mechanism to the Parallel Mechanisms. Moreover, several changes were made to the Chinese college admissions system, including the deferral of the rank-ordered list submission deadline (Wu and Zhong 2014), the increase in the number of parallel choices (Chen and Kesten 2017), the balancing of the quota allocation across provinces (Yang 2021), and the introduction of the adjustment process. Each province also made some changes according to local needs.

Adjustment (*Tiao Ji* in Mandarin) is extensively used in China for college admissions and government recruitment. During the annual college application season, popular college majors such as computer science, engineering and finance can easily attract a large pool of applicants, while less popular majors, such as literature, history, and philosophy, receive relatively fewer applications. In order to fulfill the government's enrollment targets, colleges may accept additional applicants and place them in majors with vacancies.

Typically, the entire admissions process is separated into several rounds, each corresponding to a parallel choice band. Take Guangdong, a province that has more than 100 million residents, as an example. Prior to 2018, Guangdong's admissions process consisted of four primary rounds. The first was the Early Admissions Round, which was only open to military academies and special admission programs for teachers, athletes, fine art students, etc.[1] The First-Tier College Round came next. Only the best four-year colleges in the country (usually the top 200 colleges) were permitted to recruit students in this round. As a result, the public referred to these institutions as first-tier colleges. The third round was the Second-Tier College Round, in which all remaining four-year colleges could recruit students. The last round was the Three-Year College Round, in which the three-year colleges could recruit students in this round. Before the admissions process began, each student could select a certain amount of first-tier colleges, second-tier colleges, and three-year colleges, respectively.

Since the transition from the IA mechanism to the Parallel Mechanisms, this four-round model has become the norm in many provinces. To date, several provinces, such as Sichuan, Jiangxi and Shaanxi, still follow this model. In 2018, Guangdong combined the First-Tier College and the Second-Tier College rounds and increased the number of parallel choices per choice band from 11 to 15. In 2022, this number was increased to 45. This means that Guangdong students can select and rank 45 four-year colleges (no longer differentiating the tiers) and three-year colleges, respectively. Similar policies have been practiced in Beijing, Shanghai, and other districts.

Most of the provinces require candidates to fill out the application form in this order: first, students designate a college as their first choice; in the next step, they select their preferred majors at that college (generally five to six majors); lastly, they need to indicate whether they allow a major adjustment from that college, by checking the box in the last column.[2] This process iterates through the following choices. When colleges review applications, they first attempt to place the students in their preferred majors. If all of a student's preferred majors are full, the colleges will check whether the student allows for an adjustment. If the student allows for an adjustment and her NCEE score qualifies her for an adjusted major,

1. Compared to the subsequent rounds, the Early Admissions Round matches a small number of students and may have different admissions rules. Therefore, our analysis excludes this round and focuses on the subsequent rounds.

2. In other words, if they allow that college to place them in an adjusted major. If a student allows an adjustment from a college, we say that student is an adjustable applicant to that college.

the college grants acceptance and places this student in the adjusted major. Otherwise, a college rejects applicants when (i) their NCEE scores do not qualify them for their preferred majors, and they do not allow adjustments, or (ii) their NCEE scores do not qualify them for either their preferred majors or the adjusted majors.

Since the adjustment process may affect the allocation outcomes, students and their parents must carefully consider whether to allow adjustments from specific colleges. A number of colleges, including the prestigious Fudan University, Wuhan University, and Sun Yat-sen University, have announced that they will grant acceptance to all adjustable applicants who meet the minimum cut-off requirements (Fudan University 2021; Wuhan University 2022; Sun Yat-sen University 2022). From this perspective, allowing for adjustments can be a way for low-scoring candidates to reduce their admission risk. This is because if they allow for adjustments, they are more likely to receive offers than those who have approximately the same NCEE scores but do not allow adjustments. Furthermore, even high-scoring applicants should rationally utilize the adjustment process as insurance, especially if they aspire to attend their dream college.

Considering that more prestigious colleges generally have better educational resources, management systems and international reputation, some students and their parents prioritize college prestige when applying to colleges (Guo, Guo, and Hao 2021). Even if they are assigned to an unsuitable major, students can later transfer to another major or pursue a minor or a double major. Therefore, some consider giving up the initiative to choose majors in exchange for securing the "last seat" at a prestigious college as a fair trade-off. One common strategy for candidates is to allow adjustments from multiple colleges, which can help decrease the risk of being placed in a lower-ranked college or not being admitted. In addition, there is also a strategy for students to allow adjustments from all colleges. Although the latter is highly conservative, this approach allows students to be admitted to a higher-ranked college.

However, according to Guo, Guo, and Hao (2021), while some students prioritize specific colleges, others believe that students' interests and career prospects in their preferred majors should be the main determinants when applying to colleges. Although some colleges may not have the comprehensive capabilities of top universities, the academic and industry recognition of their ace majors is relatively high. Therefore, some students may prioritize specific majors over colleges and prefer not to allow major adjustments from colleges. It is worth noting that if candidates do not allow adjustments from colleges and their preferred majors are in high demand, they may face fierce competition for seats. This may result in being placed in a lower-ranked college or not being accepted. With this in mind, candidates and their parents face the difficult decisions of whether to allow adjustments from specific colleges.

Although the adjustment process has been extensively used in Chinese college admissions, and practitioners are aware of its pros and cons, to the best of our knowledge, there is a lack of literature on this topic.[3] To fill this gap, this paper investigates the effects of the adjustment process on Chinese college admissions from the perspective of mechanism design.

In our model, each school offers two types of seats: regular seats and adjusted seats, where the regular seats are more preferred by students. Meanwhile, all students are required to follow specific rules to submit their preferences. By assuming that colleges are partitioned into tiers, we boil down the Parallel Mechanisms presented in Chen and Kesten (2017) to a series of DA mechanisms, where each round is a DA for all unmatched students and the corresponding tier of colleges. Based on the Chen-Kesten Parallel Mechanisms, we introduce Major-Adjusted Parallel Mechanisms, which consider both the regular admissions process and the adjustment process. We then conduct further analysis of the Major-Adjusted Parallel Mechanisms. First, we show that the adjustment process can boost enrollment. In other words, under the same conditions, the Major-Adjusted Parallel Mechanisms allocate at least as many college seats as the Chen-Kesten Parallel Mechanisms. Furthermore, we find that truth-telling is a weakly dominant strategy for every student with a preference ordering that can be recognized by the system. However, there is no weakly dominant strategy for other

3. Some articles on Chinese college admissions, such as Wu and Zhong (2014), and Yang (2021), mention the adjustment process but offer no further discussion or analysis.

students.

The rest of this paper is organized as follows. Section 2 reviews the relevant literature, and Section 3 sets up the school choice problem with major-adjusted seats. Section 4 introduces the mechanisms and provides an illustrative example. Section 5 analyzes the Major-Adjusted Parallel Mechanisms, and Section 6 concludes.

2 Literature Review

Understanding of the properties of the existing mechanisms is essential for designing a more sustainable and efficient mechanism. The discussion on the school choice problem dates back to the famous Gale and Shapley (1962) article, which introduces the one-to-one marriage matching model, the many-to-one college admission model and the deferred acceptance (DA) mechanism. The DA mechanism has been widely studied and applied over the past decades. However, some other matching mechanisms, such as the IA mechanism, have sparked a debate. To examine the shortcomings of pre-existing school choice plans in the United States, Abdulkadiroğlu and Sönmez (2003) formulates the school choice problem as a mechanism design problem and analyzes the properties of the IA, DA, top trading cycle (TTC) and Columbus student assignment mechanisms. The article points out that the IA is not strategy-proof, meaning that families may have the incentive to misreport their true preferences in order to obtain a better assignment. As a result, the matching outcomes are unlikely to be Pareto efficient. The Columbus assignment mechanism is inefficient; families may miss their optimal offers due to incomplete information. The authors propose the Gale-Shapley student optimal stable mechanism and top trading cycles mechanism as solutions, where the former is strategy-proof and eliminates justified envy. The latter is strategy-proof and Pareto-efficient but does not eliminate justified envy.

Since 2001, most of the Chinese provinces have transitioned their college admissions mechanisms from Boston to Parallel Mechanisms. Nevertheless, few theoretical studies have analyzed the properties of the latter. To fill this gap, Chen and Kesten (2017) formulates a parametric family of Application-Rejection mechanisms. The family of Application-Rejection mechanisms not only considers the different versions of the Chinese Parallel Mechanisms as intermediate cases but also includes the IA and DA mechanisms as extreme members with the smallest and the largest choice band size, respectively. The authors demonstrate that the Parallel Mechanisms become less manipulable as the number of parallel choices within a choice band (e) increases. This implies that the Parallel Mechanisms are still manipulable, but are less manipulable than the IA mechanism. Furthermore, the authors also show that the DA mechanism is more stable than the Shanghai mechanism (the simplest version of the Parallel Mechanisms), and the latter is more stable than the IA mechanism. In other words, Chinese provinces that have decommissioned the IA mechanism now have a less manipulable and more stable mechanism. Subsequently, Chen and Kesten (2019) conducts an experiment to study the family of Application-Rejection mechanisms. The experimental results indicate that participants are most likely to submit their true preferences under the DA mechanism, followed by the Parallel Mechanisms and then IA. Furthermore, the authors conclude that the performance of any Parallel Mechanism is intermediate between the IA and DA mechanisms.

To investigate the impact of family background on Chinese students' educational preferences, Guo, Guo, and Hao (2021) analyzed nationwide data from a questionnaire survey conducted by Peking University in 2014. The authors categorize students into two groups: one group prioritizes college prestige over their preferred majors when applying to colleges, and the other group does the opposite. This study finds that students from more affluent families were more likely to prioritize college prestige when applying to colleges, while students from disadvantaged families were more likely to prioritized their preferred majors. Accordingly, urban students are more likely to prioritize college prestige than rural students.

This section discusses the literature on the school choice problem, the Chinese parallel mechanism, and the educational preferences of Chinese students. Although Abdulkadiroğlu and Sönmez (2003) is not the first paper that discusses the deficiencies of the pre-existing admission mechanism, it addresses the issues from the mechanism design perspective and inspires subsequent studies on this topic (Chen and Sönmez 2006; Abdulkadiroğlu, Pathak, and Roth 2005; Abdulkadiroğlu et al. 2005). We hope that this paper will serve a similar purpose. Chen and Kesten (2017) is considered the most comprehensive theoretical study on Chinese college admissions. This article provides a foundation for our research. By incorporating more realistic factors, such as the adjustment process, into their proposed algorithm, we gain a better understanding of the current matching mechanism. In addition, Guo, Guo, and Hao (2021) provides us with information about the educational preferences of Chinese students. Our results may contribute to subsequent studies in related fields.

3 The School Choice Problem with Major-Adjusted Seats

First, we set up and define an appropriate school choice problem. This is a one-sided matching model where schools are not strategic agents and we call them colleges. Each college offers two types of seats. Let $S = \{s_1, s_2, \ldots, s_n\}$ denote the finite set of students, where $n \geq 2$. A generic element in S is denoted by s. The finite set of colleges is denoted by $C = \{c_1, c_2, \ldots, c_m\} \cup \emptyset$, where $m \geq 2$; $\emptyset$ is the outside option. A generic element in C is denoted by c.

Each college $c \in C$ offers two types of seats: regular seats, which are open to all applicants, and major-adjusted seats (or simply adjusted seats), which are open only to applicants who allow major adjustments. Students assigned regular seats are placed in their preferred majors, while those who are assigned adjusted seats are placed in other majors with vacancies. As a result, students prefer to be assigned a regular seat when they are matched to a college.

Accordingly, each college c has two quotas, the regular quota q_c^{reg} for the regular seats and the adjusted quota q_c^{adj} for the adjusted seats, where $q_c^{reg} \geq 1$ and $q_c^{adj} \geq 0$. We assume that the adjusted quota of each college is exogenous. Let $q^{reg} = (q^{reg}_{c_1}, q^{reg}_{c_2}, \ldots, q^{reg}_{c_m})$ and $q^{adj} = (q^{adj}_{c_1}, q^{adj}_{c_2}, \ldots, q^{adj}_{c_m})$, where q^{reg} and q^{adj} are two lists of college capacities, enumerating the number of regular seats and adjusted seats for each college, respectively. We also denote the total capacity of each college by q_c, where $q_c = q^{reg}_c + q^{adj}_c$. The outside option has an unlimited quota ($q_\emptyset = \infty$). A list of college capacities $q = (q_{c_1}, q_{c_2}, \ldots, q_{c_m})$ enumerates the total number of available seats for each college. Each college c has a strict priority order over all students, and we denote the priority order of college c by $\succ_c$. A priority profile $\succ = (\succ_{c_1}, \succ_{c_2}, \ldots, \succ_{c_m})$ is a list of strict college priorities.

Each student s has strict preferences P_s over all colleges, seats and the outside option. For any $c, c' \in C \cup \emptyset$, $c\, P_s\, c'$ means that student s strictly prefers c to c', and $\emptyset\, P_s\, c$ means that student s strictly prefers the outside option $\emptyset$ to c. The associated weak relation with P_s is denoted by R_s, where R_s is a transitive, complete, and antisymmetric binary relation on $C \cup \emptyset$. A preference profile $P = (P_{s_1}, P_{s_2}, \ldots, P_{s_n})$ is a list of strict student preferences.

When students submit their preferences to the centralized system, they first rank the colleges. We write $P_s : (c_1, c_2, c_3, \ldots, \emptyset)$ to denote that, for student s, college c_1 is his first choice, college c_2 is his second choice, college c_3 is his third choice, and so on. Next, for each college on the list, each student must decide whether to allow that college to place him in an adjusted major. If a student allows an adjustment from college c_t, he needs to indicate $c_t^{\checkmark}$ when reporting preferences. If a student does not allow an adjustment from college c_t, he simply indicates c_t. A student who indicates $c_t^{\checkmark}$ is referred to as an adjustable applicant to college c_t.

For example, suppose student j allows adjustments from her first- and second-choice colleges only, then she should report the following preference ordering: $P_j : (c_1^{\checkmark}, c_2^{\checkmark}, c_3, \ldots, \emptyset)$. Suppose student k does not allow adjustments from any college, then she should report the preferences $P_k : (c_1, c_2, c_3, \ldots, \emptyset)$. We refer to those preferences that are recognized by the system as **acceptable preferences**. The set of acceptable preferences contains all the acceptable preferences. Students can only report acceptable preferences to the system.

However, the true preferences of students may not be acceptable preferences. To specify student preferences, let c^{reg} and c^{adj} denote the regular and adjusted seats of each college $c \in C$, respectively. We assume that for the ith and the $i+1$st choices of each student s, where $i = \{1, 2, \ldots\}$, $c_i^{reg} \, P_s \, c_{i+1}^{reg}$ and $c_i^{reg} \, P_s \, c_i^{adj}$ always hold. However, indicating $c_i^{\checkmark}$ represents $c_i^{adj} \, P_s \, c_{i+1}^{reg}$, while indicating c_i represents $\emptyset \, P_s \, c_i^{adj}$, and neither of these may represent a student's true preferences.

For example, student j may have preference ordering $P_j : (c_1^{reg}, c_2^{reg}, c_3^{reg}, c_1^{adj}, \emptyset, c_2^{adj}, c_3^{adj})$. In this case, she cannot report her true preferences to the system because the system does not recognize them. To be able to submit her preferences, she has to choose between the following two acceptable preferences: (i) $P_j : (c_1^{\checkmark}, c_2, c_3, \ldots, \emptyset)$, which represents $P_j : (c_1^{reg}, c_1^{adj}, c_2^{reg}, c_3^{reg}, \emptyset, c_2^{adj}, c_3^{adj})$; or (ii) $P_j : (c_1, c_2, c_3, \ldots, \emptyset)$, which represents $P_j : (c_1^{reg}, c_2^{reg}, c_3^{reg}, \emptyset, c_1^{adj}, c_2^{adj}, c_3^{adj})$. We refer to all preferences that the system does not recognize as **unacceptable preferences**. In other words, all preferences that are excluded from the set of acceptable preferences are unacceptable preferences. For every student s with an unacceptable preference ordering, there must exist a college c_i that satisfies the following two conditions: (i) $c_i^{adj} \, P_s \, \emptyset$, and (ii) $c_{i+1}^{reg} \, P_s \, c_i^{adj}$, where c_i is the ith and c_{i+1} is the $i+1$st choice of student s, respectively.

In addition, we define two extreme preferences. The first type is the **college-prestige preferences**, where a student allows adjustments from all colleges on the rank-ordered list. For each student k who has college-prestige preferences, we denote his preferences by $P_k : (c_1^{\checkmark}, c_2^{\checkmark}, c_3^{\checkmark}, \ldots, \emptyset)$, which represents $P_k : (c_1^{reg}, c_1^{adj}, c_2^{reg}, c_2^{adj}, c_3^{reg}, c_3^{adj}, \ldots, \emptyset)$. The other is **preferred-major preferences**, where a student does not allow adjustments from any college. For each student k' with preferred-major preferences, we denote his preferences by $P_{k'} : (c_1, c_2, c_3, \ldots, \emptyset)$, which represents $P_{k'} : (c_1^{reg}, c_2^{reg}, c_3^{reg}, \ldots, \emptyset, c_1^{adj}, c_2^{adj}, c_3^{adj}, \ldots)$. Both college-prestige and preferred-major preferences are acceptable preferences; that is, these together are a strict subset of the set of acceptable preferences.

A **school choice problem** consists of a set of students S, a set of colleges C, two lists of college capacities q^{reg} and q^{adj}, and a priority and preference profile pair (or simply a profile) $(\succ, P)$. A **matching** is a function $\mu\colon S \to \{C \cup \emptyset\}$ such that $\mu(s) \in \{C \cup \emptyset\}$ and $|\mu^{-1}(c)| \leq q_c$ for all students s and colleges c. Let $\mu(s)$ denote the assignment of student s (either a college $c \in C$ or the outside option $\emptyset$) and $\mu^{-1}(c)$ denote the set of students assigned to college c. To specify the type of seats a student is assigned, for student s who is assigned an adjusted seat at college c, we write $\mu(s) = c^{adj}$; for student s' who is assigned a regular seat at college c, we write $\mu(s') = c^{reg}$. Accordingly, $\mu^{-1}(c^{reg})$ and $\mu^{-1}(c^{adj})$ denote the set of students who are assigned a regular seat and an adjusted seat at college c, respectively. A matching **mechanism** (also known as a matching rule) is a function $\varphi : \mathcal{R} \to M$, where $\mathcal{R}$ is the set of profiles given by $(\succ, P)$, and M is the set of matchings. Let $\varphi(\succ, P)$ denote the matching chosen by φ at profile $(\succ, P)$ and $\varphi_s(\succ, P)$ denote the assignment of student s at this matching.

A matching μ is **individually rational** at profile $(\succ, P)$ if all students prefer their assignments to the outside option (i.e., $\mu(s)\, R_s\, \emptyset$ for all $s \in S$). A matching μ is **non-wasteful** at profile $(\succ, P)$ if there is no student who prefers any colleges with vacancies to his assignment, that is, for all $s \in S$ and $c \in C$, $c\, P_s\, \mu(s)$ implies $|\mu^{-1}| = q_c$. A matching μ is **Pareto efficient** if there is no other matching that makes at least one student better off without making any other student worse off. That is, a matching μ is Pareto efficient if there exists no $\mu' \in M$ such that $\mu'(s)\, P_s\, \mu(s)$ for some students $s \in S$ and $\mu'(\hat{s})\, R_{\hat{s}}\, \mu(\hat{s})$ for all students $\hat{s} \in S$. A matching mechanism φ is Pareto efficient if the mechanism φ assigns a Pareto efficient matching μ to every problem $(\succ, P) \in \mathcal{R}$. In addition, a mechanism φ weakly Pareto-dominates another mechanism ψ if, for all profiles $(\succ, P) \in \mathcal{R}$ and for all students $s \in S$, $\varphi_s(\succ, P)\, R_s\, \psi_s(\succ, P)$. A mechanism φ Pareto-dominates another mechanism ψ if, for all profiles $(\succ, P) \in \mathcal{R}$ and for all students $s \in S$, $\varphi_s(\succ, P)\, R_s\, \psi_s(\succ, P)$ and $\varphi_{\hat{s}}(\succ, P)\, P_{\hat{s}}\, \psi_{\hat{s}}(\succ, P)$ for some student $\hat{s} \in S$.

There is **justified envy** in matching μ at profile $(\succ, P)$ if there are students $s, s' \in S$ and college $c \in C$ such that: (i) $c\, P_s\, \mu(s)$; (ii) $\mu(s') = c$; and (iii) $s \succ_c s'$. A matching μ is

stable at profile $(\succ, P)$ if it is individually rational, non-wasteful, and there is no justified envy. A matching mechanism φ is stable if the mechanism φ assigns a stable matching μ to every problem $(\succ, P)$. A matching mechanism φ is **manipulable** at profile $(\succ, P)$, if there exists a student $j \in S$ and $P_j^{'}$ such that $\varphi_j(\succ, (P_j^{'}, P_{-j}))\, P_j\, \varphi_j(\succ, P)$. A mechanism φ is **strategyproof** if it is not manipulable. In other words, a mechanism is strategyproof if every student has truth-telling as a weakly dominant strategy.

Following Pathak and Sönmez (2013), a mechanism φ is **weakly more manipulable** than another mechanism ψ if whenever ψ is manipulable at some profile $(\succ, P)$, φ is also manipulable at the same profile. A mechanism φ is **more manipulable** than another mechanism ψ if (i) φ is weakly more manipulable than ψ; and (ii) there exists at least one profile $(\succ, P)$ such that φ is manipulable at $(\succ, P)$ but ψ is not. Following Ehlers and Klaus (2016), a matching mechanism is **resource-monotonic** if the availability of more college capacity has a weakly positive effect on all students. Formally, a mechanism is resource-monotonic if, for all $s \in S$, $c \in C$ and each profile $(\succ, P) \in \mathcal{R}$, if $q_c \leq q_c^{'}$, then $\varphi_s((P, \succ), q^{'})\, R_s\, \varphi_s((P, \succ), q)$. A mechanism φ assigns at least as many students as another mechanism ψ if, for each profile $(\succ, P) \in \mathcal{R}$, the number of assigned students under φ is equal to or greater than the number of assigned students under ψ.

4 Mechanisms

4.1 Application-Rejection Mechanisms

To study the theoretical properties of the Chinese Parallel Mechanisms, Chen and Kesten (2017) formulate a parametric family of Application-Rejection mechanisms. The Application-Rejection mechanism (e) is equivalent to

- the Immediate Acceptance (IA) mechanism when $e = 1$,
- the Chinese Parallel Mechanism when $2 \leq e < \infty$,

- the Deferred Acceptance (DA) mechanism when $e = \infty$.

Where e is the number of parallel choices within a choice band; in other words, each student can apply to a maximum of e schools per round in the algorithm. In Chinese college admissions, the provincial governments determine their e. The simplest version of the Parallel Mechanisms, with $e = 2$, is called **Shanghai Mechanism**. That is, under the Shanghai Mechanism, each student can list only two colleges within each parallel choice band.

Within the family of Application-Rejection mechanisms (e), the IA mechanism is the only Pareto efficient mechanism, the DA mechanism is the only stable mechanism and the only strategyproof mechanism. Furthermore, Chen and Kesten (2017) demonstrate that mechanism φ^e is more manipulable than $\varphi^{e'}$, where $e' > e$. For some $k \in \mathbb{N} \cup \{\infty\}$, if $e' = ke$, then $\varphi^{e'}$ is more stable than φ^e. Otherwise, if if $e' \neq ke$, then $\varphi^{e'}$ is not more stable than φ^e.

4.2 Major-Adjusted Parallel Mechanisms

Based on the Application-Rejection mechanisms (hereafter referred to as Simple Parallel Mechanisms), we introduce the Major-Adjusted Parallel Mechanisms. In contrast to the Simple Parallel Mechanism, our mechanisms consider not only the allocation of the regular seats but also the allocation of adjusted seats through the adjustment process.

To simplify our model, we make the following assumptions. First, we assume that each parallel choice band corresponds to a specific tier of colleges. That is, we classify all colleges into multiple tiers, and each student can only rank first-tier colleges within their first choice band, second-tier colleges within their second choice band, and so forth. This assumption precludes students from ranking lower-tier colleges ahead of higher-tier colleges. This assumption also allows us to boil down the Simple Parallel Mechanisms to a series of DA mechanisms: round 1 is a DA for all students and all first-tier colleges, round 2 is a DA for all students not assigned a seat in the first round and all second-tier colleges, and so on.

We also assume that there is no constraint on the size of the parallel choice band. That is, all students can declare as many colleges as they wish. A related study is Haeringer and Klijn (2009). They investigate constrained school choice games where students can only declare up to a limited number of schools. In the context of Chinese college admissions, most provinces have been expanding their parallel choice bands (e) in recent years. Guangdong province, for example, has increased e to 45 in 2022. With such large numbers, there may not be a practical constraint for many candidates.

We present next the algorithm for the Major-Adjusted Parallel mechanisms. Let $e \in \{1, 2, \ldots, \infty\}$. Note that in the case of $e = 1$, there is no room for preference ordering. Students only need to report whether they allow an adjustment from the already determined college in each tier.

Round $t = 1$ **:** Only first-tier colleges are permitted to recruit students in this round.

Step 1: Each student $s \in S$ applies to his first-ranked college. Then each college $c \in C$ considers its applicants according to the following substeps:

Substep 1a (Regular Admissions): Each college c accepts the q_c^{reg} highest-ranked applicants according to its priority order $\succ_c$. If the number of applicants is less than or equal to q_c^{reg}, college c accepts all applicants.

Substep 1b (Adjustment): Each college c accepts the q_c^{adj} highest-ranked **adjustable** applicants from the remaining applicants according to its priority order $\succ_c$. If the number of remaining adjustable applicants is less than or equal to q_c^{adj}, college c accepts all of its adjustable applicants.

Tentatively assign all accepted students to college c. The remaining students are rejected.

Step k: Each unassigned student who has not yet applied to his eth-ranked college applies to his next choice. A student cannot apply until the next round if he has been rejected by all his first e colleges (all the first-tier colleges he listed). Each college c considers its tentatively assigned students, as well as its new applicants altogether, in two substeps:

Substep ka (Regular Admissions): Each college c accepts the q_c^{reg} highest-ranked applicants according to its priority order $\succ_c$. If the number of applicants is less than or equal to q_c^{reg}, college c accepts all applicants.

Substep kb (Adjustment): Each college c accepts the q_c^{adj} highest-ranked adjustable applicants from the remaining applicants according to its priority order $\succ_c$. If the number of remaining adjustable applicants is less than or equal to q_c^{adj}, college c accepts all of its adjustable applicants.

The first round terminates when each student is either assigned to a college or has been rejected by all of his first e choices. All tentative assignments become final. All the first-tier colleges can no longer recruit students in the subsequent rounds.

In general, **Round** $t \geq 2$ **:** Only tier-t colleges are permitted to recruit students.

Step 1: Each unassigned student s applies to his $(t-1)e+1$st-ranked college. Then each college c considers its applicants in two substeps:

Substep 1a (Regular Admissions): Each college c accepts the q_c^{reg} highest-ranked applicants according to its priority order $\succ_c$. If the number of applicants is less than or equal to q_c^{reg}, college c accepts all applicants.

Substep 1b (Adjustment): Each college c accepts the q_c^{adj} highest-ranked adjustable applicants from the remaining applicants according to its priority order $\succ_c$. If the number of remaining adjustable applicants is less than or equal to q_c^{adj}, college c accepts all its adjustable applicants.

Tentatively assign all accepted students to college c. The remaining students are rejected.

Step k: Each unassigned student who has not yet applied to his teth-ranked college, applies to his next choice. A student cannot apply until the next round if he has been rejected by all his first te colleges (all tier-t colleges he listed). Each college c considers its tentatively assigned students, as well as its new applicants altogether, in two substeps:

Substep ka (Regular Admissions): Each college c accepts the q_c^{reg} highest-ranked applicants according to its priority order $\succ_c$. If the number of applicants is less than or equal to q_c^{reg}, college c accepts all applicants.

Substep kb (Adjustment): Each college c accepts the q_c^{adj} highest-ranked adjustable applicants from the remaining applicants according to its priority order $\succ_c$. If the number of remaining adjustable applicants is less than or equal to q_c^{adj}, college c accepts all of its adjustable applicants.

The round terminates when each student is either assigned to a college or has been rejected by all of his first te choices. All tentative assignments become final. All tier-t colleges can no longer recruit students in the subsequent rounds.

The algorithm terminates when each student is either assigned to a college or rejected by the last college on the rank-ordered list. Each student who is matched to a college through the regular admissions substeps is assigned a regular seat at that college. In contrast, each student who is matched to a college through the adjustment substeps is assigned an adjusted seat at that college.

It is worth noting that the Simple Parallel Mechanisms are a special case of the Major-Adjusted Parallel Mechanisms, where the former does not allocate any adjusted seats (by skipping all the adjustment substeps). Therefore, there is no difference between the two mechanisms when no student is matched to a college through the adjustment substep. This may happen, for example, when $q_c^{adj} = 0$ for all colleges $c \in C$.

Furthermore, we note that if we consider the two types of seats, c^{reg} and c^{adj}, for each college $c \in C$ as two separate colleges, then a Major-Adjusted Parallel Mechanism would exactly correspond to a Simple Parallel Mechanism (i.e., there is a DA in each round). In this scenario, a student assigned to college c^{reg} would receive a regular seat from college c, while a student assigned to college c^{adj} would receive an adjusted seat from college c. For example, student j has preference ordering $P_j : (c_1^{\checkmark}, c_2, c_3, \ldots)$. In the algorithm, she first applies to college c_1^{reg}; if she is rejected by college c_1^{reg}, she then applies to college c_1^{adj}. And if she is rejected by college c_1^{adj}, she applies to college c_2^{reg}, then to college c_3^{reg}, and so on.

4.3 An Illustrative Example: The Major-Adjusted Shanghai Mechanism

The Major-Adjusted Shanghai Mechanism ($e = 2$) is used in this example. Suppose there are six students, $S = \{1, 2, 3, 4, 5, 6\}$, and four colleges, $C = \{a, b, c, d\}$. Colleges a and b are first-tier colleges, while colleges c and d are second-tier colleges. College capacities are given by $q^{reg} = \{1, 1, 1, 1\}$ and $q^{adj} = \{0, 1, 0, 2\}$. That is, each college offers one regular seat; college b offers one adjusted seat; d offers two adjusted seats; and colleges a and c offer no adjusted seats.

The following are the priority profile $\succ$ and the preference profile P. We assume that the priorities represent the college's evaluations of the students.

$\succ_a$	$\succ_b$	$\succ_c$	$\succ_d$
1	2	4	1
2	1	2	2
3	5	3	5
6	6	1	4
5	4	5	3
4	3	6	6

Table 1: School Priority Profile

P_1	P_2	P_3	P_4	P_5	P_6
$a^{\checkmark}$	b	$b^{\checkmark}$	$a^{\checkmark}$	$b^{\checkmark}$	$a^{\checkmark}$
$b^{\checkmark}$	a	$a^{\checkmark}$	$b^{\checkmark}$	$a^{\checkmark}$	$b^{\checkmark}$
c	d	d	$d^{\checkmark}$	$c^{\checkmark}$	$d^{\checkmark}$
d	c	c	$c^{\checkmark}$	$d^{\checkmark}$	c

Table 2: Student Preference Profile

Round 1: Only the first-tier colleges (a and b) are permitted to recruit students.

Step 1: Students 1, 4 and 6 apply to college a. Students 2, 3 and 5 apply to college b. Each college considers its applicants.

Substep 1a (Regular Admissions): According to the priority orders, college a accepts student 1, college b accepts student 2.

Substep 1b (Adjustment): College b has one adjusted seat and accepts its adjustable applicant student 5 since $5 \succ_b 3$.

Tentatively assign student 1 to college a and students 2 and 5 to college b. Students 3, 4, and 6 are rejected.

Step 2: Student 3 applies to college a and students 4 and 6 apply to b. Each college considers its tentatively assigned students, as well as its new applicants altogether.

Substep 2a (Regular Admissions): Both colleges a and b keep their tentatively assigned students since $1 \succ_a 3$ and $2 \succ_b 6 \succ_b 4$.

Substep 2b (Adjustment): College b keeps student 5 since $5 \succ_b 6$ and $5 \succ_b 4$.

Tentatively assign student 1 to college a and students 2 and 5 to college b. Students 3, 4 and 6 are rejected.

Round 1 terminates and all tentative assignments become final. Colleges a and b can no longer recruit students in the subsequent rounds.

Round 2: Only the second-tier colleges (c and d) are permitted to recruit students.

Step 1: Students 3, 4 and 6 apply to college d. College d considers its applicants.

Substep 1a (Regular Admissions): College d accepts student 4 since she has the highest priority of the three applicants.

Substep 1b (Adjustment): College d has two adjusted seats and accepts its adjustable applicant student 6.

Tentatively assign students 4 and 6 to college d. Student 3 is rejected.

Step 2: Students 3 applies to college c. College c considers its applicant.

Substep 2a (Regular Admissions): College c accepts student 3.

Tentatively assign student 3 to college c.

Round 2 terminates since each student has been assigned a seat. All tentative assignments become final.

The algorithm terminates since each student has been assigned a seat. The final assignments are $\{(1, a), (2, b), (3, c), (4, d), (5, b^{adj}), (6, d^{adj})\}$.

Given the same priority and preference profiles, the solution to the problem under the Simple Shanghai Mechanism is $\{(1, a), (2, b), (3, \emptyset), (4, c), (5, d), (6, \emptyset)\}$.

We can simply observe the effect of the adjustment process on each student by comparing their assignments under the two mechanisms. Students 1 and 2 receive the same assignments under both mechanisms, indicating that they are not affected by the adjustment process. Under the Major-Adjusted Shanghai Mechanism, student 5 is assigned to her first-choice college, while under the Simple Shanghai Mechanism, she is assigned to her fourth choice. However, being assigned an adjusted seat means that she will not be placed in her preferred major. The remaining three students receive unambiguously better assignments under our mechanism. This is mainly because the Simple Parallel Mechanism does not allocate adjusted seats, resulting in fewer available seats than the number of applicants. Consequently, two students remain unassigned under the Simple Shanghai Mechanism, while all students are assigned a seat under our mechanism.

5 Analysis of Major-Adjusted Parallel Mechanisms

We now investigate the effects of the adjustment process on Chinese college admissions. We focus on two questions. First, does the adjustment process help boost college enrollment? Second, is there a dominant strategy under the Major-Adjusted Parallel Mechanisms? We start with the first question.

5.1 Improved Efficiency and Enrollment Boost

In this section, we assume that each student has acceptable preferences, such as college-prestige preferences and preferred-major preferences, and that each student reports their preferences truthfully. Recall that the Simple Parallel Mechanisms are a special case of the Major-Adjusted Parallel Mechanisms. In addition, by assuming that colleges are exogenously partitioned into tiers, we boil down the Simple Parallel Mechanisms to a series of DA mechanisms, where each round is a DA for all unmatched students and the corresponding tier of colleges. It is known that the DA and the IA mechanisms satisfy resource-monotonicity (Chambers and Yenmez 2017; Ehlers and Klaus 2016; Kojima and Ünver 2014).

We find that for each $e \in \{1, \ldots, \infty\}$, the Major-Adjusted Parallel Mechanism weakly Pareto-dominates the Simple Parallel Mechanism.

Proposition 1 *If each student has acceptable preferences and each student reports preferences truthfully, then for each* $e \in \{1, 2, \ldots, \infty\}$*, the Major-Adjusted Parallel Mechanism weakly Pareto-dominates the Simple Parallel Mechanism.*

Proof. We first show that the Simple Parallel Mechanisms satisfy resource-monotonicity. Recall that the first round of the Simple Parallel Mechanisms is a DA for all students and all first-tier colleges. It is known that the DA is resource-monotonic. This implies that if there are some first-tier colleges offering additional seats, all students will weakly gain at the end of the first round. Even if no first-tier colleges offer additional seats, no student is worse off.

The second round is another DA for all unmatched students from the previous round and all second-tier colleges. If there are colleges offering additional seats, regardless of their tier, there will always be fewer or the same number of unmatched students and the same number or more college seats at the beginning of the round. Consequently, all students will be weakly better off at the end of the round. The same principle applies to subsequent rounds. Therefore, the Simple Parallel Mechanisms satisfy resource-monotonicity.

Then recall that if we consider the two types of seats, c^{reg} and c^{adj}, for each college $c \in C$

as two separate colleges, the Major-Adjusted Parallel Mechanism would exactly correspond to a Simple Parallel Mechanism. This implies that we can consider the Major-Adjusted Parallel Mechanism as a Simple Parallel Mechanism, where some "adjusted colleges" are offering additional seats. In this case, all students are weakly better off when all tentative assignments become final. Therefore, under the same conditions, all students will weakly prefer the assignments they receive under the Major-Adjusted Parallel Mechanisms to the assignments they receive under the Simple Parallel Mechanisms. QED

Proposition 1 shows that, under our assumptions, if a student is assigned a seat under the Simple Parallel Mechanism, that student is also assigned a seat under the Major-Adjusted Parallel Mechanism, *ceteris paribus.* Therefore, the following result follows from Proposition 1.

Corollary 1 *If each student has acceptable preferences and each student reports preferences truthfully, for each* $e \in \{1, 2, \ldots, \infty\}$*, the Major-Adjusted Parallel mechanism assigns at least as many students as the Simple Parallel Mechanism.*

Corollary 1 implies that the adjustment process can help boost enrollment. This result is consistent with our expectations. In the context of Chinese college admissions, the adjustment process is designed to enable more students to attend college. This is accomplished by using vacancies in unfilled majors as additional seats for students who are willing to allow a major adjustment, thereby avoiding the waste of college seats (especially at four-year colleges). Despite such positive aspects of this policy, it poses a dilemma for applicants, who must decide whether to allow major adjustments from specific colleges.

5.2 Weakly Dominant Strategies

This section studies the existence of (weakly) dominant strategies under the Major-Adjusted Parallel Mechanisms. The following proposition states that for students with acceptable preferences, reporting their preferences truthfully is a weakly dominant strategy; that is, misreporting their true preferences does not lead to a better assignment and may lead to a worse assignment. For those students with unacceptable preferences, there is no weakly dominant strategy.

Proposition 2 *Under the Major-Adjusted Parallel Mechanisms,*

1. *for each student with an acceptable preference ordering, truth-telling is a weakly dominant strategy.*
2. *for each student with an unacceptable preference ordering, there is no weakly dominant strategy.*

Proof. Part 1 (a student has an acceptable preference ordering):

Consider two preference profiles (P_j, P_{-j}) and (P'_j, P_{-j}), where the preferences are constant for all students except j. In profile (P_j, P_{-j}), student j reports her true preferences P_j and is assigned to college c_i (or the outside option $\emptyset$), where college c_i is her i-th choice. In profile (P'_j, P_{-j}), she reports acceptable preferences other than P_j. It is known that the DA mechanism is strategyproof (Dubins and Freedman 1981; Roth 1982, 1985), so we leave out the cases about misrepresenting the ranking of colleges and focus on the cases that student j allows adjustments from fewer or more colleges.

The first thing to note is that if student j is assigned to college c_i at profile (P_j, P_{-j}), then whether she allows adjustments from colleges ranked lower than c_i or not will not affect her assignment. Second, indicating $c_i^{\checkmark}$ cannot make student j receive a better assignment; but not indicating $c_i^{\checkmark}$ may result in a worse assignment (consider the case where she is assigned an adjusted seat of college c_i at profile (P_j, P_{-j})). Furthermore, disallowing adjustments from colleges ranked higher than c_i will not improve her assignment, since she will still be rejected by all colleges ranked higher than c_i if she applies to those colleges at profile (P'_j, P_{-j}). Last, allowing adjustments from colleges ranked higher than c_i may enable student j to be assigned to a higher-ranked college, but she will be worse off. Consider the case where student j has higher priority at c_{i-1} than some students who are assigned to that college; however, she is rejected since she did not indicate $c_{i-1}^{\checkmark}$ at profile (P_j, P_{-j}). In this case, she can be assigned to college c_{i-1} by indicating college $c_{i-1}^{\checkmark}$ at profile (P_j', P_{-j}); but, she will be assigned an adjusted seat of c_{i-1}. Therefore, being assigned to college c_{i-1} actually makes her worse off since the adjusted seats of college c_{i-1} are unacceptable to her.

In conclusion, misreporting true preferences does not improve student j's assignment, regardless of the reported preferences of other students. This means that for each student with an acceptable preference ordering, truth-telling is a weakly dominant strategy.

Part 2 (a student has an unacceptable preference ordering):

We return to the illustrative example from Section 3.4. Here we suppose that students 3 and 6 have unacceptable preferences and therefore cannot report their true preferences. We also suppose that both students have the same preferences over the second-tier colleges, where $P_j : (d^{reg}, c^{reg}, d^{adj}, \emptyset)$ for student $j = \{3, 6\}$. The following illustrates the different effects of indicating $c^{\checkmark}$ on these two students.

By reporting $P_3 : (b^{\checkmark}, a^{\checkmark}, d, c, \emptyset)$, student 3 is assigned to her fourth-choice college c and obtain a regular seat. Meanwhile, her third-choice college d still has an unallocated adjusted seat. This means that if everyone else's preferences remain the same, she can get that adjusted seat by allowing an adjustment from college d. However, indicating $d^{\checkmark}$ will result in a worse assignment for student 3 since $c^{reg}\, P_3\, d^{adj}$.

Student 6 reports $P_6 : (a^{\checkmark}, b^{\checkmark}, d^{\checkmark}, c, \emptyset)$ and is assigned to d^{adj}. If everyone else's preferences remain the same, disallowing an adjustment from college d will leave student 6 unassigned. First, she will be rejected by college d, since she no longer qualifies for the adjusted seats of that college. Second, she will be rejected by college c since college c offers only one seat and $3 \succ_d 6$. This means that not indicating $d^{\checkmark}$ will result in a worse assignment for student 6.

It is worth noting that if student 3 reports $P_3' : (b^{\checkmark}, a^{\checkmark}, d^{\checkmark}, c, \emptyset)$ and the preferences of the other four students remain the same, not indicating $d^{\checkmark}$ will result in a better assignment for student 6. This is because student 3 will be assigned to college d if she reports P_3', and college c will have a regular seat available. This means that student 6 can be assigned to college c by not indicating $d^{\checkmark}$ in this case.

Therefore, for each student with an unacceptable preference ordering, there is no weakly dominant strategy. QED

Recall that a mechanism is strategyproof if every student has truth-telling as a weakly dominant strategy. The following result follows from part 1 of Proposition 2:

Corollary 2 *If each student has acceptable preferences, then for each $e \in \{1, 2, \ldots, \infty\}$, the Major-Adjusted Parallel Mechanism is strategyproof.*

Proposition 2 has important implications, it reveals the reasons why students and their parents have ambiguous attitudes toward major adjustments. In contrast to students with acceptable preferences, students with unacceptable preferences often face difficult decisions when reporting their preferences to the centralized system. In addition, students with unacceptable preferences may be dissatisfied with their assignment outcomes and may later regret their decisions. This is the most controversial aspect of the adjustment process, and it creates tension between students and the existing admissions mechanism.

Corollary 2 indicates that the Major-Adjusted Parallel Mechanisms are strategyproof if every student has an acceptable preference ordering. In practice, however, many students may have unacceptable preference orderings, even those who report the college-prestige or the preferred-major preferences. This is because each college has different characteristics and different admissions criteria. These factors can cause students to fail to have an acceptable preference ordering.

6 Conclusion

In this study, we examine the impact of the adjustment process on Chinese college admissions from the perspective of mechanism design. In our model, each school offers two types of seats:

regular seats and adjusted seats, with the regular seats are more preferred by students. Meanwhile, all students are required to follow specific rules to submit their preferences. By assuming that colleges are partitioned into tiers, we boil down the Application-Rejection mechanisms (referred to as Simple Parallel Mechanisms in our paper) presented in Chen and Kesten (2017) to a series of DA mechanisms, where each round is a DA for all unmatched students and the corresponding tier of colleges. Based on the Simple Parallel Mechanisms, we introduce the Major-Adjusted Parallel Mechanisms, where the latter considers the allocation of both regular and adjusted seats.

By comparing the Simple Parallel Mechanisms and the Major-Adjusted Parallel Mechanisms, we find that the adjustment process can boost enrollment. In other words, under the same conditions, the Major-Adjusted Parallel Mechanisms allocate at least as many college seats as the Simple Parallel Mechanisms, implying that the adjustment process reduces the waste of college seats. Furthermore, we find that truth-telling is a weakly dominant strategy for students with an acceptable preference ordering; however, there is no weakly dominant strategy for students with an unacceptable preference ordering. Therefore, students with unacceptable preferences often face difficult decisions when reporting their preferences to the centralized system. Although practitioners are aware of the pros and cons of the adjustment process, there is a lack of literature on this topic. Our work can contribute to subsequent studies in related fields.

We have several suggestions for improving the adjustment process. For example, allowing students to indicate which majors they do not want to be assigned to, and loosening the requirements for changing majors. Doing so would make students more willing to accept adjustments from colleges and few adjusted seats will be wasted. Furthermore, we have noticed that, in recent years, some colleges have stopped offering adjusted seats and have implemented meta-major reforms (Ma et al. 2023). Each meta-major consists of multiple traditional majors; for example, the engineering meta-major includes all engineering-related majors. Instead of choosing majors in advance, students can simply declare a meta-major when they submit their preferences and then choose their preferred field of specialization with the assistance of an academic advisor after completing the first two years of the program. According to the analysis we conduct in this paper, the meta-major reform can have a positive impact on the current matching mechanism. First, students no longer need to decide whether to allow adjustments, so we can return to the Simple Parallel Mechanisms. Second, all seats at the college can now be used as regular seats. Since the Simple Parallel Mechanisms satisfy resource-monotonicity, more available seats could make all students weakly better off. Therefore, we recommend that other colleges implement meta-major reforms as well.

Future research can be extended in several directions. One direction is to relax some of the assumptions we have made, such as the fixed tier-partition assumption and the constrained-preference assumption. We also suggest further empirical or experimental studies to verify our findings. In addition, a possible extension would be to investigate the factors that influence students' preferences for adjustment. We could conduct surveys or experiments to gather information if relevant data are lacking. We have also noticed that some provinces, such as Liaoning and Shandong, have recently abolished the adjustment process. We could focus on this aspect.

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