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Chinese Postgraduate Application: Two-sided Matching Research

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Abstract. As the incredible fast speed of development of the Chinese society, and the spreading covid-19 in these years, the competition in China increasing, represented by the increasing number of the postgraduation application and the increasing unemployment rate. Therefore, the difficulties and the complexity of the Chinese postgraduate application keep increasing, which leads to an extra competitive level to the graduated students. This paper discovers the inefficient causes of the Chinese postgraduate application system through the lens of the two-sided matching model and provides several suggestions to improve the system with the actions of students, schools and the third party (the Education Ministry).

Keywords: Two-sided matching, Chinese postgraduate system, strategy proof, pareto efficient.

1 Introduction

Today, competition in society continues to increase. From 2019 to 2021, the China Human Resource Market Information Monitoring Center monitored the market supply and demand of high-paying employment service agencies in more than 100 cities across the country, finding that labour market demand is grossly out of proportion with supply, especially for highly competitive jobs, with an average of 24 people competing for one job [1]. This not only affects those who are already in the labour market but also causes increased employment anxiety for university students. Due to the scarcity of jobs, more and more companies in China are tending to recruit employees with higher education backgrounds. Therefore, not only is the number of Chinese postgraduate students increasing but the number of Chinese students applying for masters at foreign universities is also increasing [2].

For postgraduate applications, there is a matching problem between examinee and university, and it plays a vital role between the Chinese National University Entrance

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H. Mallick et al. (Eds.): ICEMCI 2022, AEBMR 231, pp. 1587–1598, 2023.
https://doi.org/10.2991/978-94-6463-098-5_179

Examination (NEMT) and the Chinese labour market. Two-sided matching theory is important in research on how to reasonably combine two non-overlapping participants in the market according to their preferences. The university enrollment mechanism is one of two-sided matching theory's application objects in the field of education, with the main purpose being how to design a system to match university and students more reasonably and maximise efficiency under the condition that university enrollment quotas are limited.

The work observed the phenomenon mentioned above through the lens of the entire Chinese postgraduate application system, seek to understand the integrity and effectiveness of the whole mechanism, analysing whether there is pareto efficient and strategy proof in the system, and find out the causes behind the inefficiency of the entire system and tackle the causes of these inefficiencies with three possible suggestions.

2 Literature review

Two-sided matching originated from the marriage matching problem in 1962, when Gale and Shapely proposed a marriage matching strategy to solve the problem of male and female mate selection, proving that this process results in non-empty stable matching [3]. On this basis, Gale and Shapely worked out a basic algorithm for two-sided matching – the "deferred-acceptance algorithm" – also known as "Gale-Shapely algorithms" and proved that the "deferred-acceptance algorithm" can make applicants obtain stable matching when they are under the hypothesis of strict preference. Subsequently, Shapely and Shubik put forward their companion model – "the assignment game" – which introduced monetary factors into the algorithm as a measure of utility. Based on "the assignment game", two-sided matching theory has gradually been applied in various fields [4]. For example, in 1998, Roth and Peranson improved the National Resident Matching Program (NRMP), a private organsation created in 1952 in the United States created to place medical university students into residency training programmes located across the US, by applying a two-sided matching model to the programme to make it more stable and efficient [5].

Two-sided matching was first applied in finance in China. To be more specific, in 2006, Wensheng found the existence of "deferred-acceptance algorithms" in the process of lending by analysing the three development stages of the Chinese bank credit market, and there were plenty of strategic behaviours which led to low market efficiency. Thus, Wensheng designed a matching programme to improve the stability and efficiency of the credit market for non-target customers based on the NRMP algorithm. Starting with the financial industry, two-sided matching theory has gradually been applied to other major fields in China, especially to education [6].

Indeed, although two-sided matching theory was first applied in the financial field in China, the education industry has become the most concentrated field of its application. Several researchers have successively proposed different models based on the "Gale-Shapely algorithm", helping to design doctoral admission mechanisms and new university entrance examination admission mechanisms to further ensure the stability of the matching mechanisms. However, to-date there has been little attention on postgraduate admissions in China. Thus, it is particularly important to analyse and guide postgraduate enrollment by using two-sided matching due to the intensity of the competition in this kind of enrollment in China.

3 Explanation of the system

Based on the two sided-matching model, the Chinese graduation application model can be described as follows: Assuming that there are two different groups – university and students – S is a finite set of students, S_A is student set 1, $S_A \subseteq S$ .S_B is students set 2, and $S_B \subseteq S$ .C is a finite set of universities. C_A is university set 1, which have their own enrollment cut-off point, $C_A \subseteq C$. C_B is university set 2, whose enrollment cut-off point is determined by a centralised system — the Chinese Ministry of Education, $C_B \subseteq C$. For each university $c \in C$, c has q_c seats. The preferences of university and students can be defined as $\gtrsim c$ and $\gtrsim s$. Student s has a ranking $\gtrsim s$ over $C \cup \{s\}$, and university c has a ranking $\gtrsim c1$ over $S \cup \{c\}$, which ranks all students who apply to c according to their standardised test scores. In addition, university c also has a ranking of $\gtrsim c2$ over $S \cup \{c\}$, which ranks students who apply to c according to their retest scores.

Def 1: Matching μ is a correspondence from $S \cup C$ to $S \cup C$ such that $\mu(s) \in C \cup \{s\}$, $\mu(s) = \{s\}$, meaning that a student is not accepted by any university, s is matched with itself.

Def 2: The final number of admissions to each university is no more than q_c. $\mu(c) \subseteq S$ such that $|\mu(c)| \leq q_c$.

Def 3: $\mu(s) = C \Leftrightarrow s \in \mu(c)$, for every $s \in S$ and $c \in C$.

Condition 1: Students are rational, if $\mu(s) = c$, then $c \gtrsim_s \{s\}$. Moreover, if a student is rejected by c and chooses to apply to c' for adjustment, there must be $c \gtrsim_s c' \gtrsim_s \{s\}$.

Condition 2: Only students who choose C_A university as their preferred university are assigned to S_A, with other students are assigned to S_B. For student s_A, he or she is required to pass both the university enrollment line and centralised enrollment line. If s_A only passes the centralised enrollment line but fails to pass the university's enrollment line, he or she will apply for adjustment. For student s_j, he or she is required to pass the centralised enrollment line. All students who fail to pass the centralised enrollment line will match to them self, in other words failed to match with school.

Condition 3: University preferences are different in different steps. University c will add students to its retest list based on $\gtrsim_{c1}$, and will send an updated offer of places from c to s based on $\gtrsim_{c2}$.

Condition 4: University c will place q'_c acceptable students on its retest list. As students who are on the retest list may not receive a final offer, there can be more $|q'_c|$ than $|q_c|$. However, c will not accept any adjustment applications if $q'_c \geq q_c$, the number of adjustment applications applied by c is equal to the number of its vacant seats.

Condition 5: If s remains unmatched in the retest, s is allowed to join another round of adjustment.

Therefore, considering the descriptions the Chinese graduation application algorithm as below:

Step 1: Each student s_i should choose c_i as their first preference university, while each student s_j should choose c_j as their first preference university, after which they will take the unified examination.

Step 2: After test scores are published, all universities will generate $\gtrsim_{c1}$. Given the centralised enrollment line and the university's enrollment line, c_i will add q'_{c_A} candidates to its retest list, c_B will add q'_{c_B} candidates to its re-test list, and they will both reject the other applicants. If s'_i is rejected by c_A but passes the centralised enrollment line, then s'_A will go to step k.

The algorithm ends when every student is either accepted by a university or has been rejected by every university that they have chosen. (see Figure 1)

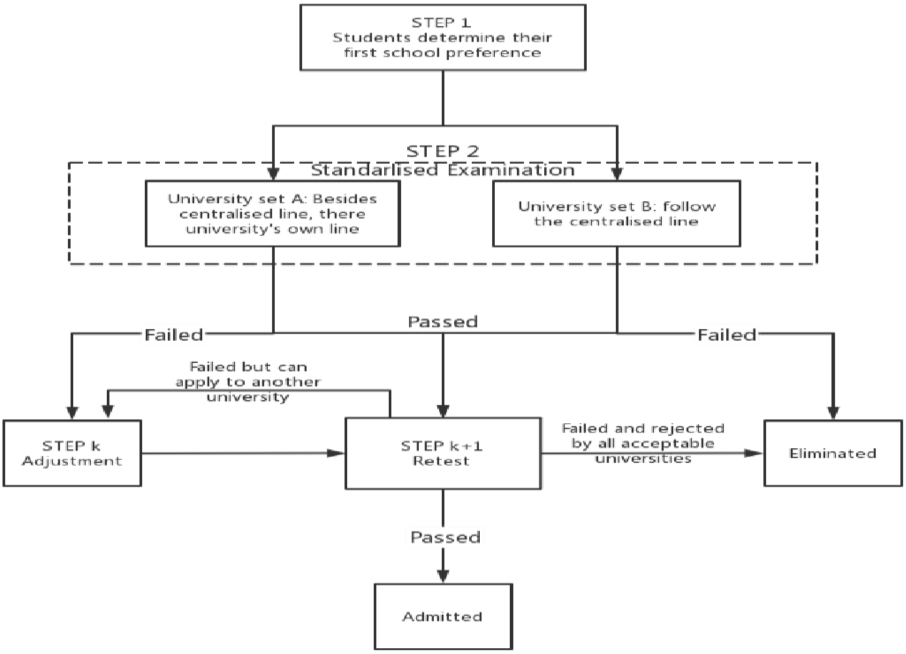

Fig. 1. Chinese Postgraduate Application System [Owner-draw]

4 Two-sided Matching Research

4.1 Brief analysis of Chinese postgraduate admissions

China's postgraduate system of education underwent an important period of development from 1998 to 2008, with the scale of postgraduate education expanding rapidly due to a wave of popularisation of higher education [7]. Aiming to improve quality issue of education after this expansion, China explored alternative approaches to the university admissions process. However, several issues and defects still exist in the system despite many adjustments and the introduction of several new models over years. Now considering the several possible problems that exist in the system and may cause inefficiency.

4.1.1 Whether students are strategy proof when choosing their preference?.

Being strategy-proof refers to there being a weakly-dominant strategy for every player to reveal his/her private information [8]. For instance, given no information about what others do, people fare best or at least not worse by being truthful. So, it is first vital to define what is truthful. To be more specific for the context of Chines postgraduate admissions, it is vital to define what is a truthful action for a student, and what is not. In recent years, as the number of candidates for Chinese postgraduate application has increased, there is an imbalance between students' first preference of university and the university preference, which means there are many students who fail to be allocated to their first-choice university and fall into the adjustment process. A common phenomenon of not truthful action is that in this context is that some students choose several preferences and accept multiple retest invitations from different universities, or even change their preferences right before a retest. Based on previous research, approximately one-third of candidates enter the adjustment stage, so such trend stimulates the students to choose not to be truthful [9]. However, in this study assuming that all students are rational and make decisions after considering what other students will do. Therefore, it can be concluded that students have an incentive to not be truthful so as to achieve a better matching outcome, and there is no strategy proof approach to the Chinese postgraduate application system.

4.1.2 Is the Pareto-efficient established in the Chinese postgraduate admission system?.

Pareto optimal is the ideal state of resource allocation, which assumes that an inherent group of people and distributable resources make at least one person better off by changing from one state of distribution to another without making anyone worse off [10]. In the adjustment system in China, students have the right to reject an offer from their preferred university, thus, it is possible that the university will have vacancies even if the admissions process is finished. For instance, student s_i who chooses university c_i as one of his or her preference universities receives an offer from university c_i, however, student s_i may reject this offer so as to participate in a retest from his or her other preference university, university c_j. But if student s_i fails to pass the test, the adjustment and admission system is now closed, student s_i has not been accepted by any university, and university c_i has not filled its enrollment quota, which means the waste of a vacant place at that university. In this situation, there is Pareto improvement if student s_i accepts the offer from university c_i. On the other hand, according to the graphs below, in the first test, S_3 fails to pass the enrollment line and falls into the adjustment process, and all other students (who have passed the enrollment line) go into the next step - re-test. However, there is a possibility that S_4 and S_3 are successfully matched to university B, which means that another student who was added to the retest list by university B is better off. Thus, Pareto-efficient may not be established. (see Figure 2)

Table 1. Three possible preferences for School A [Owner-draw]

Ranking	$\succsim A$
1	S_1
2	S_2
3	S_3

A (Uniform examination)

Table 2. Three possible preferences for School B in the uniform examination process [Owner-draw]

Ranking	$\succsim B$
1	S_4
2	S_5

B (Uniform examination)

Table 3. Three possible preferences for School C during the adjustment and the retest process [Owner-draw]

Ranking	$\succsim B'$
1	S_5
2	S_3
3	S_4

B (During the adjustment and retest)

The table 1 shows the preference ranking for school A, with student 1 be the first ranking, student 2 be the second ranking and the student 3 be the rank in the last. Table 2 reveals three possible ranking preferences for school B during the uniform examination process, with student 4 rank at first and student 5 rank at second. Table 3 reveals the three possible ranking for school B during the adjustment and the retest process, which represented by the $\succsim B'$.

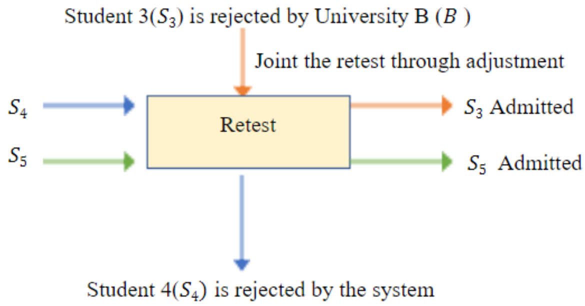

Fig. 2. Retest Process [Owner-draw]

4.1.3 Issue - Uneven distribution of resources.

Simply dividing universities in China into the top 34 universities and other universities leads to a problem of uneven distribution of resources. In China, every year the number of applicants for popular universities is much higher than the number of applicants for unpopular universities. As a result, popular universities must spend a lot of time and energy evaluating students, and many excellent students are not chosen by their preferred university, while unpopular universities always have a lot of empty seats.

As this happens every year, some universities deliberately give students relatively low marks in their centralised examination as, with this strategy, they can add fewer students to their retest lists so that there will be more empty adjustment seats for excellent students who are rejected by other universities [11]. This seems to be better for these universities, however, it has two adverse effects. First, the strategy of deliberately giving students low scores reduces the acceptance rate of the centralised examination. As a result, more students may be eliminated from the application system, consequently, the least popular universities may not be able to enroll more students. Second, for students who are given low marks by universities but could have received higher scores, their low scores put them at risk of being eliminated from the application system. Even if they're not eliminated, as long as they are rejected by a university later, they have to apply to another, perhaps less prestigious, university for adjustment, which is unfair for these students.

Considering a Chinese graduation application model without retest, there are three universities:

$$C = \{A,\ B,\ C\},\ q_A = q_B = q_C = 2,\ A \in C_A\ ,\ B \in C_A\ ,\ C \in C_B$$

And six students:

$$S = \{s_1,\ s_2,\ \cdots,\ s_6\}$$

Students' preferences are shown in the table 4:

Table 4. Preferences for students ($s_1 - s_6$) [Owner-draw]

$\succsim s_1$	$\succsim s_2$	$\succsim s_3$	$\succsim s_4$	$\succsim s_5$	$\succsim s_6$
A	A	A	B	B	C
B	B	B	A	A	B
s_1	s_2	s_3	s_4	s_5	s_6

If all students pass the centralised examination, universities' preferences are shown in the table 5:

Table 5. Preferences for universities after uniform examination [Owner-draw]

$\succsim A$	$\succsim B$	$\succsim C$
s_1	s_4	s_6
s_2	s_5	/
s_3	/	/

Since $A \in C_A$, $B \in C_B$, are allowed to have their own cut-off lines, those students who fall below the line are required to apply for adjustment, which is shown in gray in the Table 5. Therefore, s_3 would apply to B but B would reject s_3 for there aren't any empty seats left at the university. As mentioned earlier, s_3 has a preference ranking: $A \succsim_{s_3} B \succsim_{s_3} \{s_3\}$, and now s_3 has been rejected by A and B, which means that s_3 has no choice but to match herself., which means failed to match with school. The table 6 shows the output after adjustment.

Table 6. Matching results under normal conditions [Owner-draw]

$\succsim A$	$\succsim B$	$\succsim C$
s_1	s_4	s_6
s_2	s_5	/

As the Table 6 shows, s_1,s_2 are matched with A, s_4,s_5 are matched with B, s_6 is matched with C.

In another case, however, if B anticipates getting student s_3 from A, who is better than s_4 or s_5, then B has the incentive to give students lower marks, as shown in the Table 7:

Table 7. Preferences for universities if B deliberately gives students low marks [Owner-draw]

$\succsim A$	$\succsim B$	$\succsim C$
s_1	/	s_6
s_2	s_4	/
s_3	s_5	/

In this case, s_4 and s_5 receive scores which are lower than what they should have got. As a result, B has an empty seat, and s_3 will apply to B, s_5 will be matched with himself as A has no seats.

Table 8. Matching results if B deliberately gives students low marks [Owner-draw]

$\succsim A$	$\succsim B$	$\succsim C$
s_1	s_3	s_6
s_2	s_4	/

Based on Table 8, s_1, s_2 are matched with A , s_3, s_4 are matched with B , s_6 is matched with C , s_5 is matched with himself. Thus, it can be concluded from these two cases that university B and student s_3 will be better off by receiving a lower score, while s_5 will be worse off. In general, resources are concentrated in C_A , and resources are not allocated properly for all universities.

5 Suggestions for the Chinese postgraduate system

Then, putting forward several suggestions that may help the system to achieve a more efficient two-sided matching. Setting a university's enrollment line is a measure to give universities autonomy in enrollment, but there are some problems with its implementation in practice. For example, without supervision, universities may misuse their power to create their own enrollment lines. This is because universities have incentives to lower their enrollment line, which is more beneficial to students. In addition, universities may want their cut-off point as high as possible, simply because they regard their enrollment line as a symbol of status. There is no doubt that these actions exacerbate competition.

But suppose there are no classifications and only one type of university, with all students having to take the same test, and the adjustment process and all universities having the same enrollment line. This may help to eliminate applicants' prejudice and discrimination against different universities. Also, students may have more information during their application if the system is simplified, for instance knowing the enrollment line, since it is same for all universities. Therefore, all universities are able to have a fairer and less competitive for students. In this way, it may be possible to achieve more efficient resource allocation in the Chinese postgraduate application system. (see Figure 3)

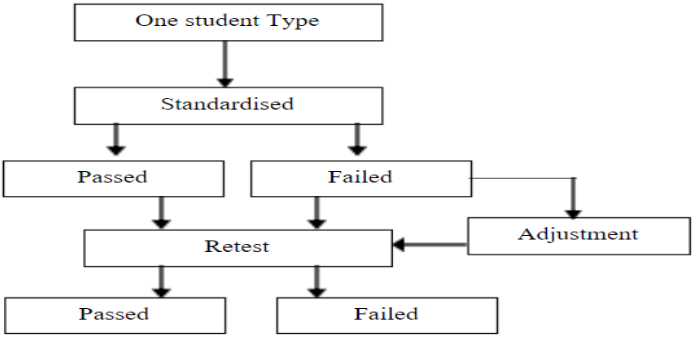

Fig. 3. One school type and one student type diagram [Owner-draw]

5.1 Suggestion - Empowering universities & designing more types of university

As mentioned above, one major inefficiency in the Chinese postgraduate application system occurs due to the process of adjustment, whereby the adjustment process only exists if there are vacancies at the university. In most cases, less prestigious or popular universities face the situation of a shortage of students choosing them as their first preference. In other words, these universities are in the majority during the adjustment process. However, as mentioned above students tend to be not truthful, it will lead to negative influence of wasting a lot of labour and resources on the process by increasing the complexity and extra work of universities.

One way to improve this is to allow universities to participate more in the entire process, rather than only letting a third-party (the Chinese Ministry of Education) participate. More specifically, universities could be given the right to decide their enrollment line. By classifying universities into more than two different types, each type of university could have its own enrollment line and in doing so, students could receive more information about the enrollment line of the university they're applying for, and therefore choose their preference and enable a more successful matching outcome.

School Type A — Enrollment line A
School Type B — Enrollment line B
School Type C — Enrollment line C

5.2 Suggestion — Ensure information and requirement transparency

Another considerable issue in the Chinese postgraduate application system is the insufficiency of information transparency in universities in China, which means students do not have the ability to get more information during the adjustment process, resulting in them failing to understand the enrollment line and the number of vacancies for each university, for example. Therefore, universities could publish more detailed information and their application requirements to ensure the transparency of information disclosure. In doing so, applicants could better understand the difficulty of the second test and the adjustment ratio. Based on the above, candidates could evaluate their actual strengths more comprehensively and thereby reduce the chance of blindly filling in applications. In addition, universities could promptly notify examinees when it is discovered that applicants are unqualified or all places are filled, which could save time for examinees to adjust their next preference universities.

6 Conclusions

This study constructed a two-sided matching model for China's postgraduate admissions system to achieve a simplified examination-adjustment-retest process for Chinese postgraduates and interpreted this system from an economic perspective. This study identified problems in China's postgraduate admissions system, that the current model does not achieve the Pareto optimality and is not strategy-proof. Moreover, the study shows examples of the current uneven distribution of resources and a waste of resources due to the complexity of the adjustment process. However, there are several shortcomings in this study. Firstly, the difficulty of quantifying the benefits and losses from admission results for each student and school. In addition, the lack of criteria for dividing the enrollment score line. Furthermore, due to the funding constraints, this study was not able to organize behavioural experiments to verify the outcome of new models in realistic situations. The practical implications of this paper are that, for students, this study will help Chinese postgraduate applicants to better understand the admission rules and choose their preferred universities more wisely and lead to a more efficient application outcome when applying for an examination, while, for universities, this study will help to rationalise the demarcation of their enrollment score lines so that they can achieve a more efficient allocation of resources.

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