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A WELFARE COMPARISON OF SCHOOL CHOICE MECHANISMS

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To my parents

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ABSTRACT

In recent years, China has experienced a trend of changing from the Boston mechanism (BM) to the Chinese parallel mechanism for high school and college admissions. Using a unique data set from the high-school-assignment system in China that combines survey data eliciting students' school preferences with administrative data that cover students' school choices and assignment results under both mechanisms, this paper compares the welfare performance of BM, the Chinese parallel mechanism, and the Deferred Acceptance (DA) mechanism. We find DA yields higher average welfare than the Chinese parallel mechanism, which is higher than the average utility under BM. We also find a more manipulable mechanism hurts students from low socioeconomic districts. Less manipulable mechanisms are more likely to assign students with higher score percentiles to schools with higher education quality, especially for students from higher socioeconomic districts. However, lower-scored students from higher socioeconomic districts decreased their human capital production after the mechanism was changed to the Chinese parallel mechanism.

CHAPTER 1

INTRODUCTION

School choice, namely, giving the students the chance to select which school to attend subject to schools' capacity constraints, is a widely discussed topic in education economics. Students have different preferences over schools and meanwhile, schools assign different priorities to different students. How to assign students to schools when the schools have limited quotas is an interesting question. To prevent inequality in education resource allocation, most countries do not assign students based on how much they are willing to pay. And to reduce the probability that students are unable to be assigned to any school, most countries let the students apply to multiple schools instead of only one school.

Therefore, in a lot of countries, students are allocated to schools via centralized assignment mechanisms. These mechanisms require every student to submit a rank order list (ROL) of schools, and assign students to schools through an algorithm based on the submitted ROLs and certain priority rules.

The two most popular centralized school choice mechanisms are the Boston mechanism (BM) and the Deferred Acceptance (DA) mechanism. Theoretical as well as empirical literature have analyzed the properties of these two mechanisms and discussed their advantages and shortcomings. (e.g., theoretical: Gale and Shapley (1962); Pathak and Sonmez (2008); Roth (2008); Abdulkadiroglu et al. (2011); empirical: He (2016); de Haan et al. (2016); Hwang (2016); Calsamiglia, Fu, and Guell (2017); Agarwal and Somaini (2017); Kapor, Neilson, and Zimmerman (2017)). Which mechanism is preferable remains a central debate.

DA has the advantage of being strategyproof: it is an equilibrium in which every student lists her true preference on the ROL. Therefore, DA can reduce students' loss from making strategic mistakes. By contrast, BM is manipulable - students can benefit from misrepresenting their true preferences on the ROLs. Under BM, if a student fails to get into her first choice, her chance of getting into the second choice diminishes significantly, which may lead to an undesirable outcome. Therefore, people have the incentive to avoid ranking

competitive schools as the first choice.

However, theoretical studies such as Abdulkadiroglu et al. (2011) argue that under incomplete information conditions, BM may yield higher total welfare because it allows students to express the intensity of their preferences rather than just ordinal preferences. Pathak and Sonmez (2008) argue that BM will benefit the students who have more relevant information or who can game the mechanism better. If students from lower socioeconomic backgrounds have less relevant information or have a lower ability to game the mechanism, BM may increase inequality in the sense that it lowers the chances for poorer students to get into good schools.

The Chinese version of BM is called the Immediate Acceptance (IA) mechanism.¹ It used to be popular in both college and high school admissions. In recent years, China has experienced a trend of changing from IA to the Chinese parallel mechanism.² The Chinese parallel mechanism is a mixed version of BM and DA. That is, for some rounds, the mechanism works as DA, whereas for other rounds, it works as BM. Theoretically, the Chinese parallel mechanism is not strategyproof, but it is less manipulable than BM (Chen and Kesten (2016, 2017)). The welfare loss from missing the first choice is smaller under the Chinese Parallel mechanism than under BM, which can be viewed as "insurance". Theoretically, such insurance may also make the Chinese parallel mechanism fairer than BM (Balinski and Sonmez, 1999). That is, students with higher test scores are more likely to be assigned to the schools they prefer.

Existing literature addressing the debate on which mechanism is preferable recovers students' preferences over schools by establishing and estimating a structural model based

1. As Chen and Kesten (2017) introduced, the algorithm of IA is similar to BM. The only difference is that under IA in China, the unique priority rule for all schools to any student is the student's exam score, so IA is a college admission version of BM. In the rest of paper, we will still use the term BM which is more widely recognized.

2. For college admissions, each college in China usually allocates its quota to provinces, whereas for high school admissions, in each city, high schools admit students mainly within the city. High schools entrance exam takers need to have household registration (Hukou) or have temporary residence permission in that city. Therefore, the competition pool for college admission is students within the whole province while for high school admissions, the competition is within each city.

on some assumptions regarding students' beliefs in the possibility of being admitted to each school. This paper, using a unique data set on high school admission in a large city in China, compares the welfare performance of three mechanisms: the BM, DA, and the Chinese Parallel mechanism. Note that according to the contract regarding the confidentiality of the data set, we do not identify the city by name in this paper. The dataset mainly contains the submitted ROLs, test scores, admission results and home address of students under both the BM and Chinese parallel mechanism. Students are able to rank at most three schools on their ROLs, which is a small number compared to the total number of schools. Another unique issue in China is that students' entrance exam scores are the unique priority score for every high school. In addition to the administrative data, we conducted a survey among middle school graduates in 2014 that elicited students' true preferences over the high schools. We then merged the survey results with the administrative data via students' unique identification numbers. With this data set, we can recover students' preferences over schools without the belief assumptions, and because we observe students' ranking behaviors under both the BM and Chinese parallel mechanism, we do not need to simulate what the students would have submitted under BM.

Before we present our model, we first present some summary statistics on the sorting behavior under the BM and Chinese parallel mechanism; that is, under which mechanism are students with higher scores more likely to be assigned to schools with higher education quality. This point is an important because under the assumption that student ability and school quality are complementary (will be tested in later sections), assigning students to schools with higher education quality will maximize the total human capital production in the society. We examine whether the sorting behavior is different across districts, in particular, whether after the change of mechanism, a redistribution of sorting behavior took place, that is, whether higher-scored students from districts with low SES are more likely to be assigned to schools with higher education quality under the Chinese parallel mechanism. We also present the summary statistics to show whether students with higher test scores

are assigned to schools farther from their homes. The summary statistics can show the relationship between school education quality and average distance to students' homes, and also whether students with higher scores need to travel more.

We next model students' preferences over high schools. We assume a student's utility from getting into a high school is a linear function of student characteristics and school characteristics, and the unobservable error term is assumed to be independent of the observables and i.i.d. follow Type 1 extreme value distribution. Therefore, we apply a rank-ordered logit model to our survey data, which is students' true ordinal preference over the high schools. We allow students to have a diverse preference over the schools. In the estimation, we fix the coefficient associated with home-school distance to -1. That is, we use willingness to travel as the unit of measurement of students' utility.

Our estimation results suggest students with higher test scores prefer schools with higher education quality than students with lower test scores. Also, holding students' test scores constant, students from high-socioeconomic-status districts prefer schools with higher education quality more than students from low-socioeconomic-status districts. These results indicate the complementarity of student ability and school quality. Hence, positive sorting can benefit human capital accumulation for the society, which will also be discussed.

In 2014, when the survey was conducted, the Chinese parallel mechanism was used. After we estimate students' preferences over the schools, we simulate the counterfactual admission outcome under DA, assuming students submit their ROLs according to their true preferences. Henceforth, we compare students' welfare under the Chinese parallel mechanism and DA. Because we also have data under BM, we assume students' relative preferences over schools did not change. We then calculate the average utility of students' admission outcome, and compare the three mechanisms. To our best knowledge, this paper is the first to compare the welfare under the three mechanisms. This paper is also the first paper on school choice that utilizes the students' admission records under two different mechanisms and meanwhile combined with survey data.

From our data set, the most direct observation is that only 2% of the survey respondents listed their ROLs exactly the same as their true preferences. That is, at most 2% of the students are sincere. We also use a conservative measurement of each student's magnitude of manipulation. For the participants of the 2014 survey, we find that for all the ranks in the students' ROLs, 50% of them are also listed in the survey. These observations suggest students are very strategic in manipulating the mechanisms. We suspect the reason behind this phenomenon is that high school admission in China is merit based and the length of ROL is small relative to the number of schools that can be listed. Students whose scores are low are not likely to list schools with high education quality on their ROLs. With few naive students, we suspect not everyone is able to game the mechanism efficiently and students are likely to make strategic mistakes.

Our results in the welfare comparison show a significant increase in average welfare when switching from the Chinese Parallel mechanism to DA. On average, students are willing to travel 0.097 kilometers farther to go to the school they would have been assigned to under DA than under the Chinese parallel mechanism. When switching from the BM to the Chinese Parallel mechanism, the average utility of students also increases, reaching almost the same size as switching from the Chinese parallel mechanism to DA, approximately 0.097 kilometers willingness to travel. The results suggest the less manipulable mechanism leads to higher social welfare.

Another important finding in this paper is the redistribution of welfare when the mechanism changes. In general, students from districts with a higher socioeconomic status benefit from the more manipulable mechanism. We find that when switching from the BM to the Chinese parallel mechanism, students from higher-socioeconomic-status districts suffer a loss of 0.2365 kilometer in willingness to travel, but students from lower-socioeconomic-status districts see a gain of 0.7674 kilometer in willingness to travel. But when changing from the Chinese parallel mechanism to DA, students from both higher and lower socioeconomic districts gain and students from lower social economic status districts gain significantly more.

The remainder of the paper is organized as follow. Chapter 2 reviews the literature and introduces our contributions. Chapter 3 introduces the background of our research and the mechanisms. Chapter 4 introduces the data we are using and presents some summary statistics. Chapter 5 sets up the model and estimation strategy and shows the estimation results. Chapter 6 compares the welfare under the three mechanisms. Chapter 7 shows the magnitude of manipulation using the survey. Chapter 8 compares the effect of change in sorting after the mechanism change. Chapter 9 concludes.

CHAPTER 2

LITERATURE REVIEW AND OUR CONTRIBUTION

This paper mainly contributes to the debate on the advantages and shortcomings of school choice mechanisms. Our paper brings new evidence to the literature of mechanisms design and school choice: whether the government should switch to less manipulable school choice mechanisms, that is, in China, from the BM to the Chinese parallel mechanism, or from the Chinese Parallel mechanism to DA.

Theoretical literature debating the performance of BM versus DA characterizes students as naive students and sophisticated students (Pathak and Sonmez (2008)) and shows the BM benefits sophisticated students and hurts naive students. However, Abdulkadiroglu, Che, and Yasuda (2011) and Miralles (2008) argue that in the context of incomplete information, when students are playing at Bayesian equilibrium, the BM yields higher average welfare than DA. Therefore, the welfare performance of the BM relative to DA depends on the proportion of naive students and also on the distribution of students' preferences. But if students from lower-socioeconomic-status families are more likely to be naive or have a lower ability to game the mechanism, the BM will hurt these students and henceforth increase social inequality. Our paper contributes to this debate by showing evidence that more manipulable mechanisms hurt students from low socioeconomic districts.

Theoretical debate on the welfare performance of the mechanisms leads to empirical work that tries to find evidence on the welfare performance. Empirical work in this field includes He (2014), Calsamiglia, Fu, and Guell (2016), Agarwal and Somaini (2015), and Hwang (2016). All of these studies apply some structural model on the data on students ROLs under the BM to estimate students' true preferences over schools, and then simulate students' ROLs under DA, and henceforth compare the welfare under the two mechanisms. The biggest challenge in these literatures is the assumption regarding students' beliefs about the possibility they can get into each school when submitting a ROL; in particular, students' preferences over schools are estimated based on these belief assumptions, so if the

belief assumptions are wrong, the estimation will be biased. Abdulkadiroglu, Agarwal, and Pathak (2015) and Fack, Grenet, and He (2015) uses data under strategyproof mechanisms, assuming the ROLs the students submitted are their true preferences. However, under the mechanisms the authors analyze, students cannot rank all the schools on the ROLs, so theoretically, those mechanisms are not strategyproof and their assumptions are subject to doubt. Our paper uses survey data to recover students' true preferences over schools rather than recovering the preferences from the ROLs. So compared to the above literatures, our paper eliminates the assumptions regarding students' beliefs about the possibility of being admitted to their preferred schools, and do not need to simulate the counterfactual outcome, but compare the welfare directly. In addition, differing from the above literatures that assume students' ranking behaviors, we compare the survey data with students' ROLs and analyze how students are manipulating the mechanism, especially the magnitude of manipulation, which previous studies have not yet examined, except in experimental labs (Calsamiglia, Haeringer, and Klijn (2010), Chen and Kesten (2017)).

Our paper also contributes to the matching literatures. First, assuming students prefer schools that help them produce more human capital, we provide a test on the assumption of complementarity between school quality and student ability, which is an "education version" of Becker's marriage model (1973). But Becker (1973) does not discuss via what mechanism society can maximize human capital production conditional on positive sorting. We fill in the blank of Becker (1973) by showing empirically whether less strategyproof mechanisms achieve more positive sorting and henceforth increase human capital accumulation.¹

1. Riehl (2016) also analyzes the impact of the change of selection rules on the degree of positive sorting, but Riehl (2016) did not analyze the change of school choice mechanism as we do.

CHAPTER 3

THE BACKGROUND AND THE MECHANISM STUDIED

3.1 Background

In most cities in China, for high school admissions, the education bureau of local government uses the entrance exam score as the unique priority rule for all high schools over all students. That is, students who have higher entrance exam scores are prioritized to be admitted to any high school. Note that our case is quite different from the cases studied in New York, Barcelona, or Boston, where students demographic characteristics determine their priority scores. In general, Chinese high schools have three categories: public ordinary high schools, civilian ordinary high schools, and vocational high schools. The first category has a better education quality relative to schools in the other two categories, and students can take the college entrance exam at the end of their third year, as can the students from civilian ordinary high schools. However, civilian ordinary high schools have a much lower education quality than public ordinary high schools and students who graduate from there almost have zero percent chance of getting into First-Level Colleges¹. Vocational high schools usually train students in various professions rather than provide them a general education to students. Students from this third category of high schools cannot take college entrance exams; therefore, vocational high schools usually have very low thresholds for students to get in. Students without a college degree would have great difficulties finding a good job, and students who graduated from colleges with a high reputation are more likely to be well ahead of their peers in their career paths. As a result, middle school students whose scores can qualify them to get into a public ordinary high school will generally choose to go.

In our research, we look at high school admission in a large coastal city in China with a

1. The Chinese Education Bureau classifies public colleges into three levels. First-Level is the highest level. The First-Level colleges receive much more government funding than other colleges and have higher education quality. According to the Chinese Statistical Bureau, the top 40 colleges with the highest graduate salaries are all First-Level Colleges.

population of over 6 million². (Due to confidentiality contracts, we are not able to identify the city by name.) The city's per-capita GDP ranks first in its province. Every year, more than 12,000 middle school graduates in the urban area of the city take the high school entrance exam. In 2014, the number of high schools or special programs students can put on their ROLs for ordinary high school was 47, and the number was the same for vocational high schools.

Every year, the official procedures for high school admission work as follows. First, each high school announces its enrollment quotas in the fall semester³, and in mid-May, students submit their ROLs. Students are able to submit two ROLs: one for ordinary high school, and the other for vocational high schools. The students are allowed to rank up to three schools for each of the two ROLs. If a student chooses to submit only one ROL (e.g, only the ordinary high school ROL), she will have no opportunity to get into the category of schools for which she did not submit a ROL. Then, in mid-June, students take high school entrance exams. After approximately two to three weeks, the exam scores come out and students are able to check them online. After the entrance exams are graded and the scores are announced, the education bureau ranks students according to their test scores and draws a bottom score line for ordinary high schools. Usually, this bottom line is the 51th percentile. Students whose test scores are lower than that line will not be considered by ordinary high schools; that is, only the students who are in the top 49% are admitted to ordinary high schools, and the total quota of all ordinary high schools is enough to accommodate the top 49%.

Then the admission process starts. Students whose test scores are lower than the bottom line and who submitted their vocational high school ROLs will go to another admission system for vocational high school admission. Those admission results come out in August, and students are immediately notified about the result. Note that the following matching

2. This number includes urban and rural population.

3. Chinese middle schools, high schools and colleges all use the semester system, which is the same as the semester system in the U.S. The fall semester starts in late August.

process is for ordinary high schools only (public and civilian), and when a student has submitted her ordinary high school ROL, she will first be put into the ordinary high school admission mechanism, and only when she is not admitted to any ordinary high school will her vocational high school ROL be considered. This paper focuses on the public ordinary high school admissions which are basically for students whose entrance exam scores are above the top 49th percentile. We also exclude the students who are early-admitted.⁴

3.2 The Change in the Mechanism

3.2.1 *The mechanism in the city before 2008*

Before 2008, the city used the Boston Mechanism. Students were only allowed to rank 3 schools on their ROLs, and the unique priority score was the entrance exam score. After getting the students' ROLs and exam scores, the algorithm could be described as the following:

- Round 1: Each school considers all students who rank it first and assigns its seats to students in the order of their test scores from high to low until either there are no seats left or no such students left.
- Round 2: The second choice of the students who have not yet been assigned will be considered. Each school that still has available seats assigns the remaining seats to the students who rank it as the second choice in the order of their test scores from high to low until there are no seats left or no such students left.
- Round 3: The 3rd choice of students who have not yet been assigned is considered.

4. In a lot of cities in China including the one our research is based on, some students are admitted through an early admission process. The purpose of the early admission The decision of early admission is made before the students submit their ROLs and these students are always students with extremely high academic ability and their names are publicly announced before the students submit their ROLs. Therefore, these students do not influence the non-early-admission students' decision to rank the schools, so we exclude the early admission students in our calculation and focus on non-early admission students. The specific admission process of the early admission students is presented in Appendix F.

Each school that still has available seats assigns the remaining seats to students who rank it as the 3rd choice in the order of their test scores from high to low until there is no seat left or no such students left.

The students who are not admitted by all the three schools on their ROLs will be randomly assigned to a school that still has available seats.

3.2.2 The Mechanism in the city since 2008

In 2008, the city changed the admission mechanism into Chinese parallel mechanism. We first introduce the Chinese parallel mechanism used in the city on which our research is based and following that, introduce the Chinese parallel Mechanism in the generic format in the next section.

Students are only allowed to rank at most 3 schools on their ROLs, and the unique priority score for all the high schools over all students in the city is the entrance exam score. These were unchanged. After getting the students' ROLs and exam scores, the mechanism since 2008 works as follows:

- Round 1: Every student applies to her first choice. Each school rejects the lowest-scored students in excess of its capacity and temporarily holds the other students.
- Round 2: Every student who is rejected in Round 1 applies to her next choice on her ROL. Each school pools new applicants together with those who are held from Round 1 together and rejects the lowest-scored students in excess of its capacity. Those who are not rejected are admitted by the schools. Note that the admission result in Round 2 is final.
- Round 3: The 3rd choice of students who have not yet been assigned is considered. Each school that still has available seats assigns the remaining seats to students who rank it as the 3rd choice in the order of their test scores from high to low until there is no seat left or no such student left.

The process terminates after any round k when every student is assigned a seat at a school, or if students who remain unassigned list no more than k schools on their ROLs.

The students who are not admitted by all the three schools on their ROLs will be randomly assigned to a school that still has available seats.

In summary, in the mechanism before 2008, if one is rejected in the first round, she is considered by her second choice only when the school she lists as the second choice still has available seats. However, in the mechanism since 2008, the admission in the first round is temporary. And, if one is rejected by her first choice, she will always be considered by her second choice - the school she lists as her second choice will pool the students who are temporarily admitted in the first round together with those who are rejected in the first round but list it as the second choice, and rank them altogether according to their test scores.

3.3 Chinese parallel Mechanism: The Generic Form

As presented in Chen and Kesten (2016), the Chinese parallel mechanism is indexed by a permanent-execution period e , which is a positive integer. That is, $e \in \{1, 2, \dots, \infty\}$, which is called "block" in the following introduction:

Block $t = 1$:

- Each student applies to her first choice. Each school considers its applicants and ranks them according to their priority scores, and then tentatively assigns students based on their ranks until its quota is filled up. The remaining applicants are rejected.

In general,

- Each rejected student, who is yet to apply her e -th choice school, applies to her next choice. If a student has been rejected from all her first e choices, then she

remain unassigned in this block and does not make applications until the next block. Each school considers its applicants and ranks all the applicants in this block according to their priority scores and then tentatively assign students based on the applicants' ranks until its quota is filled up. The rest applicants are rejected.

- The block terminates whenever each student is either assigned to some school or has remained unassigned in this round, i.e., has been rejected by all her first e choices. At this point, all tentative assignments are final and the quota of each school is reduced by the number of students permanently assigned to it.

In general,

Block $t > 1$:

- Each unassigned student from the previous block applies to her $(te+1)$ -st choice school. Each school considers its applicants and ranks the applicants according to their priority scores and then tentatively assign students based on the applicants' ranks until its quota is filled up. The rest applicants are rejected.

In general,

- Each rejected student, who is yet to apply her $(te + e)$ -th choice school, applies to her next choice. If a student has been rejected from all her first $(te + e)$ choices, then she remains unassigned in this block and does not make applications until the next block. Each school considers its applicants and ranks all the applicants in this block according to their priority scores and then tentatively assign students based on the applicants' ranks until its quota is filled up. The rest applicants are rejected.
- The round terminates whenever each student is either assigned to some school or has remained unassigned in this round, i.e., has been rejected by all her first $te + e$ choices. At this point, all tentative assignments are final and the quota of each school is reduced by the number of students permanently assigned to it.

The algorithm terminates when each student has been assigned to a school. At this point, all the tentative assignments are final.

Remark 1: Boston mechanism, Deferred Acceptance mechanism and Chinese parallel mechanism in which one is able to submit a ROL containing at most K schools can be viewed as a composition of several blocks $e = \{e_1, e_2, \dots, e_k\}$ and $K = e_1 + e_2 + \dots + e_k$.

- (1) The Boston mechanism is the case where for each $e_j \in e$, $e_j = 1$.
- (2) The Deferred Acceptance mechanism is the case where $e = e_1$ and $K = e_1$.
- (3) The Chinese parallel mechanism is the case where for each e_j , $1 \leq e_j < K$.

Remark 2: In the Chinese parallel mechanism, the mechanism works similar to the Boston mechanism between blocks and similar to Deferred Acceptance mechanism within blocks.

We then introduce the Boston Mechanism and Deferred Acceptance mechanism in turn.

3.4 The Boston Mechanism

With the priority scores and submitted lists, the matching process has several rounds, and the Boston Mechanism works as follows:

- Round 1: Each school considers all students who rank it first and assigns seats to students in the order of their priority scores from high to low until either there are no seats left or no such students left.

Generally, in:

- Round k : the k th choice of the students who have not yet been assigned is considered. Each school that still has seats available assigns the remaining seats to students who rank it as k th choice in the order of their test scores from high to low until either there is no seat left or no such students left.
- The process terminates after any round k when every student is assigned a seat at a school, or if students who remain unassigned list no more than k schools on their

ROs. Students who are still unassigned will be randomly assigned to a school that still has available seats or remain unassigned, depending on the city.

3.5 Deferred Acceptance Mechanism

With the priority orderings and submitted lists, the Deferred Acceptance Mechanism works as follows:

- Round 1: Every student applies to her first choice. Each school rejects the lowest-priority students in excess of its capacity and temporarily hold the other students.

Generally, in:

- Round k : Every student who is rejected in Round $(k-1)$ applies to the next choice on her list. Each school pools new applicants and those who are held from Round $(k-1)$ together and rejects the lowest-priority students in excess of its capacity. Those who are not rejected are temporarily held by the schools.

The process terminates after any Round k when no rejections are issued. Each school is then matched with students it is currently holding. Depending on the city, those who are unmatched will be randomly assigned to some school that still has remaining seats, or remain unassigned.

CHAPTER 4

DESCRIPTIONS OF DATA

4.1 Administrative Data

Our data in this research come from two sources: administrative data and survey data. Administrative data are from all the middle school graduates from 2006 to 2014. Usually, students finish their middle school education when they are 14 or 15 years old. In the administrative data, we have students' ROLs, their test scores, their final assignments, the middle school they graduated from, and the district where their middle schools and high schools are located. One additional point we need to note is that the final assignment for the students who have taken the high school entrance exams and participated in the admission algorithms, but are not admitted by an ordinary high school is displayed as missing in the administrative data. As mentioned previously, the education bureau draws a bottom score line every year for ordinary high schools (roughly the 51st percentile), below which students cannot be admitted by any ordinary high school. Those students whose final admission results are missing are the students who did not get into an ordinary high school. Although they can be admitted to vocational high schools, the admission process for these schools is completely different, and the data on that process are in another branch of the bureau of education in the city and are currently unavailable for us, which is why their admission results are displayed as missing in our current data set.

Our research focuses on the students whose test scores are above the ordinary high school bottom line. Because students whose test scores are below the bottom line are not allowed to be admitted to ordinary high schools, those students' preferences and strategies do not influence those students who get into ordinary high schools, because they cannot get into any ordinary high school anyway. Also, a small number of students choose to go to high schools outside the city and we consider this as outside options for students. Because they basically did not participate into the admission mechanism, we do not consider these students either.

Therefore, our analysis focuses on those students who go through the ordinary high school admission process and are qualified to be assigned to an ordinary high school.

4.2 Survey Data

With only the administrative data, we would have difficulty in measuring the students welfare, because we don't know students' true preferences over the high schools in the city. Literature such as He (2014), Agarwal and Somaini (2016), and Calsamiglia et al. (2016) estimated students' true preferences over schools based on certain assumptions on students' ranking behaviors. Instead of estimating students' preferences using strategic reports (ROLs), we conducted a survey in mid-May 2014 which explicitly asked students' true preferences over the high schools. The survey was conducted approximately two weeks before the students submitted their ROLs, but after the early-admission students were announced. The survey covered 27 middle schools across all four administrative districts in the urban area of the city. (Students who go to middle schools in the rural areas do not compete with the students in the urban area and cannot include high schools in the urban areas on their ROLs.) The target of our survey is middle school graduates in the 2014 academic year. Most of them would submit their ROLs in late May and take high school entrance exam in mid-June. The total number of participants was 8434 - almost two thirds of the total exam takers in that year. Some schools did not participate because doing so was inconvenient or because the administrative staffs of those schools were not willing to cooperate with us. For those schools that did participate, almost every student in that school participated.

We conducted the survey at school during class break time, and it took approximately 10 to 15 minutes to complete. We stated clearly at the beginning of the survey that this survey had no bearing on high school admission and was for research use only and that the information of individuals would be strictly kept secret. The participants did not know the details of our research, so they had no incentive to deliberately "cooperate" with us. Moreover, during the survey time, at least one of our research assistants monitored each

classroom to ensure that the students were not communicating to each other while completing the survey questions and also to ensure they treat the survey seriously. Therefore, we could not find any incentive for the participants to lie in the survey.

Note that students are required to submit their ROLs before the high school entrance exam. As a result, students know neither their own scores nor the distribution of the test scores of all the test takers when they submit their ROLs. Yet they do have some guidelines on what schools their test scores allow them to get into and how fierce the competition is for each school. First, after three years study, students usually can get a correct sense of their own academic abilities, and they also know the quality of their middle school relative to others, that is, how well their middle school generally performed in high school entrance exam in recent years. Middle schools do not provide the cutoff lines for the high schools in previous years, so usually, students check previous years admission lines for the high schools in which they are interested. More importantly, third-year middle school students take several modeling exams that are issued by the education bureau. The number, pattern, organization, and the difficulty level of questions closely resembles those on the real high school entrance exam. Because students in all middle schools in the city take the same modeling exams, they will be told how well they have done relative to their competitors in the whole city. Therefore, students have a fairly accurate prediction of how they will do on the high school entrance exam.

In the survey, we first asked whether the student would go through the ordinary admission process, that is, whether they were early-admission students, students with specialties, and whether the requirement to take the entrance exam was waived. Then we asked how they rated the degree of importance of different aspects of high schools, such as teachers quality, students quality, infrastructure quality, and the pressure to study. We asked them to rank the importance of these items from 1 (Not important at all) to 5 (Very important). The goal of these questions was to give students a guideline for what schools they might consider good, because they already had quite a lot of information on the high schools they

were going to choose.

Following these questions, the survey asked the students to write down seven high schools they were considering based on their ability, and then explicitly asked the students to rank five of the seven high schools from the most preferred to the fifth preferred. We asked students to consider the questions seriously and think about which schools were good fits for them. For example, schools with extremely good reputations always take students with very high academic performance, and the competition pressure is large; therefore, such schools are not good fits for the students with relatively low abilities. Our question is designed to prevent students from misunderstanding the question as asking which schools have good reputations, and thus to list some schools that do not actually fit them (Narita (2016)).

Other literature has also shown the point that the schools that have good education quality may not be the best for the students with poor academic performance (Riehl (2016)). Therefore, we make the following assumptions on how students form their preferences over high schools:

Assumption 1 (A1): All else being equal, a student is more likely to prefer school a to school b if school a can help her produce a higher level of human capital.

Assumption 2 (A2): When completing the survey, every student i knows whether school a can help her produce a higher level of human capital than school b , for every school a and b .

The reason we asked students to list their top five schools is that the survey time was limited and the total number of ordinary high schools and vocational high schools is large. Therefore, students would have difficulty considering a long list of schools carefully. Moreover, the students were actually not considering a long list of schools, because they have limited source of information and not enough time and resources to analyze the factors that formed their school preferences. From Table 15 of Appendix B, we can see that 42% of the students whose scores were above the ordinary school cut-off line listed fewer than five schools on the survey. Therefore, asking them to rank a long list of schools would not help

a lot. We can see from the surveys that students almost all view the quality of education as the most important factor that determines their preferences. The English translation of the survey is in Appendix A.

After we collected and organized, we put the participants' answers to the paper survey into a computer-readable format and then merged them with administrative data in late August after the assignment results were finalized. The number of students we successfully merged was 7865, which is more than half the total test takers in the city in 2014. Inputting error in the students names or IDs, the typists misreading students handwritings, or students' not writing their IDs or names on the survey explain the unmatched students. We chose to conduct the survey a short time before the students submitted their ROLs, because, first, had we conducted it after they submitted their ROLs, their survey answers regarding their true preferences would have been contaminated by their strategies, and thus, would not have been their true preferences. Second, had we conducted it too long before the students submitted their ROLs, the students might not have formed their preferences completely and might not have had a clear sense of what high schools they would be able to get into, conditioning on their study abilities. Moreover, by conducting the survey a short time before the students submitted their ROLs, we were able to avoid students' true preferences over high schools changing before they submitted their ROLs. We can trust that students survey answers represent their true preferences.

Table 1 shows the summary statistics of the survey question asking the students how important they consider their peers' academic performance. From the survey, we can see that a vast majority of students' thought their classmates' academic ability was important and would prefer to study in a school with higher academic performing students.

In 2016, we conducted a supplemental survey that covered about 60 teachers. The English translation of this survey is in Appendix G. In this survey, we asked why even a student whose test score is high enough to get into a school with a high reputation would choose not to apply such a school. More than 95% of the teacher answered that in such

schools, the competitive pressure is too high. This evidence shows that students prefer schools that have higher academic performance, but when they ranked the schools, they did not take the admission possibility into consideration.

Moreover, we observe that only 2% of the survey respondents listed their ROLs exactly the same as the first three schools of their survey answers. That is, at most 2% of the students are sincere, which is quite low compared to the findings in other literature. The main reason for the difference is that students list their true preference on the survey, but for the students whose test scores are not high, they can hardly get into their top five most preferred schools, and therefore did not list them on their ROLs. Actually, the average cutoff line for the high schools the survey participants listed as the favorite is more than 30 points higher than their test scores, which is another evidence showing that the students did not consider the admission possibility when they listed the schools, but they only considered how much they liked the schools. Therefore, we justify that the surveys indeed represent students' true preferences over the high schools.

We will focus mainly on those non-early-admission students whose scores are above the ordinary school cutoff line, because the ordinary high school cutoff line is determined exogenously, independent of students' strategies, and the early-admission students can be viewed as a reduction of the quota of the relevant schools from the perspective of non-early-admission students. The strategy of the students whose test scores are below the ordinary school line, that is, the 51st percentile, has no impact on the admission results of other students, because no matter how they rank the schools, their ROLs are not considered. Among those non-early-admission students whose test scores are above the cutoff line, we will also exclude the students with arts and sports specialties, because their admission is also determined before submitting their ROLs.

4.3 Summary Statistics: Sorting Behavior

4.3.1 *Difference in Socioeconomic Status across Districts*

Before we introduce our model, we provide some important summary statistics. We first show the fact that the average socioeconomic statuses in the four districts are not equal. Table 2 displays the average labor-force income of the four districts in the city, which is an important indicator of the inequality in socioeconomic status (SES). The data source is the statistic public report of the statistic bureau of the city. District 4, which is located along the coast, has a long history of economic development, and also the central business district locates there, so it has the highest average labor-force income. District 3 is the district where most old industries locate, and during the reformation of the nation-owned industries in 1997, lots of workers were laid off. These facts make it the poorest district in the urban area of the city. Although during the past 10 years, significant development occurred in the whole city, the imbalance of the social and economic development is still obvious. The first row of Table 2 shows the average salary of the labor force of the four districts in the year 2006, and the second row shows the same summary statistics using the data in the year 2007. In the analysis in the following parts of the paper, we characterize Districts 1 and 4 as Higher Socioeconomic Status (HSES) districts, and Districts 2 and 3 as Lower Socioeconomic Status (LSES) districts.

Table 3 shows the percent of exam takers above the 51st percentile (public ordinary high school cutoff line) in each district is composed of all the students above the 51st percentile in years 2007 and 2008. We can see that District 4 has the highest percentage of students above the 51st percentile, whereas for District 2 and 3, this percentage is the lowest. Therefore, the summary statistics show a clear correlation between the districts' SES and the average students' academic performance.

4.3.2 *Measurement of Education Quality*

In this part, we look at how the mechanism change impacts the change in the redistribution of assigned schools' education quality for students in HSES districts and LSES districts.

The measurement of a high school's education quality is the average percentile of the entrance exam for the incoming students. This variable is a reasonable indicator for high school education quality for the following reasons:

First, the high schools' reputations are built on the performance of college entrance exams, which, to a large extent, depends on the students' abilities. As Hunt (1963) pointed out, "The C student from Princeton earns more than the A student from Podunk not mainly because he has the prestige of a Princeton degree, but merely because he is abler. The golden touch is possessed not by the Ivy League College, but by its students." Also, empirical evidence, such as Akyol and Krishna (2017), shows that a school's incoming students' quality affects students' preferences over that school more than value added.

Second, most middle school students and their parents do not know the concept of value added, yet a high school's reputation is built on people's knowledge of the general performance of its college entrance exam performance, which is usually measured by the percentage of students at that high school who are admitted to the First-Level colleges. Based on our data on the percentage of students from the main high schools who are admitted to the First-Level colleges, we find the correlation between the First-Level-college entrance rate and the average percentile of the schools' incoming students is 0.96.¹

Third, in the 2016 survey, we asked the teachers to what degree did they agree that a high school's education quality can be represented by the incoming students' test scores, and all the teachers answered "Strongly Agree", "Agree", a few of them answered "Neutral" and

1. First-Level College Entrance rate is important for students with relatively high ability, but students also care about entrance rate for Second-Level or even lower level college. Plus, there are 2 high schools (although not top high schools) whose First-Level College entrance rate were missing. As a result, we do not use this variable as indicator for a high school's education quality.

no one disagreed.

4.3.3 Measure the Degree of Sorting: Student Percentile and Education

Quality

In this part, we first present the correlation between students' score percentiles and the education quality of the schools they are assigned to under the two mechanisms. Table 4 displays their correlation coefficients for the whole city, HSES districts, and LSES districts under the two mechanisms.

The interpretation of the correlation coefficients between the education quality of assigned schools and the students' score percentiles is the change in the education quality of the assigned school when the student's percentile increases, say, by 1%. This coefficient increases after the mechanism change. The increase took place at the city level and in both HSES districts and LSES districts. That is, under the Chinese parallel mechanism, students with higher score percentiles are more likely to be assigned to schools with higher education quality. To further examine this phenomenon, we regress the education quality of the assigned school on the student test score percentiles for HSES districts and LSES districts under BM and Chinese parallel mechanisms separately. Figure 1 and Figure 2 display the line fits for HSES districts and LSES districts under BM and Chinese parallel mechanisms, respectively.²

We calculate the specific values of the slopes and constants in the figures by a fully saturated model as follows

2. The dots in the graphs plot the average education quality of the high schools assigned to students in each ten percentile.

$$\begin{aligned}
EduQuality_i = & \beta_0 + \beta_1 * Percentile_i + \beta_2 * PAR_i + \beta_3 * HSES_i + \beta_4 * PAR_i * Percentile_i \\
& + \beta_5 * Percentile_i * HSES_i + \beta_6 * PAR_i * HSES_i + \beta_7 * Percentile_i * PAR_i * HSES_i + \epsilon_i,
\end{aligned}
\tag{4.1}$$

where $EduQuality_i$ is the outcome variable, which is the education quality of the school to which student i is assigned. PAR_i is a dummy variable - it equals to 1 if in the year when student i took the high school entrance exam, the Chinese parallel mechanism was used. $HSES_i$ is a dummy variable indicating whether student i is from higher social economic districts (District 1 or 4) - if yes, coded as 1 and 0 otherwise.

We present the full results in Appendix C. In summary, the main results as follows:

- Under the Chinese parallel mechanism, a 1% increase in Percentile is associated with a 0.1361% increase in assigned schools' education quality for students from HSES districts, and a 0.0451% increase in assigned schools' education quality for students from LSES districts.
- For students from HSES districts, those with $Percentile > 81.9\%$ are assigned to schools with higher education quality under the Chinese parallel mechanism than under BM;
- For students from LSES districts, those with $Percentile > 51\%$ are assigned to schools with higher education quality under Chinese Parallel mechanism than under BM;
- For students with $Percentile > 83.4\%$, the increase in the assigned schools' education quality under Chinese Parallel mechanism relative to BM is larger for HSES students than for LSES students.

Students from HSES districts with lower test scores are the "losers" from the switch of mechanism in the sense that they are assigned to schools with lower education quality, but

the students from LSES districts in the entire percentile range above the 50th percentile gain from the switch of the mechanism, because the less manipulable Chinese parallel mechanism gives some "insurance" to higher score students (this theoretical property is discussed in Chen and Kesten (2017)). This can be viewed as an evidence that students from LSES districts are not good at manipulating the mechanism.

To view the sorting from the schools' perspective, Figure 3 plots the relationship between the main public ordinary high schools' average incoming students' percentile and these schools' standard deviation of incoming students' percentile. It shows that under both BM and Chinese parallel mechanism, the mean and standard deviation of the incoming students' percentile are strongly correlated, and the relationship is negative under both mechanisms. Under BM, the correlation is -0.8944 while under Chinese parallel mechanism, it is -0.8274. That is, the high schools that take in students with lower average test scores have larger test score variance across the incoming students. Put it in another way, schools that have better education quality almost only take in students with outstanding performance, but schools with lower education quality, although they mostly take the bottom students, may be able to take some students who are not the bottom students.

From the graph, we can see that under Chinese parallel mechanism, the high education quality schools are have less variances in the incoming students' test scores than under BM, but low education quality schools have higher variances in the incoming students' test scores than BM. That is, under Chinese parallel mechanism, students with lower academic performance will be less likely to get into a good school by gaming the mechanism because Chinese parallel mechanism is less manipulable than BM. However, because in our specific case, under the Chinese parallel mechanism, students are still only allowed to rank at most three schools on the ROL, which is a short ROL, and therefore, this mechanism is still manipulable. Therefore, students with higher test scores may still make mistakes and fail to get into schools with high education quality. Especially, it can be the case that students with higher test scores rank the schools too aggressively under Chinese parallel mechanism and

therefore failed to get into all of their three choices and ended up getting into a high school with low education quality. As a result, the variance of the schools with lower education quality may be higher under Chinese parallel mechanism than under BM.

4.3.4 Measure the Degree of Sorting: Student Percentile and Home-School Distance

This part shows the relationship between students' test score percentile and the home-school distance to their assigned school. We first regress the assigned school's distance from student's home on the student's score percentile. Figure 4 and Figure 5 show the regression line.³

We set up a regression similar to that in equation (4.1), but change the dependent variable to the home-school distance of the student's assigned school. We present the regression analysis and the results in Appendix D.

The most obvious result is that although higher score percentiles are more likely to be assigned to schools with better education quality, they are, on average, assigned to schools farther from home. From this, we show that schools' education quality is positively correlated with average distance from students' homes. We show the main public ordinary high schools and their education quality and average distance from students' homes in Table E.1 in Appendix E.

3. The dots in the graphs plot the average home-school distance of the high schools assigned to students in each ten percentile.

CHAPTER 5

MODEL SETTING AND ESTIMATION METHODOLOGIES

5.1 Model Setting

Let $I = \{i_1, \dots, i_n\}$ be the set of students, and let i be a generic student. Let $S = \{s_1, \dots, s_m\}$ be the set of schools, and let s be a generic school. The outside options for individual i is denoted as \mathcal{O}_i . Suppose each student has a weak ordinal preference relation R_i over the schools and let P_i be the strict counterpart of R_i . To define the weak and strict preference relations, denote $v_{i,s}$ as the cardinal utility of student i 's getting into school s , we then have

$$sR_i s' \iff v_{i,s} \geq v_{i,s'}, \text{ and} \quad (5.1)$$

$$sP_i s' \iff v_{i,s} > v_{i,s'} \quad (5.2)$$

Let $R = (R_i)_{i \in I}$ and $P = (P_i)_{i \in I}$ denote the profile of weak and strict preferences, respectively and let V denote the set of all cardinal utility vectors; that is, $V = (v_i)_{i \in I}$, where $v_i = (v_{i,s_1}, v_{i,s_2}, \dots, v_{i,s_m})$. Let $L = (s_1, s_2, s_3)$ be all the possible ROLs and ΔL be the set of possible distributions of the possible rank order lists. Let A be the set of all possible allocations and a be a generic element in A . To be precise, a is a profile of student-school pairs (i, s) , which, for any $s \in S$, the number of students assigned to it is less than its quota, and for any student, she is either assigned to a school or being unassigned.

Let the score of student i be t_i . Because the priority of a student is determined by how well she did in the entrance exam relative to other students, we normalize the test score $t_i \in [0, 1]$. In this paper, we denote the test scores such that the larger the test score, the better, i.e., if one scores highest in the year, her test score is 1 and if scored the lowest, test score is 0. Let $t = (t_i)_{i \in I}$ be the profile of test scores.

Define a mechanism to be a function ψ which maps the profile of ROLs and test scores to an element in A . Mathematically, $\psi : (L, t) \rightarrow A$. The BM, DA and Chinese parallel mechanisms are all examples of such mechanisms, and denote them by ψ^{BM} , ψ^{DA} and ψ^{CP} , respectively. Define a strategy be a function σ which maps the profile of preferences V , test scores t and unobserved heterogeneity v to an element in ΔL under a certain mechanism, i.e., $\sigma : (V, t, v; \psi) \rightarrow \Delta L$. Note that the unobserved heterogeneity mainly includes students' ability of gaming the mechanism, mentioned in literature such as He (2014), or the availability of information, or other unobserved factors that may determine how they submit their ROLs. The distribution of assignment outcomes under a certain mechanism is determined by the joint distribution of students' ROLs and test scores.

Assumption 3 (A3): Across the years, among the students, their v , that is, their unobserved heterogeneity that determines their strategies, does not change.

This is the key assumption that can enable us to make the direct comparison of welfare under the two mechanisms. The distribution of ROLs changed when the mechanism changes and so did the assignment results and thus the welfare. The way that students submits their ROLs is determined by various factors and the mechanism that the education bureau uses to assign students is only one of them. Many factors are unobservable such as the ability of gaming the mechanism (He (2014)) or whether the student is naive or sophisticated (Pathak and Roth (2008)). Unlike other empirical literature that make assumptions on the distribution of students' unobservable factors, we assume that the distribution of these unobserved factors did not change across years, so that we can use the realized average utility of students in 2007 - when BM was used - as a proxy of counterfactual of 2008 when Chinese parallel mechanism was used, and do the welfare comparison directly rather than simulate the assignment results under a counterfactual mechanism.

Assumption 4 (A4): Across the years, the students' relative preferences over the high schools do not change.

In the 2016 follow-up survey, we asked the teachers whether changes had been made

in high schools' education quality and/or other important features. We also asked them whether the students' relative preferences over high schools had changed over the years. The answer to both questions is unanimously "No". Thus, we could not find any evidence to refute this assumption.

Based on assumptions (A3) and (A4), we can simulate previous years' students' preferences over schools and compare the outcome of the years when BM was implemented and the years when Chinese parallel mechanism was implemented to get the welfare impact of the change of mechanism.

We now model students' preferences over schools. Following Beggs, Cardell and Hausman (1981), we define the good as a bundle of underlying attributes and use a discrete-choice model to estimate the impact of changing an attribute on a student's preference over a school. Specifically, assume the cardinal utility of student i getting into school s takes the following functional form

$$v_{i,s} = W_s \alpha - d_{i,s} + \epsilon_s \quad (5.3)$$

where X_s is a vector of school characteristics of school s , and $d_{i,s}$ is student i 's home to school s , the coefficient of which is normalized to -1. The shortcoming of this model is that it assumes every student i has the same taste on the observed characteristics of a school. This assumption is very restrictive and far from reality, so we let the coefficient to have some variation among students. Let

$$\beta_i = \gamma_0 + Z_i \gamma \quad (5.4)$$

where γ_0 is constant, Z_i is a vector of individual characteristics and γ is the coefficients associated to the individual characteristics.

We replace α in equation (5.3) with β_i and get the following model

$$v_{i,s} = X_{i,s}\beta - d_{i,s} + \epsilon_{i,s} \quad (5.5)$$

where $X_{i,s}$ is a vector of school characteristics times student characteristics, and therefore is a vector of school-student interacted characteristics.

The school-specific characteristics includes:

(1) Whether a high school is a small-classes high school - if a high school is a small-classes high school, in that high school, a class can contain at most 40 students; if not, a class can contain at most 50 students;

(2) High School Education Quality, measured by the average score percentiles of incoming students.

(3) Whether the school is a mandatory living-on-campus school - some schools require students to live on campus and they usually go back home once a week;

(4) Whether the school is a part-living-on-campus school - some schools allow only some of their students to live on campus because they have limited number of space and whether a student can live on campus is determined by a case-by-case basis according to the students' applications. Usually those who live relatively close to campus cannot live on campus.

The student-specific characteristics include the following:

(1) Students' gender (We coded male as 0 and female as 1). The reason that these two variables are included is that students with different genders may have significant physiological and psychological differences which may influence their preferences over schools with different characteristics;

(2) Students' home-school distance to different schools indicates their home address, which is, first, an indicator (although noisy) of their socioeconomic status because the distribution of residents' socioeconomic status is uneven across the city - residents in certain areas have significantly higher socioeconomic status than those in other districts. The impact of home-school distance on students' willingness to live on campus is also important. Therefore, we interact this variable with whether the school requires living on campus or allows only

some students to live on campus.

(3) Students' entrance exam score percentile. We include this variable because test score is an important indicator of one's academic ability, and that will add more heterogeneity into students' preferences. Note that including students' score percentiles does not mean the preference estimate is based on the possibility of admission, because the score-percentile variable is directly built into the cardinal utility, and there is no expected utility at this point. Students with different abilities may have different preferences over the schools.

We run the rank ordered logit regression for students graduated from the four districts separately. The reason is that the socioeconomic status of each district differs considerably. This fact has been shown in Table 2.

Students' socioeconomic status can have an impact on their preferences over high schools. For example, students from poor families may have difficulty affording the cost of living on campus. Also, rich families may have better career opportunities than poor families if they fail to get into a good college; therefore, the intensity of their preferences over the schools with different education quality may be different.

$\epsilon_{i,s}$ is the unobserved disturbance term. We assume $\epsilon_{i,s}$ is independent of $X_{i,s}$ and $d_{i,s}$. In the data set, we have students' home addresses, which are the addresses where their household registration is located. The household registration address depends on where the main labor force in that household works and officially is very hard to move. In particular, if one prefers a school to another, she cannot move her household registration closer to her more preferred school. We can therefore partially rule out the case of sorting on distance, but this is still one of the restrictions of our model.

The interacted variables included in $X_{i,s}$ are the following:

- (1) School's education quality, measured by the average entrance exam percentile of its incoming students;
- (2) Whether the school is a small-class school or not;
- (3) Whether the school requires living on campus or not;

- (4) Whether the school allows partially living on campus or not;
- (5) Student's gender times whether the school is a small-class school or not;
- (6) Student's gender times whether the school requires living on campus or not;
- (7) Student's gender times whether the school allows partially living on campus or not;
- (8) Student's gender times the school's education quality;
- (9) Student's score percentile times the school's education quality;
- (10) Student's score percentile times whether the school is a small-class school or not;
- (11) Student's score percentile times whether the school requires living on campus or not;
- (12) Student's score percentile times whether the school allows partially living on campus or not;
- (13) Student's home-school distance times the school's education quality;
- (14) Student's home-school distance times whether the school is a small-class school or not;
- (15) Student's home-school distance times whether the school requires living on campus or not;
- (16) Student's home-school distance times whether the school allows partially living on campus or not;

The coefficient of a student's home-school distance is normalized to -1, which means that it is used as the unit of measurement of one's cardinal utility over a school. All the coefficients are interpreted as the trade-off with the willingness to travel.

5.2 Estimation Methodology and Estimation Results

Let

$$v_{i,s} = X_{i,s}\beta - d_{i,s} + \epsilon_{i,s} = u_{i,s} + \epsilon_{i,s} \tag{5.6}$$

Following Beggs, Cardell and Hausman (1981), we apply a rank-ordered logit model with the home-distance variable normalized to -1 to estimate the indirect utility function of student i 's getting into school s . We assume $\epsilon_{i,s}$ follows type 1 extreme value distribution, and $\epsilon_{i,s}$ are independent of the observables. If student i rank K schools with the order of $R = (s_1, \dots, s_k)$ in the survey, the join probability of the student's choice will be

$$\pi(R_i) = Pr((s_1, \dots, s_K)_i) = Pr(v_{is_1} > v_{is_2} > \dots > v_{is_K}) = \prod_{k \in \{1 \dots K-1\}} \frac{e^{u_{is_1}}}{e^{u_{is_k}} + \dots + e^{u_{is_{k+1}}} + e^{u_{is_K}}} \quad (5.7)$$

and the likelihood function is

$$\mathcal{L}(\beta) = \sum_i \log \pi(R_i) \quad (5.8)$$

Some basic assumptions underlying this model and some important notes need to be emphasized here. First, this model assumes that there is no correlation between unobserved characteristics of the alternatives. We also assume that the coefficients β is identical across the population. The heterogeneity in the population is captured by the individual-school characteristics. Note that this model is not a random coefficient model, but we let the variation of coefficients among the individuals to be governed by a certain way. The coefficients can be identified by the variations in the characteristics of schools or individual-school interacted characteristics because what we want to look at is the impact of changing in the school or individual-school interacted characteristics on the students' ordinal preferences over the schools, and the change in individual characteristics will not change $\pi(R_i)$.

Other school choice studies (e.g. Fack, Grenet and He (2015)) have also used this rank-ordered logit model. A similar model, but with random coefficients is used in Abdulkadiroglu, Agarwal and Pathak (2017). We use maximum likelihood to estimate the coefficients. We as-

sume students' relative preferences over the schools do not change across years, and therefore the coefficients do not change across years. These coefficients can represent those in 2007 and 2008. Note that we have the variables of the characteristics of high schools in previous years, except for the students' home address. We simulate previous years' students' home-school distance using the following methodology: we impute a previous years' student's address by randomly drawing from the address of the students who are in the same middle school as him/her. The reason is due to the middle school assignment mechanism as described above, we can be pretty sure that a students in a middle school live close to that middle school, and because the middle-school assignment neighborhoods did not change over time, we can justify the use of the address of a student in 2014 as a proxy for the address of a previous year student from the same middle school.

In order to measure one's utility of getting into a certain school, we use home-school distance as the unit of measure of utility. The unit of distance is 2-kilometers. The reason of using home-school distance as the measurement of cardinal utility is because when school characteristics and individual characteristics are controlled, it is reasonable to assume that every student prefers a school closer to home.

We have provided some evidence to justify the assumption that the students' relative preferences are stable across years. Based on this assumption, the coefficients associated with the $X_{i,s}$ do not change across years. This is a quite strong assumption which has rarely been used often in previous literature, but we can still reasonably believe that it is true. In addition to the 2016 survey, other evidence that students' preferences are stable includes the fact that no public ordinary high school had moved its campus or had performed any main reconstruction to their infrastructure.

5.3 Estimation Results

Table 5 presents the estimation results of the coefficients in the utility function.

0. Choosing 2-kilometers as the unit of distance is for calculation convenience.

These coefficients are γ_0 and the vector of γ in equation (5.4) which captures the diversity of individual preferences over the school characteristics. Note that the interpretation of β_i in equation (5.4) is the trade-off between the change of relevant characteristics and the willingness to travel. Our discussion first focuses on the coefficients associated with high school education quality, i.e. the coefficients associated with the variables *EducationQuality* and other variables times *EducationQuality* in the table. Suppose student i were admitted by school s , the coefficient β_i associated with it is interpreted as how farther a students with observable characteristics X_i would have been willing to travel to a school with education quality marginally higher than school s . In other words, willingness of traveling is used as "price" to measure students' utility.¹ The larger the β_i is, the higher student i values a school's education quality. We call β_i student i 's marginal value of education quality.

The results in Table 5 show that for all districts, students with higher test score percentiles prefer schools with higher education quality. For example, for students in District 4, fixing the gender and home-school distance, a student with 10% higher score percentile is willing to travel about $2 \times 9.669 \times 0.1 \times 0.1 = 0.2$ kilometers more to a school with 10% higher in the education quality than a student with score percentiles 10% lower than her, for the same school with 10% higher in education quality. Students from HSES Districts with higher score percentiles prefer schools with higher education quality more than students from LSES Districts with higher test scores.

Since we suppose that the $\epsilon_{i,s}$ has mean zero, i.i.d. with Type 1 extreme value distribution, the cardinal utility of student i over school s is them expressed as $\tilde{v}_{i,s}$ as presented in Equation (5.9), where $\hat{\beta}$ is the vector of estimated coefficients using the data in year 2014 applying the rank-ordered logit model

$$\tilde{v}_{i,s} = \hat{v}_{i,s} + \tilde{\epsilon}_{i,s} = X_{i,s}\hat{\beta} - d_{i,s} + \tilde{\epsilon}_{i,s} \quad (5.9)$$

1. Because the government has strict regulations on the tuition fee over all the public ordinary high schools, there is no variation of tuition fees among schools.

To calculate welfare, we need to simulate the error term. We have assumed that students' strategies do not change across the years and that the missing survey data are independent of students' strategies. By construction, the error term follows Type 1 extreme value distribution, so for every student i , we draw the error term 500 times, and then calculate the mean of the values of the error terms as the error term. Let this mean value be $\tilde{\epsilon}_{i,s}$. For every student i , we can calculate the estimated cardinal utility of the school she is assigned to under the Chinese parallel mechanism.

CHAPTER 6

WELFARE COMPARISON

6.1 The Chinese Parallel Mechanism vs. Deferred Acceptance Mechanism

Since we have already simulated the true preferences of students over the high schools in year 2014 and in Assumption (A3), we assume that students' strategies does not change across years; also, we have already assumed that the relative preferences over the high schools does not change across the years. We therefore use the relative preferences over high schools in year 2014 to represent the true preferences for all years under the regime of the Chinese parallel mechanism. Also, we know that DA is strategyproof, i.e. it is an equilibrium for every student to list their true preferences. Therefore, we assume that students' strategies under DA is truth telling and simulate the students' ROLs under the DA mechanism accordingly. Based on the simulated ROLs under DA and the students' test scores, we run the DA mechanism and calculate the welfare under DA and compare it with the realized welfare outcome under BM. The results are presented in Table 6.

The DA mechanism yields a higher average social welfare than the Chinese parallel mechanism. Under DA, students are on average assigned to a school that is 0.097 kilometers closer to home than under the Chinese parallel mechanism. This number is significant. Note that in Table 3, we show that the LSES districts have fewer students who passed the public ordinary high school cutoff line, and therefore the average difference in the city equals to the weighted average difference of the HSES districts and LSES districts. The results indicate a difference in the change of welfare across the districts: although students from HSES districts and LSES districts have higher average welfare under DA relative to Chinese parallel mechanism, the benefit from DA is significant for students from LSES districts, but insignificant for students from HSES districts. Also, the size of benefit for the students from LSES districts is about 10 times as the benefit from the HSES districts, which is a relatively

surprising result which we will discuss in later parts of the paper.

We also compare the sorting behavior under DA, Chinese parallel mechanism and BM. The correlation coefficient of students' marginal value of education quality and the education quality of assigned schools is presented in Table 7. Note that student i 's marginal value of education quality is the β_i in Equation (5.4), as we defined in Chapter 5.

The results show that under DA, students with higher score percentiles are more likely to be matched to high schools with higher education quality than Chinese parallel mechanism than BM. At least from our data analysis, the less manipulable the mechanism is, the stronger positive sorting it displays, which is true for students from HSES districts and LSES districts. This is because in China, students' preferences over the high schools are highly correlated - a school's education quality and distance from home are two main factors that determine students' preferences. Schools with higher education quality are more competitive. Under more manipulable mechanisms, students who are on the margin of being admitted by a school with high education quality may try to avoid ranking it first, but under DA, students can rank the schools according to their true preferences and will rank schools with high education quality high, and therefore students with higher score percentiles are more likely to be admitted by schools with higher education quality.

6.2 The Chinese Parallel Mechanism vs. the Boston Mechanism

We then compare the welfare performance under Chinese parallel mechanism and BM. But because our survey was conducted in 2014 when the Chinese parallel mechanism was implemented, as a results, without any assumption on students' beliefs, we cannot recover the students' true preferences over the high schools under BM. For the students under BM, we can only recover the "average utility" of the students with observables X_{is} and d_{is} over each school, which is $\hat{v}_{i,s}$ in equation (5.9). Although we cannot call it "welfare", yet the average utility comparison is still valuable. So we will compare the students' average welfare under Chinese parallel mechanism to the average utility of students under BM.

Note that this is not the cardinal utility for student i to be assigned into school s because the unobservable $\epsilon_{i,s}$ is correlated with students' strategies. To be more clear, the ROL one submits depends on the cardinal preferences over the schools and her strategy (how she games the mechanism), but the cardinal preferences depends on observables and unobservables, so a student i with higher $\epsilon_{i,s}$ is more likely to rank school s at a higher rank, that is, $E[\epsilon_{i,s}|ROL_i] \neq 0$. The $\hat{v}_{i,s}$ is interpreted as the average cardinal utility of every student i with observable characteristics $X_{i,s}$ and $d_{i,s}$ over school s suppose every such individual i gets into school s . To estimate student i 's cardinal utility over school s , we will involve in assumptions on student i 's belief about the chance of getting into school s if she submits a certain ROL. We can simulate the error term under Chinese parallel mechanism because we assume that the missing of survey data is random, and we assume that students' strategies do not change across years, therefore, we assume that the joint distribution of students' preferences and ROLs for the surveyed students is the same for all students under Chinese parallel mechanism. But we do not know this joint distribution under BM since we do not impose specific belief assumptions on students, so we cannot simulate the error term, but indeed we can calculate the average utility of students under BM. The results on the comparison are in Table 8.

The results show that the average welfare under Chinese Parallel mechanism is equivalent to 0.097 kilometers higher than the average utility under BM. But the switch from BM to Chinese parallel mechanism leads to benefit-loss redistribution over the HSES districts and LSES districts. Students from HSES districts suffer a loss equivalent to 0.2365 kilometers willingness to travel, but students from LSES districts enjoy a gain equivalent to 0.7674 kilometers willingness to travel.

6.3 Discussions

Comparing the results in Section 6.1 and Section 6.2, it is interesting to see the change across the HSES districts and LSES districts. When shifting from the more manipulable

BM mechanism to the slightly less manipulable Chinese parallel mechanism, students from HSES districts are the losers, but if the mechanism is changed into a strategy-proof DA mechanism, they will also benefit from the strategy-proof mechanism. When we use DA as the benchmark of comparison, we find that students from LSES districts performs best under DA, followed by the Chinese parallel mechanism less, and perform the worst under BM.

The direction of the change in welfare in our paper is consistent with De Haan et al. (2015) and Kapor, Nielson and Zimmerman (2017) which use survey to elicit students' true preferences. But our results is opposite to He (2014), Calsamiglia, Fu and Guell (2017), Hwang (2016) and Agarwal and Somaini (2017) which indicate that BM outperforms DA in terms of social welfare.

One explanation to our welfare comparison result is as follows: theories such as Abdulkadiroglu et al. (2011) and Miralles (2008) argue that compared to DA, BM gives students a chance to demonstrate their intensity of preferences and henceforth may lead to higher ex ante social welfare. However, in their theoretical settings - for instance, Abdulkadiroglu et al. (2011) - the students' priority scores to the schools are determined by a lottery, which, by construction, has a relatively large uncertainty. As a result, students have are given relatively larger chance to demonstrate their intensity of preferences. But our research has a different setting: in China, the unique priority score for every student to every school is the entrance examination score. As we have shown, students who are by the end of their third year are pretty sure about their ability and can have a relatively correct guess on how they would perform in the high school entrance exams, so although students do not know their scores when they submit their ROLs, in our empirical setting, there is relatively less uncertainty in their priority scores than in the case where priority scores are determined by a lottery. Therefore, in our case, students can hardly demonstrate the intensity of their preferences over schools and that's why more manipulable mechanisms are less efficient, which is different to the the theoretical literature.

School choice papers like He (2014) estimate students' preferences over schools from their ROLs based on strong assumptions on students' belief of possibility of being admitted if submit a certain ROL. Their assumptions imposes that students, in some sense, play the game at equilibrium, or play non-dominated strategies. That is, to some extent, they rule out students' strategic mistakes. However, from the surveys, one can observe students' strategic mistakes and the findings indicate that strategic mistakes can cause significant welfare loss. Therefore, although theoretically, under equilibrium play, BM may yield higher average welfare than DA, yet when students make strategic mistakes, this is not likely to be true. Therefore, it is worthwhile to examine how students are gaming the mechanism.

CHAPTER 7

MANIPULATION BEHAVIOR

From a direct comparison of students' survey and the ROLs they submitted, we find that fewer than 2% of the total students list their three choices on the ROLs exactly the same as their first three schools on the survey, meanwhile the order is also exactly the same. Therefore, we want to see the distance of manipulation of mechanism under the Chinese Parallel mechanism. Note that these results are generated by direct observation of the 2014 survey data on the non-early admission students who are above the public ordinary cutoff line. Table 9 shows the results.

To calculate the degree of manipulation, we use the following index:

$$\frac{\sum_i \#(ROL_i \cap SURVEY_i)}{3|I|} \quad (7.1)$$

The equation is the normalized degree of manipulation, namely, the "distance" between students' true preferences and their ROLs - how "far away" are their ROLs from their true preferences. Here, i indicates a student, and I is the set of students. $\#$ is the cardinality of two sets. Therefore, the numerator is the summation of the number of common elements in each student's ROLs and surveys. The denominator is the total number of elements in all the students surveys.

Using this formula, we calculate the normalized distance of manipulation is 0.509. The interpretation is that for all of the ranks in the ROLs of students who are non-early admission students, and above the cutoff line, and also finished the survey, 50% of them are also listed in the survey. This result shows that students are very strategic when they are ranking the schools. The number is low compared to Agarwal and Somaini (2017), De Haan et al. (2015) and Kapor, Nielson and Zimmerman (2017). The main reason is that in China, school choice are merit-based. Therefore, students whose academic ability are low, although prefer schools with high education quality, are not likely to list those schools on their ROLs because it is

unlikely for them to get in. That’s why students with low academic ability list schools with high education quality on the survey but not on the ROLs. Therefore, the magnitude of manipulation is relatively large in our case compared to other literatures.

We also measure the difference in the utility of students’ first, second and third choice on their ROLs and their favorite, second favorite and third favorite school, respectively. Mathematically, that is

$$\bar{v}_{ROL_j} - \bar{v}_{SURVEY_j} \tag{7.2}$$

where ROL_j and $SURVEY_j$ mean the j th school on the ROL and on the survey, respectively. We show this difference under both BM and the Chinese parallel mechanism. Table 10 shows the result.

We can see that students are manipulating both BM and the Chinese parallel mechanism. Under both mechanisms, the average utility of students’ three school choices are lower than their actual favorite, second favorite and third favorite schools. However, under the Chinese parallel mechanism, all the three ranks of the students have higher average utilities than under BM. we conducted the t-test on the average utilities of the three choices under the two mechanisms and the difference is significant. Chen and Kesten (2017) and Chen, Jiang and Kesten (2016) show that theoretically, students rank a school they like significantly more as their first choice under the Chinese parallel mechanism than under BM. But the evidence they provide is either in the laboratory setting or with limited observational data. We use complete and abundant data to show that the students’ behaviors are consistent with their theoretical prediction. However, Chen, Jiang and Kesten (2016) only give a theoretical prediction of students’ first choice, not their second or third choice, or choices thereafter. The key issue is that it is hard to characterize the equilibrium under BM or the Chinese parallel mechanism. Our evidence shows that under the Chinese parallel mechanism, students rank their more preferred schools on all their three choices than under BM. Since in our case, theoretically, the Chinese parallel mechanism provides an ”insurance” for only the

first choice, the fact that students rank a school that they prefer more as their first choice is consistent with theory, but their ranks for the second and third choice are surprising. We suspect that it is students' strategic mistakes.

CHAPTER 8

SORTING COMPARISON

8.1 Correlation between Student Ability and Assigned School Quality

As Riehl (2016) defined, complementarity exists if student's ability and school's education quality are not additively separable. The result shows that the interact of student percentile and education quality term is positive and significant, which means that the student's ability and school's education quality are complementarity. The complementarity property is important because Becker's (1973) shows that if complementarity condition holds, matching students with higher ability to schools with higher education quality maximizes the total human capital in the society. Therefore, under the assumptions (A1)-(A2), and assuming that students' answers to surveys reveal their true preference over schools, more sorting is better for human capital production in the society.

Therefore, the benefit of the sorting is important: whether a student with a certain score percentile can benefit from being assigned to a high school with higher education quality? And by how much? Let the so called "value of sorting" of student i be

$$\beta_i^{Sorting} \times Percentile_i \times Quality_s \tag{8.1}$$

where $\beta_i^{Sorting}$ is the coefficient associated to the interacted variable $Percentile * EducationQuality$. It shows the marginal benefit from sorting for a student with score percentile $Percentile_i$. This parameter is interesting because it measures whether students with a certain score percentile and SES background can benefit from the change of sorting due to mechanism change. If after the change of sorting, the students who benefit from it do not value education quality higher than those who lose from the change, then even there is an

increase in sorting, it is not necessarily that total human capital in the society will increase.¹ The correlation between $\beta_i^{Sorting} \times Percentile$ and the assigned school's education quality under BM and Chinese Parallel mechanism is presented in Table 11.

The results indicate that after the mechanism change, in both HSES districts and LSES districts, there is higher correlation between $\beta_i^{Sorting} \times Percentile_i$ and the assigned schools' education quality. This means that under Chinese Parallel mechanism, on average, students with higher test scores and meanwhile value education quality more are assigned to high schools with higher education quality.

8.2 Value of Sorting: Regression Analysis

Based on the results in Becker's marriage model (1973), when student score percentile and education quality are complementarity, it is natural for us to imagine that an increase in the correlation coefficient between education quality of assigned schools and the students' score percentiles will lead to an increase in the total "value of sorting". However, we observe a decrease in the average value of education quality assigned to students after the mechanism change. (Table 12)

The correlation coefficient only captures the feature of the matchings on average, without descriptions on the distribution of features of the matchings. If students who have higher marginal value of education quality are matched to schools with higher education quality after the switch of mechanism, but the gain from students with higher marginal value of education is less than the loss of students with lower marginal value of education, on average, there can be loss in value of education quality. This observation makes us to investigate the distribution of the reallocation of education resource.

In order to show which students benefit more from the change in sorting, we run the following fully saturated regression

1. Note that Becker (1973) does not talk about whether higher sorting necessarily produces higher total human capital in the society.

$$\begin{aligned}
ValueSorting_i = & \beta_0 + \beta_1 * Percentile_i + \beta_2 * PAR_i + \beta_3 * HSES_i + \beta_4 * PAR_i * Percentile_i \\
& + \beta_5 * Percentile_i * HSES_i + \beta_6 * PAR_i * HSES_i + \beta_7 * Percentile_i * PAR_i * HSES_i + \epsilon_i,
\end{aligned}
\tag{8.2}$$

The results are presented in Table 13.

We can summarize the main relevant results as follows:

- Under Chinese Parallel mechanism: 1 percent increase in Percentile is associated to an increase in the value of sorting equivalent to 0.17 kilometers willingness to travel for students from HSES districts; For students from LSES districts, this number is 0.0451%;
- For students from HSES districts, those with *Percentile* > 79.4% get higher value of sorting under Parallel mechanism than under BM;
- For students from LSES districts, those with *Percentile* > 51% get higher value of sorting under Parallel mechanism than under BM;
- For students with *Percentile* > 86.2%, the increase in the value of sorting under Chinese Parallel mechanism relative to BM is larger for HSES students than for LSES students.

Therefore, the reason that the switch of mechanism reduces the total value of sorting is that students from HSES districts with relatively lower score percentiles are assigned to high schools with lower education quality. This point has been addressed in Chapter 5. This section shows that the change in sorting hurts the this group of students not only in the sense that they are assigned to schools with poorer education quality, but also they value education quality more than the students from LSES districts but with higher score percentiles.

Students with lower test scores from HSES districts, if assigned to schools with higher education quality, can produce higher level of human capital than students from LSES districts. The reason could be that they have better family background and therefore have higher potential. But in fact, students with lower scores from HSES are assigned to schools with lower education quality after the mechanism change, so although the average utility increased after the mechanism change, yet from the perspective of sorting, students with higher potential got hurt from Chinese parallel mechanism.

CHAPTER 9

CONCLUSION AND FUTURE WORK

This paper address the debate on the trade off between two basic properties of mechanisms: whether a less manipulable mechanism will yield lower average social welfare. Using a unique dataset on high school admission mechanism in China across both BM and Chinese parallel mechanism, combined with a survey asking students' true preferences, we analyze the welfare performance of the BM, Chinese Parallel mechanism and DA.

Our findings show that students are very strategic under the context of merit-based admissions. When taking students' strategic mistakes into account, the less manipulable the mechanism is, the higher average social welfare it yields. There is also significant redistribution of welfare and we show that students from districts with lower social economic status are hurt more under more manipulable mechanisms. Also, the correlation between students' score percentiles and the education quality of students' admitted school is also higher under less manipulable mechanisms. However, that will hurt the students from higher social economic districts with lower score percentiles, but these students, had they been admitted to schools with higher education quality, can produce more human capital than students who benefit from the increase of sorting.

This paper also brings in perspectives for future work. First, our paper combines survey data with administrative data on students' school choice records under both mechanisms, so it is interesting to estimate students' true preferences over schools with and without the survey, and then compare the results. To estimate students' preferences over schools using only their ROLs, we can follow the methodologies in Agarwal and Somaini (2017). If the results are the same, we can verify that students have correct beliefs about the possibility of being admitted by the schools. If not, it can be viewed as another evidence that students have wrong beliefs about the possibility of being admitted by the schools, which also demonstrates the value of the survey.

Another important future work is to look at the students' academic outcomes after being

admitted by the two different school choice mechanisms. As we see from Figure 3, under BM, the variance of the incoming students' entrance exam scores is higher than under the Chinese parallel mechanism, which indicates that students with higher academic abilities will be with peers with higher abilities under the Chinese parallel mechanism. How will this phenomenon influence the students with different abilities is worth studying. Because we currently do not have the students' academic performance in high schools, we are not able to do the research now, but that will be an interesting research in the future.

BIBLIOGRAPHY

Abdulkadiroglu, Atila, Yeon-Koo Che, and Yosuke Yasuda. (2011). "Resolving Conflicting Preferences in School Choice: The Boston Mechanism Reconsidered." *American Economic Review*, 101(1): 399-410

Abdulkadiroglu, Atila, Nikhil Agarwal, and Parag Pathak. (2017). "The Welfare Effect of Coordinated Assignment: Evidence from the NYC High School Match", forthcoming *American Economic Review*

Abdulkadiroglu, Atila, and Tayfun Snmez. (1999). "House allocation with existing tenants." *Journal of Economic Theory*, 88(2): 233-260.

Abdulkadiroglu, A., and Sonmez, T. (2003). School choice: A mechanism design approach. *The American Economic Review*, 93(3), 729-747.

Agarwal, N., and Somaini, P. (2017). Demand Analysis using Strategic Reports: An application to a school choice mechanism (No. w20775). National Bureau of Economic Research.

Akyol, Perlin, Krishna, Kala (2017). Preferences, selection, and value added: A structural approach. *European Economic Review*, 2017, vol. 91, issue C, 89-117

Balinski, M., and Sonmez, T. (1999). A Tale of Two Mechanisms: Student Placement. *Journal of Economic Theory*, 84, 73 - 94

Becker, Gary, S. (1973). "A Theory of Marriage: Part 1". *Journal of Political Economy*, 81(4): 813-846

Beggs, S., Cardell, S., and Hausman, J. (1981). Assessing the Potential Demand for Electric Cars. *Journal of Econometrics*, 16, 1-19

Calsamiglia, C., Fu, C., and Gell, M. (2017). Structural estimation of a model of school choices: the Boston mechanism vs. Its Alternatives.

Chapelain, Alex Le (2015). Estimating students' preferences and bounded rationality in Mexico city. Working Paper

Chen, Yan, and Onur Kesten. (2017) "Chinese college admissions and school choice

reforms: A Theoretical Analysis. *Journal of Political Economy*", 125(1): 99-139.

Chen, Yan, Ming Jiang and Onur Kesten. (2016) Chinese College Admissions and School Choice Reforms: An Experimental Study, Working Paper

De Haan, Monique, Pieter A. Gautier, Hessel Oosterbeek and Bas van der Klaauw. (2015) "The performance of school assignment mechanisms in practice."

Gale, David, and Lloyd S. Shapley. (1962). "College admissions and the stability of marriage." *The American Mathematical Monthly*. 69(1): 9-15.

Haeringer, Guillaume and Flip Klijn (2009). "Constrained school choice". *Journal of Economic Theory* 144.5, pp. 1921-1947

He, Y. (2014): Gaming the Boston Mechanism in Beijing, Unpublished mimeo, Toulouse.

Hunt, Shane (1963): "Income Determinants for College Graduates and the Return to Educational Investment, Ph.D. thesis, Yale University

Hwang, S. I. M. (2016). A Robust Redesign of High School Match.

Kapor, Adam, Christopher A Neilson, and Seth D Zimmerman (2017). "Heterogeneous Beliefs and School Choice Mechanisms", Working Paper

Miralles, A. (2008): School Choice: The Case for the Boston Mechanism, Mimeo.

Narita, Yusuke (2016), "Match or Mismatch: Learning and Inertia in School Choice", Working Paper

Pathak, Parag A and Tayfun Sonmez (2008). "Leveling the playing field: Sincere and sophisticated players in the Boston mechanism". *The American Economic Review* 98.4, pp. 1636-1652

Riehl, Evan. (2016) "Assortative Matching and Complementarity in College Markets", Working Paper

Roth, Alvin E., and Elliott Peranson. (1997). "The effects of the change in the NRMP matching algorithm." *JAMA* 278(9): 729-732.

Roth, Alvin E., and Elliott Peranson. The redesign of the matching market for American physicians: Some engineering aspects of economic design. No. w6963. National bureau of

economic research, 1999.

Roth, Alvin E. "Deferred Acceptance Algorithms: History, Theory, Practice, and Open Questions," *International Journal of Game Theory*, Special Issue in Honor of David Gale on his 85th birthday, 36, March, 2008, 537-569

Train, K. (2009). "Discrete Choice Methods with Simulation." Cambridge University Press, Cambridge, second edition.

TABLES

Table 1: *Students' view about the peer academic performance*

	Number
Not Important	26
Not very important	30
Normal	297
Important	1,788
Very important	5,610
Total	7,651

Table 2: *Average Salary of the Districts (Unit:Thousand Yuan)*

	District 1	District 2	District 3	District 4
2006	2.4	2.3	2.0	2.7
2007	2.9	2.8	2.5	3.2

Table 3: *Percent of Exam Takers above the 51th percentile in each District*

	District 1	District 2	District 3	District 4
2008 (Parallel)	31%	14%	14%	41%
2007 (BM)	31%	16%	14%	39%

Table 4: *Change in the correlation coefficient between student score percentile and education quality of the assigned school*

	City	HSES Districts	LSES Districts
Parallel	.6334	.6552	.5546
BM	.5953	.6032	.5384

Table 5: Coefficient Estimation Results

	District 1	District 2	District 3	District 4
<i>EducationQuality</i>	-8.375*** (2.466)	-2.477* (1.124)	-3.273*** (0.943)	-5.619*** (0.992)
<i>SmallClass</i>	-0.420 (1.717)	1.160 (0.598)	-2.861*** (0.723)	-0.789 (0.522)
<i>LiveOnCampus</i>	1.950 (2.061)	-3.307*** (0.833)	-5.875*** (0.861)	-1.229 (0.674)
<i>PartialOnCampus</i>	-1.312 (1.763)	-2.374*** (0.604)	-4.706*** (0.711)	-1.883*** (0.509)
<i>Gender * EducationQuality</i>	0.546 (0.892)	0.397 (0.400)	0.836* (0.347)	-0.373 (0.360)
<i>Gender * smallClass</i>	-0.499 (0.530)	-0.422* (0.202)	1.009*** (0.259)	-0.340 (0.180)
<i>Gender * LiveOnCampus</i>	-1.025 (0.615)	-0.324 (0.255)	0.366 (0.300)	-0.422 (0.216)
<i>Gender * PartialOnCampus</i>	-0.590 (0.540)	-0.258 (0.194)	0.888*** (0.255)	-0.406* (0.172)
<i>Percentile * EducationQuality</i>	14.73*** (3.163)	5.887*** (1.498)	7.890*** (1.317)	9.669*** (1.286)
<i>Percentile * SmallClass</i>	-0.416 (2.448)	-4.281*** (0.868)	-1.373 (1.059)	-1.219 (0.725)
<i>Percentile * LiveOnCampus</i>	-2.199 (2.744)	2.907** (1.105)	3.434** (1.202)	0.478 (0.856)
<i>Percentile * PartialOnCampus</i>	1.336 (2.480)	1.590 (0.879)	1.514 (1.049)	1.230 (0.699)
<i>Distance * EducationQuality</i>	0.392*** (0.0576)	0.325*** (0.0261)	0.201*** (0.0242)	0.425*** (0.0222)
<i>Distance * smallClass</i>	0.298*** (0.0305)	0.345*** (0.0138)	0.410*** (0.0113)	0.338*** (0.0114)
<i>Distance * LiveOnCampus</i>	0.248*** (0.0430)	0.257*** (0.0198)	0.345*** (0.0189)	0.231*** (0.0168)
<i>Distance * PartialOnCampus</i>	0.251*** (0.0356)	0.250*** (0.0143)	0.357*** (0.0120)	0.232*** (0.0125)

* Significant at 10% ; ** Significant at 5% ; *** Significant at 1%

Table 6: *Change in Welfare in the city and Redistribution of Welfare among the Districts (DA minus Parallel)*

	City (Weighted)	HSES Districts	LSES Districts
Difference	0.097***	0.028	0.27***

*Significant at 10%; **Significant at 5%; ***Significant at 1%

Table 7: *Change in the correlation coefficient between marginal value of education and education quality of assigned schools*

	City (Weighted)	HSES Districts	LSES Districts
DA	.7209	.7356	.6877
Parallel	.5900	.6225	.5546
BM	.5720	.5873	.5312

Table 8: *Change in Welfare in the city and Redistribution of Welfare among the Districts (Average Welfare Parallel minus Average Utility BM)*

	City (Weighted)	HSES Districts	LSES Districts
Difference	0.097	-0.2365**	0.7674***

*Significant at 10%; **Significant at 5%; ***Significant at 1%

Table 9: *Survey Covers ROL (none-early-admission students with score above the ordinary high school cut-off line)*

	0	1st	2nd	3rd	1st,2nd	1st,3rd	2nd,3rd	1st,2nd,3rd	Total
0 schools	121								121
1 schools		425	93	24					542
2 schools					589	68	20		677
3 schools								102	102

Table 10: *Difference in the average utility on the ROLs and surveys ($\bar{v}_{ROL_j} - \bar{v}_{SURVEY_j}$)*

	j=1	j=2	j=3
BM	-3.602***	-5.328***	-5.579***
Parallel	-2.987	-3.289***	-4.272***

*Significant at 10%; **Significant at 5%; ***Significant at 1%

Table 11: *Change in the correlation coefficient between $\beta_i^{Sorting} \times Percentile_i$ and education quality of assigned schools*

	HSES Districts	LSES Districts
Parallel	0.4368	0.4420
BM	0.3882	0.4233

Table 12: *Change in the average "value of sorting" (Parallel minus BM)*

	HSES Districts	LSES Districts
Change	-0.2811***	-0.0297***

*Significant at 10%; **Significant at 5%; ***Significant at 1%

Table 13: *Student-School Quality of Assigned School: Fully Saturated Model Analysis*

	Coefficients
<i>Percentile</i>	8.989*** (0.342)
<i>PAR</i>	-0.0825 (0.370)
<i>HSES</i>	-2.008*** (0.301)
<i>PAR</i> × <i>Percentile</i>	0.218 (0.517)
<i>Percentile</i> × <i>HSES</i>	6.473*** (0.404)
<i>PAR</i> × <i>HSES</i>	-1.158** (0.441)
<i>PAR</i> × <i>Percentile</i> × <i>HSES</i>	1.344* (0.600)
Constant	-3.054*** (0.247)

* Significant at 10% ; ** Significant at 5% ; *** Significant at 1%

FIGURES

Figure 1: HSES Districts Contrast (BM in 2007 and Chinese parallel mechanism in 2008)

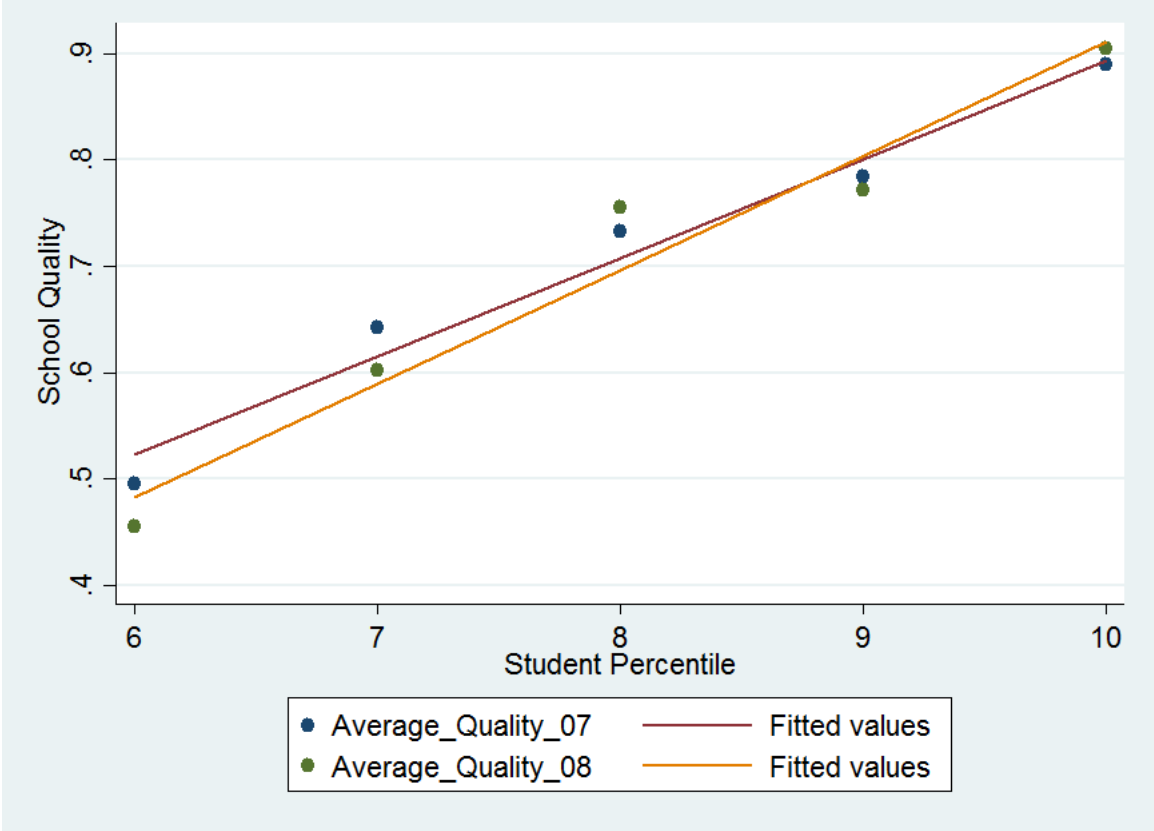


Figure 2: *LSES Districts Contrast (BM in 2007 and Chinese parallel mechanism in 2008)*

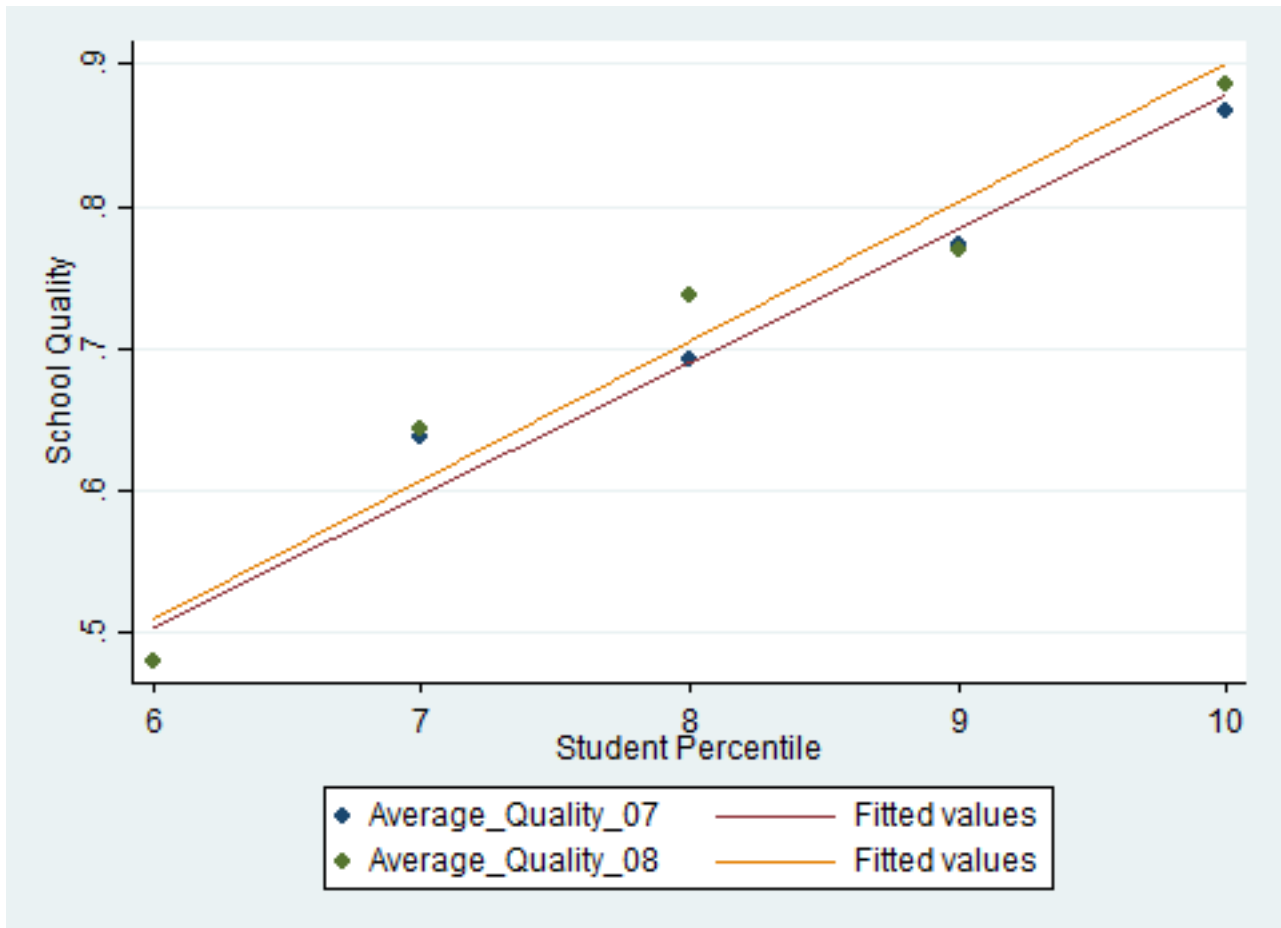


Figure 3: Plot of the mean and standard deviation of incoming students' quality of each school

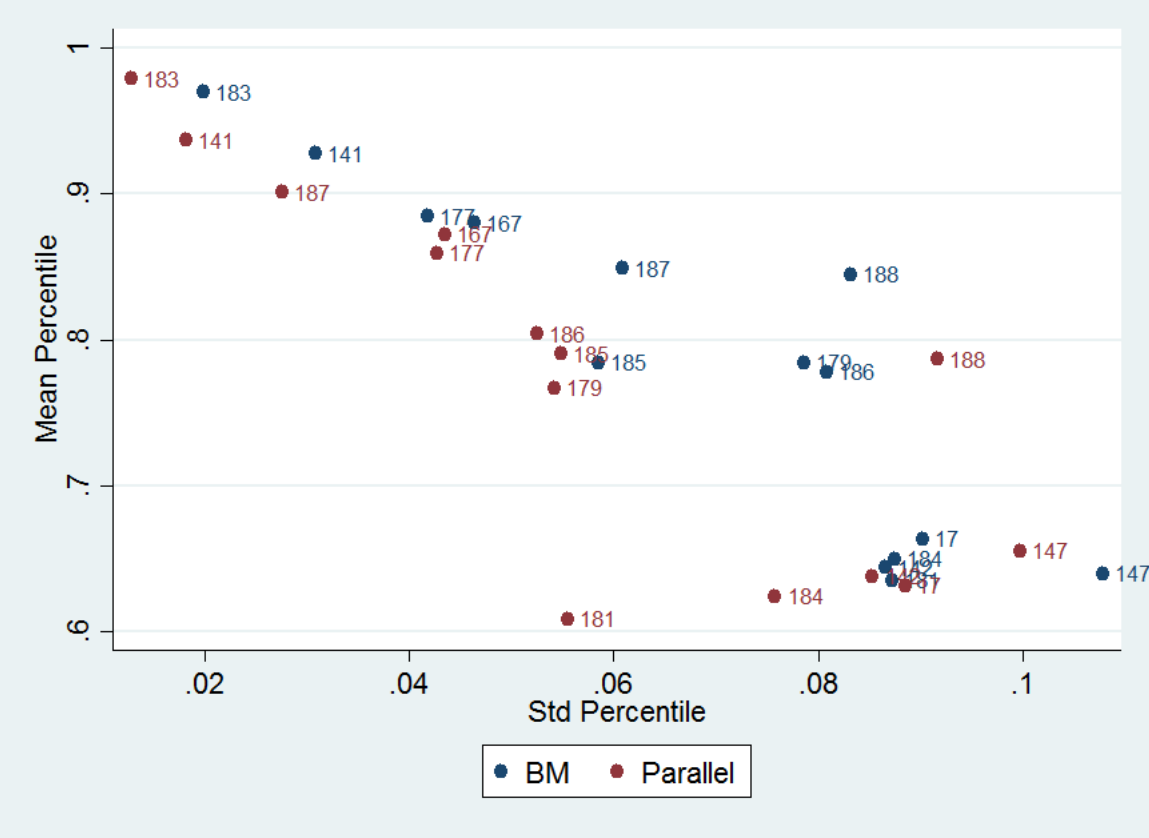


Figure 4: HSES Districts Contrast (BM in 2007 and Chinese parallel mechanism in 2008)

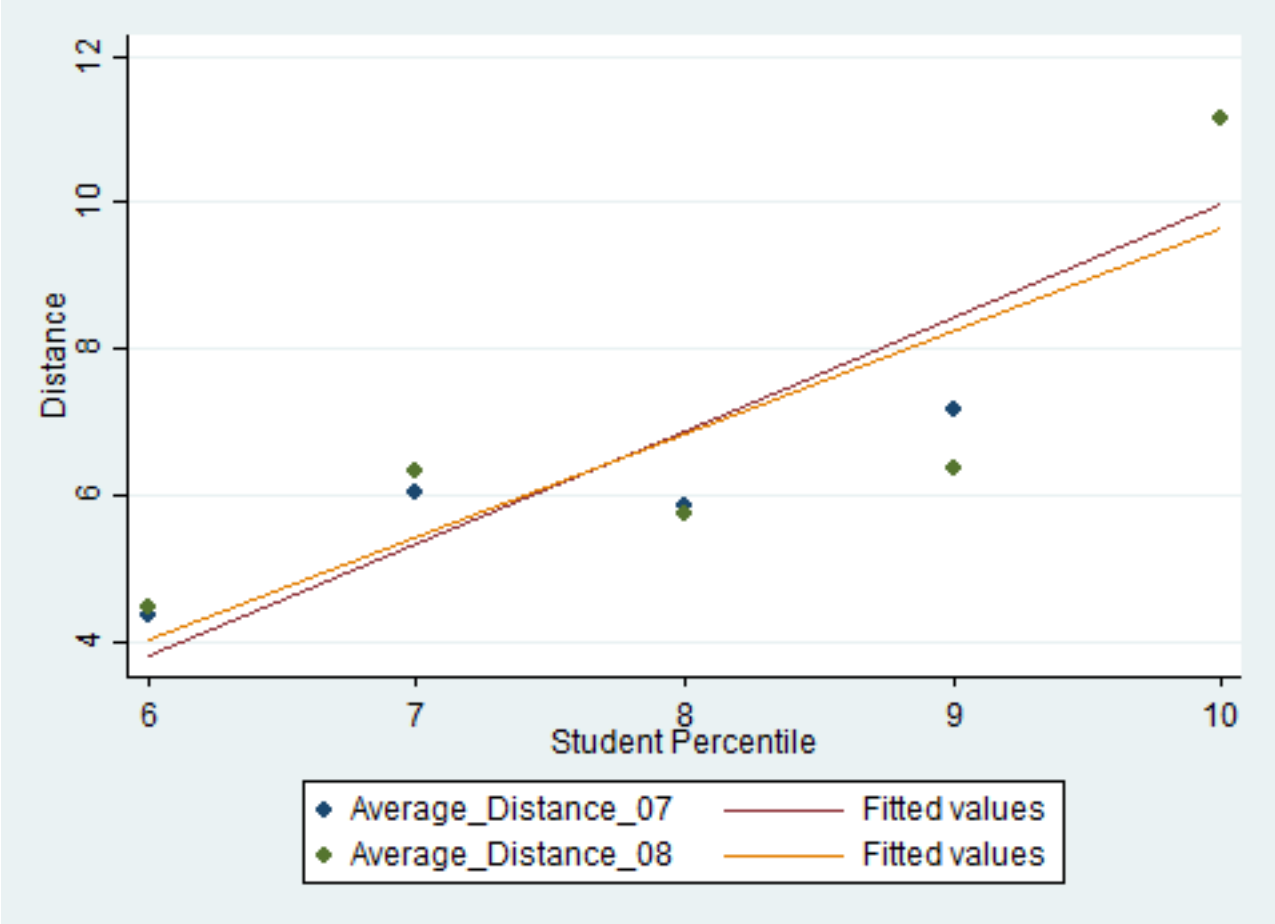
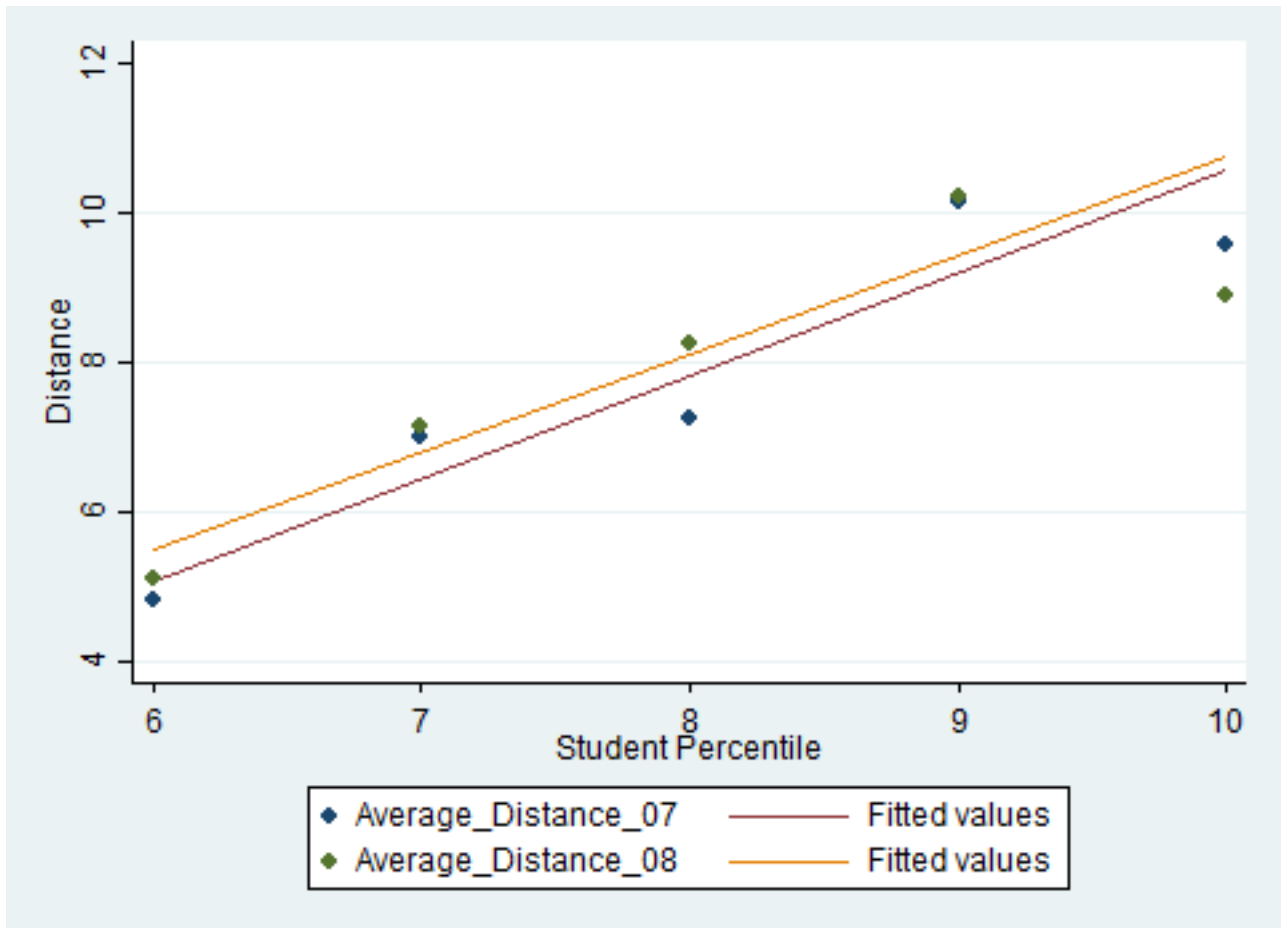


Figure 5: *LSES Districts Contrast (BM in 2007 and Chinese parallel mechanism in 2008)*



Appendices

APPENDIX A

SURVEY TO MIDDLE SCHOOL GRADUATES IN 2014

Appendix A presents the English translation of the whole survey.

Dear students: We are researchers of Educational Science Research Department. Please take a few minutes to complete this questionnaire. The purpose of this questionnaire is for research only it has no relationship with the results of high school entrance exam, neither does it have any relationship with high school admission. Any personal information in this questionnaire will be treated as highly confidential. Please answer the questions carefully.

Thank you!

School:

Class:

Name:

Gender:

Student ID:

Questions:

Q1. Are you Arts or Sports Specialty Student?

A. Yes B. No

Q2. Are you directly upgrading student?

A. Yes B. No.

Q3. Are you quota student?

A. Yes B. No

Q4. Are you a student who graduated in previous years?

A. Yes B. No

Q5. Please choose the level of importance of the following factors that you consider when you choose ordinary high schools or vocational schools:

A. (1) The academic quality (e.g. college entrance exam scores):

5. Very important

4. Relatively important
3. Normal
2. Not so important
1. Not important at all

(2) The employment condition after graduation and the professional training (Please answer this question if you are possible to choose vocational schools; do not answer if you do not consider vocational schools)

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

B. The infrastructure condition of schools (e.g. equipment, computers, sports fields)

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

C. Whether the school provides scholarship or tuition waive

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

D. The distance from school to home:

5. Very important
4. Relatively important

3. Normal

2. Not so important

1. Not important at all

E. Low pressure at school:

5. Very important

4. Relatively important

3. Normal

2. Not so important

1. Not important at all

F. Good study atmosphere of the school:

5. Very important

4. Relatively important

3. Normal

2. Not so important

1. Not important at all

G. The schools especially good performance at arts or sports:

5. Very important

4. Relatively important

3. Normal

2. Not so important

1. Not important at all

H. The strict management in students study and life:

5. Very important

4. Relatively important

3. Normal

2. Not so important

1. Not important at all

I. Schools environment (e.g. beautiful and clean campus, good safety condition around the campus):

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

J. Schools living condition for students (e.g. the quality of food, school bus condition, accommodation condition):

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

K. The outside-class life condition

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

L. Good classmates:

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

M. Whether the school has special classes:

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

Please list other factors not listed above that you think important:

6. When you are considering the choice of high schools, how important are your opinion and other peoples opinion:

A. Your own opinion:

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

B. Parents opinion:

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

C. You teachers suggestion:

5. Very important
4. Relatively important
3. Normal
2. Not so important
1. Not important at all

7. With your studying ability, please list 7 schools - ordinary high schools or vocational

schools you may consider as your choice (do not consider order):

8. Please pick up 5 schools that you want to get in most from the above 7, and list them in the order of intensity of your willingness to get in: 1. Most Preferred School:

2. Second Preferred School:

3. Third Preferred School:

4. Fourth Preferred School:

5. Fifth Preferred School:

9. When filling your rank order list, how many previous years admission lines for the schools will you refer to:

A. Do not refer to any previous year admission lines

B. Refer to the admission lines for only last year

C. Refer to the admission lines for the past two years

D. Refer to the admission liners for the past three years

E. Refer to the admission lines for more than past three years

10. Your last modeling exam score (excluding PE) is:

APPENDIX B

ADDITIONAL TABLES

Table B.1 shows the proportion of zbs students, those who are arts or sports special students (those students will go through a separate admission process). The total number of students who are above the ordinary high school cut-off line is 5612 among whom 2845 students were covered by the survey.

Table B.1: *Summary of surveyed students*

	2014	Survey
non-zbs:	3,500 62.37%	1627
zbs:	1,904 33.93%	1131
special:	117 2.08%	49
no information:	91 1.63%	38
Total:	5,612	2845

Table B.2 shows that among the students whose test scores are above the ordinary high school cut-off line, more than a half give a total order of all the five schools in their surveys.

Table B.2: *Summary statistics of surveyed students*

	Number
2 schools	297
3 schools	313
4 schools	416
5 schools	1,422
Total	2,448

APPENDIX C

SORTING ON EDUCATION QUALITY: FULLY SATURATED MODEL

To give a clearer view of the relationship between students' percentile and the school quality they are assigned to, we present a fully saturated regression model. We want to examine how the impact of the switch of the mechanism on the assigned schools' education quality differs for students with different test score percentile and social economic background. To do this, we run the following fully saturated regression model

$$\begin{aligned} EduQuality_i = & \beta_0 + \beta_1 * Percentile_i + \beta_2 * PAR_i + \beta_3 * HSES_i + \beta_4 * PAR_i * Percentile_i \\ & + \beta_5 * Percentile_i * HSES_i + \beta_6 * PAR_i * HSES_i + \beta_7 * Percentile_i * PAR_i * HSES_i + \epsilon_i, \end{aligned} \tag{C.1}$$

where $EduQuality_i$ is the outcome variable, which is the education quality of the school that student i is assigned to. PAR_i is a dummy variable - it equals to 1 if in the year when student i took the high school entrance exam, the Chinese parallel mechanism was used. $HSES_i$ is a dummy variable indicating whether student i is from higher social economic districts (District 1 or 4) - if yes, coded as 1 and 0 otherwise. Table 16 presents the results

It shows that the test score percentile of a student is the largest and most significant factor that determine the admission outcome. It also shows the gain from switching the mechanism is different for students from different districts and with different score percentiles because the coefficient associated to the mechanism dummy is a function of student characteristics.

Let θ_i be the coefficient for student i associated with the mechanism dummy PAR . Then, according to model (C.1)

$$\theta_i = \beta_2 + \beta_4 * Percentile_i + \beta_6 * HSES_i + \beta_7 * Percentile_i * HSES_i \quad (C.2)$$

Here, θ_i is interpreted as student i 's "benefit" (in terms of assigned school's education quality) from switching the mechanism. Some interesting facts are observed from the results in Table 4. On one hand, the θ_i is an increasing function of students' score percentiles, for both higher SES and lower SES districts. This is consistent with the theory in Chen and Kesten (2017) and Chen, Jiang and Kesten (2015). On the other hand, the marginal increase in θ_i when score percentile increases is larger for students from higher SES districts than for students from lower SES districts - for higher SES students, one percent increase in score percentile is associated to 0.1361% increase in θ_i , i.e. the benefit from switching the mechanism, while for lower SES students, one percent increase in score percentile is associated to 0.0451% in the θ_i . For students from higher SES districts, θ_i is positive only for students with test score percentile higher than 81.9%, but for students from lower SES districts, it is positive for all students whose percentile is above 50%. However, the marginal increase of assigned school's education quality when increasing a student's test score percentile is larger for students from higher SES districts than those from lower SES districts. Therefore, θ_i for students in higher SES districts is higher than that for students in lower SES districts for students whose percentile is higher than 83.4%.

Table C.1: *Education Quality of Assigned School: Fully Saturated Model Analysis*

	Coefficients
<i>Percentile</i>	0.964*** (0.0337)
<i>PAR</i>	-0.0189 (0.0365)
<i>HSES</i>	0.0286 (0.0297)
<i>PAR</i> × <i>Percentile</i>	0.0451 (0.0510)
<i>Percentile</i> × <i>HSES</i>	-0.0238 (0.0399)
<i>PAR</i> × <i>HSES</i>	-0.0925* (0.0435)
<i>PAR</i> × <i>Percentile</i> × <i>HSES</i>	0.0910 (0.0592)
<i>Constant</i>	-0.0278 (0.0244)

* Significant at 10% ; ** Significant at 5% ; *** Significant at 1%

APPENDIX D

SORTING ON HOME-SCHOOL DISTANCE: FULLY SATURATED MODEL

Similar to the previous subsection, to examine the diversity of the impact of switching the mechanism on the distance from the assigned school to students' home, we run the same regression as Equation (D.1) as presented in the previous section, but the only difference is that the dependent variable here is the distance from student i 's home to the school assigned to student i . The regression is therefore

$$\begin{aligned}
 Distance_{i,s} = & \beta_0 + \beta_1 * Percentile_i + \beta_2 * PAR_i + \beta_3 * HSES_i + \beta_4 * PAR_i * Percentile_i \\
 & + \beta_5 * Percentile_i * HSES_i + \beta_6 * PAR_i * HSES_i + \beta_7 * Percentile_i * PAR_i * HSES_i + \epsilon_i,
 \end{aligned}
 \tag{D.1}$$

The results are presented in Table D.1.

The most obvious result is that the coefficient associated with score percentile is the largest and most significant one, and it is positive, which is consistent with our previous results - students with higher scores are more likely to get into a school with better education quality and education quality is positively correlated with average distance from students' homes, so students with higher scores are assigned to schools farther from home. The results also show that students whose score percentile is below 50% from higher SES districts have the coefficient associated with the dummy variable PAR greater than the coefficient associated to PAR for students from lower SES districts. That is, it is predicted that students whose scores are above the 51th percentile in higher SES districts are assigned to schools farther to their homes under Chinese parallel mechanism than students from lower SES districts in all score ranges above the 50th percentile. Also, for students in higher SES districts, those with score percentile below 73.7% are assigned to schools farther from home

Table D.1: *Home-School Distance of Assigned School: Fully Saturated Model Analysis*

	Coefficients
<i>Percentile</i>	13.90*** (0.937)
<i>PAR</i>	0.505 (1.014)
<i>HSES</i>	-2.406** (0.808)
<i>PAR</i> × <i>Percentile</i>	-0.275 (1.425)
<i>Percentile</i> × <i>HSES</i>	1.856 (1.099)
<i>PAR</i> × <i>HSES</i>	0.587 (1.197)
<i>PAR</i> × <i>Percentile</i> × <i>HSES</i>	-1.207 (1.643)
<i>Constant</i>	-2.543*** (0.672)

* Significant at 10% ; ** Significant at 5% ; *** Significant at 1%

under Chinese parallel mechanism than under BM. However, students in lower SES districts are predicted to be assigned to schools farther from home under Chinese parallel mechanism than under BM.

Since we have shown that there is a positive correlation between the high school education quality and average distance from students' homes, it is worthwhile to analyze whether the benefit of being assigned to schools farther from home is higher than the cost of being assigned to schools further from home. To do this, we need to first present a model to estimate students' value of education quality. We use home-school distance as the unit of measurement, that is, we interpret students' value of education as how farther she is willing to travel to get into a school with a certain increase in education quality.

APPENDIX E

EDUCATION-QUALITY AND STUDENT-STRATEGY

RELATED TABLES

Table E.1: *The Education Quality and Average Home-School distance of Main Public Ordinary High Schools*

	Education Quality	Average Home-School Distance
183	0.965	13.72
141	0.921	10.98
167	0.839	11.76
187	0.866	9.19
185	0.786	7.95
186	0.787	7.44
179	0.748	8.57
188	0.771	8.86
184	0.636	13.96
147	0.661	7.64
181	0.630	6.88
142	0.630	7.08
17	0.650	9.00

Table E.2: *Summary Statistics on High School Education Quality (Measured by Mean Percentile of Entrance Exams)*

	Mean	Std	Max	Min
2007	0.766	0.123	0.961	0.586
2008	0.764	0.126	0.968	0.601
2009	0.789	0.118	0.969	0.632
2010	0.777	0.126	0.968	0.596
2011	0.788	0.124	0.963	0.606
2012	0.807	0.121	0.966	0.632
2013	0.828	0.114	0.973	0.638
2014	0.828	0.095	0.967	0.670

Table E.3: *Number of Students got into their first, second and third choice in 2007 and 2008*

2007	R1	R2	R3	None
District 1	1328	372	59	38
District 2	598	261	27	29
District 3	634	271	24	21
District 4	1616	551	107	51
2008	R1	R2	R3	None
District 1	566	757	167	117
District 2	206	358	97	69
District 3	196	363	158	40
District 4	667	890	333	244

APPENDIX F

PROCESS OF EARLY ADMISSION

The early admission students are officially called the "quota students" (Chinese pin yin: zhi biao sheng, which in the following part, we use "zbs" for short). Students who become zbs students will receive a large priority - it can be viewed as an early admission before the students' submit their ROLs. The students who are selected as zbs students all have good academic performance throughout the three years. The purpose of the zbs student policy is to prevent good students from being hurt by having a bad day on the exam day. Also, because the education quality of middle schools differ a lot across districts, and zbs policy will guarantee some of the good students from the poorest district can also get into good high schools.

The admission process of these students is as follows: First, at the beginning of each academic year (usually September), the education bureau of the city assign a certain proportion of the quota of 8 schools which has the best reputation for education quality as zbs students, and then allocate the quota of zbs of each high school to middle schools in different districts. Note that the number of zbs quota each middle school can get is different, i.e. middle school A may get 20 zbs quota of high school 1 and 10 zbs quota of high school 2 while middle school B may get 30 zbs quota of high school 1 and 5 zbs quota of high school 2. Which middle school gets how many zbs student for which high school is unknown, but it is usually through negotiation between middle schools and high schools and also by negotiation between the education bureau of the city and the education bureau of the district. Second, when the allocation of zbs is done, each middle school determines which students can be zbs of which high school and after the final decisions are made, the decisions will be publicly announced. The zbs in each middle school are students with good performance throughout the three years. Third, when submitting ROLs, the zbs must rank the high school of which he/she is zbs as the first choice. In the first round of the admission algorithm, the zbs will be added a certain number of points when being considered by their first choice. However,

if he/she is rejected by the first choice, the zbs will not have the points added when being considered by the second and third choice. Other than that, the admission process is running as introduced in the previous section. Relative to the full credits of the entrance exam and the intensity of competition, the number of scores added to the zbs students' scores is really large and as a result, almost all the zbs students got into their first choices.

The following questions are not within the scope of our study: (1) Whether zbs policy is a good policy and whether it has achieved its goal or not. (2) How a student makes decisions of whether choosing to be a zbs student or not, and choosing to be a zbs student of which high school. Because who finally are selected as zbs students of which school is publicly announced on the website and how many quota students are there in each high school is also public information, we treat the zbs students as a reduction of the quota of relevant high schools and focus our attention on none-zbs students.

APPENDIX G

SURVEY TO MIDDLE SCHOOL TEACHERS (2016)

1. From the perspective of education quality, please give marks to these schools (full point is 100 points)

List of the Public Ordinary High School Names Are Provided Here

2. From the perspective of education quality, please give marks to these special classes (full point is 100 points)

List of the Special Programs Are Provided Here

3. What fractions of the middle school graduate students' preferences over the schools can your answer to the above two questions represent? (Ignore students' test scores)

4. To what degree do you agree with the following statement: Students' preferences over the public ordinary high schools did not change in the past 10 years

- A. Strongly agree
- B. Agree
- C. Neutral
- D. Disagree
- E. Strongly disagree

5. To what degree do you agree with the following statement: The higher the cutoff line of a school (or special class) is, the better education quality it has

- A. Strongly agree
- B. Agree
- C. Neutral
- D. Disagree
- E. Strongly disagree

6. If a students' ability is enough to be admitted by the school with best education quality, but he/she chooses not to go, but goes to another public ordinary high school in the urban area of the city, what could be the reason?