Philipps Universität Marburg

– BACHELOR THESIS –

To obtain the academic degree Bachelor of Science in Economics
at the School of Business and Economics of the Philipps University of Marburg

Title of the bachelor thesis:

A comparison of the matching market for college admissions in the USA and China

Research Group Institutional Economics

Supervisor: Prof. Dr. Elisabeth Schulte

Second reviewer: Patrick Hoffmann, MM.Sc.

Student: Jonathan Hauff Ortega

Address:

E-Mail:

Submission date: January 8th, 2021

万般皆下品, 唯有读书高

“All pursuits are of low value, only studying the books is of high value.”

Chinese proverb (Yu and Suen 2005)

A comparison of the matching market for college admissions in the USA and China

By Jonathan Hauff Ortega

TABLE OF CONTENTS

1. Introduction

"*The matching of students to universities has profound implications for the education and labor market outcomes* […]" (Chen and Kesten 2017, 101). Since "*admission mechanisms* […] *matter for* […] *long-term economic growth,* […] *better matching can improve the allocation efficiency of human resources*" (Wu and Zhong 2014, 198).

The aim of this thesis is to conduct a deep analysis of the matching market for college admissions in the United States of America and the People's Republic of China (hereinafter: USA and China). I refer to college as the bachelor degree defined in the Bologna process, also called the undergraduate level at a higher education institution. A matching market is a market in which both sides, students and universities, need to agree in order for a transaction to take place. The agreement in this type of market goes beyond prices, and deals majorly with the preferences each player has for the players in the other side of the market. A transaction is a student's enrollment in a higher education program. A matching procedure is defined as the "*institutional arrangement"* needed so that a match between students and colleges can be accomplished (Roth 1982, 617). A match takes place when a student is offered admission to an institution.

The problem of college admissions is by nature a dichotomy, in which two situations are possible: admission or rejection. With that in mind, I have written this thesis with a particular interest to highlight two major dichotomies. The first one, is the entirely opposite college admission systems that run in both countries, China and the USA. The second one, is the situation both sides of the market face, students and universities, during the admission-rejection procedure. In particular, this dichotomy refers to the players themselves, since the problems both sides of the market in a conglomerate face are sometimes very similar (e.g. signaling and searching costs, or under- and overmatching). This thesis is written to take advantage of these dichotomies to conduct a one-to-one analysis of the aspects, characteristics, and problems this particular market faces.

I have identified that the problem of college admissions is divided into three major events. What happens before the matching of students with colleges, which is the application procedure and the activities that both sides of the market engage in to attract each other in the future. What happens while the applications and rejections are running, that is the matching mechanisms that pair both sides of the market. Lastly, the result those matching mechanisms create after the matching has taken place, which is the market outcome and errors in the admission-rejection process.

In this thesis, I begin by introducing the institutional framework that shapes the market for college admissions in the USA and China. Then, I present the three mechanisms of market design that together form a family of application-rejection mechanisms (Immediate Acceptance, Deferred Acceptance, and Parallel Acceptance). I explain how these mechanisms shape the college admission process in both countries, and I present how the theoretical models sometimes differ from what happens in reality in both countries. In the last part, I dive into further approaches that explain other aspects of the matching market for college admissions, such as signals in the application process and errors in the selection process. This thesis culminates with a closing discussion, where I summarize the analysis presented and connect the major findings.

2. Institutional framework: College admission systems in China and the USA

The Chinese and the US-American college application and admission procedure are very different to each other. Perhaps, one could say they are opposite systems, or even a dichotomy that reflects their very different economic and political systems. The US-American system for college admissions runs completely decentralized, showcasing how college admissions typically work in western countries. It also displays how in the USA many crucial decisions, such as the future of the labor force, are left to the market to solve. On the other side of the world there is China, with a one-of-a-kind admissions system that runs entirely centralized in its organization. Just as in college admissions, in China many labor and education decisions are part of the political agenda and carefully planned to achieve particular results.

2.1. Chinese College Admissions (CCA)

Since the 7th century, the Chinese government has promoted education as one of the most important institutions in life (Yu and Suen 2005, 8). Today, the country is known for its "Education fever", which refers to the nationwide obsession of parents to give their children access to the best schools and resources they can afford (Yu and Suen 2005). For many families this is the only way that their children can get a chance to access a better standard of life. In Chinese culture, entering university represents for millions of high school seniors a "one-way-ticket" out of poverty and a chance for social mobility, especially for those living in the countryside.

Applying to college in China is one of the most competitive things a Chinese student gets to do in their entire life. In 2009, around 10 million high school seniors competed for the

6 million spots in more than 2300 higher education institutions. This means an admissions rate of about 60%, but only 3% for the 70 top universities (Wu and Zhong 2014, 198). Today, the number of applicants has just continued increasing. Notwithstanding, high competitiveness for higher education is nothing new in China.

In 1905, after almost 1.300 years of existing, the Keju examination ended. The Keju, also referred to as the Imperial Examination, used to be a highly competitive centralized set of examinations that ran through various rounds and chose the best students that would initially serve as scholars. These selected students would become officials, holding high government positions later in their careers. Back then, a high score in the Keju examination could also ensure wealth for the whole family (Yu and Suen 2005, 19). The Imperial Examination and even the system that runs Chinese College Admissions today have been working under the same principle, "*that officials must be selected on the basis of ability and intellectual achievement rather than birth*" (Feng 1999, 40). This is one of the reasons that the Chinese culture is impregnated with an obsession on education, because this is the opportunity for any children to compete with the kids of any official for a place in higher education based completely on merit and hard study.

From 1905 and until 1952, with the fall of the Imperial examination, CCA were running decentralized and, just like in the United States today, students could get multiple admission letters from many colleges. The enrollment-to-admissions ratio back then was low and many students were left unmatched, because they were rejected from the universities they applied to and missed applications deadlines for other institutions (Chen and Kesten 2017, 100). Later on, there still were many students left unmatched after the score submission round, but it happened mainly because they failed to rank their preferences in the right order.

In 1952, the Ministry of Education introduced a new version of a centralized matching examination. This mechanism was called the National College Entrance Examination (NCEE), which is referred to as *Gaokao* (高考) in China. Today it is the biggest running centralized admissions system and for sure one of the most massive matching mechanisms in the world (Chen and Kesten 2017). In China the *Gaokao* is not only a requirement to enter college, it is a system that shapes people's futures, in which many families adapt their life decisions (like where to live and what to spend), in order to give their children the best chances at this highly competitive exam. It is a zero-sum game: one point more in one student's score may get many other students out of college".

In China, college admissions is considered as "a battle that determines one's fate: one point [difference] in the exam can determine whether you go to heaven [i.e., universities] or hell [i.e., becoming a farmer]"(Yang, 2006). (Chen and Kesten 2019, 99).

In China, the *Gaokao* score exclusively determines who gets into which college and who stays out of receiving a higher education. The *Gaokao* consists of two to three days of standardized tests covering all high school subjects. It takes place once a year in June, followed up by submitting the scores to the Ministry of Education at the local province to compete for the spots at universities. The score is valid only for the current year, meaning that students who failed to get into college can only retake the examination one year later. Colleges are officially ranked into tiers of decreasing prestige, meaning that tier 1 is for the institutions of highest prestige, to which major international universities in Shanghai and Beijing belong. Tier 2 is for the best local universities and starting in tier 3 the prestige of the universities decreases and so does the competitiveness for spots among students too. In China, attending a higher tier institution is involved with a lot of prestige and is usually more important to society than the subject one is studying. This has again to do with the country's obsession with education.

Although every province is in charge of managing its own college applications, 28 of the 31 provinces have followed a major trend and shifted their systems to similar versions of the so called Parallel Acceptance (PA) algorithm. The algorithm matches students to institutions taking into account the score a student gets at *Gaokao*, the student preference list and the preferences of the universities over the *Gaokao* scores, where a higher score is preferred. The application process has three steps: the central examinations, the preference submission and the final matching of students with universities (Wu and Zhong 2014, p. 198). The last step consists of admissions, rejections and enrollment. High school seniors get to apply to the universities they would like to assist by listing them in decreasing order of preference in the system. Depending on the province, the submission of the preference list will be before or after taking the exam and before or after knowing the results. These small variations have an enormous impact on how prospective students strategize their preferences to get a seat in the highest ranked university they can (Wu and Zhong 2014).

2.2. US-American College Admissions (USACA)

College applications in the United States are a completely different story. There is not only one entrance exam nor one common system as in China, so that different application procedures are available depending on the state or if high school seniors are choosing between private and

public universities. In contrast to China, in the United States college admissions have always been completely decentralized, meaning not only that every prospective student is responsible to individually apply to their preferred universities, but also that every university has its own criteria for assessing the applicants. This means that prospective students need to inform themselves about the requirements each university and even each program has. Universities take all their admission decisions independently from each other. Some of them would even consider to have empty places before allowing a not preferred student into their programs.

Since the quality of high schools can vary a lot around the country, depending on the state and on private or public funding, official Grade Point Averages (GPA's) or other public scores are not very informative at all. Therefore, instead of a public examination, in the USA there are many private initiatives to ensure better certification of the knowledge and aptitudes of the prospective students. These market solutions have arisen in the USA from the need of both parties to conduct better screening and signaling procedures and avoid a bad match for both, students and institutions. One of these initiatives is a central examination referred to as SAT (originally: Scholastic Aptitude Test), which was founded in 1926 by College Board, a private but non-profit organization (NGO). The SAT tests students' aptitudes in many high school subjects and can be retaken many times during the year a student is applying. High SAT scores are highly correlated with better chances of getting into college, but still participants with perfect SAT score have under 50% of chance of getting into top ranked colleges, like the Ivy League schools (Chade et al. 2014, 972). To get better chances of getting into top ranked institutions, students not only need to be good at school, but also show extracurricular engagement and participation in social or beneficial activities. Since the USACA is a big market, there are not only plenty of preparation courses and application advisors, but also other private central examinations. The second most popular started in 1959 and it is called the American College Testing (ACT), which has become a major alternative to the SAT.

Another very important initiative in the USACA market is the Common Application, popularly referred to as the Common App. It was founded as an NGO in 1975, initially only for elite colleges to make it easier to select students and increase applications. The Common App is not a clearinghouse, but a platform to lower transaction costs for both parties. Today it has become the major application platform in the USA, with more than 800 institutions participating in the country (Ehrenberg and Liu 2009). All these private initiatives and even every college application itself involve many monetary fees, meaning that prospective students not only need to strategize their choices, but are also limited by budget constraints.

In the United States, students take both centralized exams like the Scholastic Aptitude Test (SAT), and also complete college-specific requirements such as college admission essays. Students can apply to more than one college, but since the application process is costly, students typically send only a few applications (the majority being between two to six applications […]). (Hafalir et al. 2018, 2-3)

In China, a high school senior needs to prepare for long and tedious hours to write the best Gaokao they can. Afterwards, they submit a preference list, with the hopes of getting the best one spot from one of the listed choices. This hard preparation goes for more than a year, similarly to the United States, where high school seniors start at the end of 11th grade with the application procedure, since many universities run early admissions in November/December of a student's last year. Instead of only preparing for one centralized exam, in the USA the prospective students are required to take either the SAT or the ACT exam, write essays, submit recommendation letters, compose a CV, sometimes take an interview with the recruitment team or a former student, and some institutions even have other special requirements. Thanks to initiatives like the Common App, it is today possible to apply to many colleges at once, but still, one could say the matching in the USA is a hard task to do. With the difference that prospective students may get more than one admission and are chosen by signaling many characteristics and not only the score of one exam.

3. Rejection-admission mechanisms: IA, DA & PA

3.1. Introduction to the algorithms in market design

In the last section, I presented the institutional framework of the college admissions in the USA and China. In this section, I will dive into the technical aspects of the matching market for college admissions in both countries. In this context, three types of matching mechanisms are relevant: Immediate Acceptance (IA), Deferred Acceptance (DA), and Parallel Acceptance (PA). The three of them belong to the same family of application-rejection mechanisms, but what distinguishes them from each other is the order in which they go through the listed preferences and the timing when applicants are rejected.

In the highly competitive market for college admissions, as it is in matching markets, prices do not play a major role in allocating the seats at college to its applicants. Instead, both parties need to agree to transact with each other, meaning that no one can force anyone to go to a university or to admit a senior they do not want to. Since prices do not play a major role here, other methods need to be applied to achieve the best matching outcome. Some of these methods

include what we have seen in the last section, like both sides of the market screening and signaling each other.

What plays a role in matching markets are costs. In the college application market, costs can be monetary or non-monetary. In the latter, costs represent, for example, work, time, and opportunities. In China, the only additional cost implied when applying to an additional college, is the opportunity cost of not being able to list another institution in the preference list with finite choices. However, besides the opportunity costs, the marginal cost of an additional application is zero, since it is just about listing a particular university instead of another one. The incomplete information Chinese students face is not knowing how high the *Gaokao* score of the other applicants might be, where a one-point difference may push them out of admission.

In the United States students are able to apply to as many colleges there are in the country. However, they face the additional cost of every application involving a fee of up to $90 USD and on average $44 USD (Kowarski 2019), plus the additional institutions' specific paperwork and the uncertainty of not knowing what admissions offices value and how they value it (school grades, SAT/ACT scores, essays, extracurricular activities, among others). Therefore, every additional application highly decreases its marginal value and it may even reach the point where the marginal value of an additional application is negative: this can be seen in the form of losing time and effort for the other applications (Chade et al. 2014, 972-973). Costs are different in both countries, but before diving into the mechanisms, I will present in the following subsections an overview of some basic concepts that apply to the three application-rejection mechanisms.

3.1.1. Not everyone can go to college

The competition for college seats, regardless of the country and time, is a market with scarce resources. This means that more people are competing for a spot in college than college spots are available. From the other perspective, universities compete against each other for the best students. Good students are also scarce resources, and universities need to signal to potential applicants why they are a good choice for them too. Under this view, for society, an admissions offer carries the opportunity cost that someone else has been rejected: "[…] *in a system without excess capacity the cost of giving some students multiple offers is that multiple students get no offers.*" (Abdulkadiroğlu et al. 2005, 366). In the USA prospective students can get as many offers (admission letters) as universities they applied to, but in China they can get as much as one admission, regardless of the amount of colleges a senior listed in the preference list.

3.1.2. Colleges and students are agents with preferences

College admissions is a two-sided market. This refers to the condition that agents cannot switch their side of the market. Students apply to colleges, but if a student is not satisfied with her market position, she can only leave the market, but cannot switch to the side of a university. The same condition applies to universities. In contrast, a one-sided market is when agents can switch market positions effortless, for example, when an agent can be seller and buyer just depending on which side of the transaction she is engaging (Roth and Sotomayor 1990, 1-2). In the two-sided college admissions market, where positions cannot be switched, colleges and students are agents and this is important. It means that both sides of the market have preferences over each other. In some countries, like in Turkey, we find the opposite to this, that college are not agents but indivisible public goods to be allocated among students (Balinski and Sönmez 1999). We also find two-sided markets with just one side being an agent in other college related situations, like when matching students with dormitories, where students choose their preferred place to live, but the dormitories themselves have no preference over the students (Roth 1982).

In China and the USA students can classify in order of preference the colleges they would like to attend, and colleges can classify the students they would like to admit too. In China those preferences constitute only to the *Gaokao* score and in the USA it constitutes to the many factors previously explained, like motivation letters and SAT scores, but in both countries universities are sure (or at least they think they are) about what type of students they want to have in which programs. Both sides can play strategically and every outcome will lead to a different welfare, both for the individuals and for society (Chen and Sönmez 2006). The purpose of a matching algorithm would be, under the assumption that agents have preferences, to achieve the highest welfare among all possible outcomes. An algorithm that minimizes the incentive to misrepresent individual preferences achieves a high welfare as long as the matches it produces are stable (Roth 1982).

3.1.3. Stability is key

In market design, there are plenty of possible mechanisms that can match two disjoint sets to each other. Disjoint refers to sets that do not share common elements. In this context, colleges and high school seniors. For example, an algorithm can randomly pair colleges and students, like in a lottery. A second option, is to give away seats in college as a „first come first served“, so anyone can enroll as long as there are free spots available. Alternatively, just auction the study places to the highest bidder. Nevertheless, all of these examples lack one very important aspect of a good matching algorithm: they do not produce a stable outcome.

A stable match refers to a match that cannot be blocked by any other pair in the market. In our context, this means that a student prefers her actual match to any other university that prefers her too; the university prefers that student to any other student that is not match to her (Gale and Shapley 1962, 10). The contrary of a stable pair is a blocking pair, i.e., two agents are not matched to each other but would prefer to be. A stable outcome is any outcome with no blocking pairs. When just one side of the market are agents, e.g. college admissions in Turkey, stability is referred to as the elimination of justified-envy (Chen and Sönmez 2006). The reason stability in the matches is so important is because without it, the blocking pairs would simply seek to transact outside of the market and this would cause the existing matching procedure in the market to fail (Roth 2015, 141-143).

3.1.4. Students apply to colleges

Seniors propose to colleges and colleges take the final admission decision. Since we are used to this situation, it seems like it is the only one possible. In fact, the opposite is possible too. Colleges propose to seniors and the seniors take the final decision. However, besides for students with very high performance, the second situation is never the case. The reason for that, is that, in practice it would take high search costs for the over 2.000 colleges in each of the two countries to apply for the millions of students willing to enter every year. "*On the philosophy that the colleges exist for the students rather than the other way around, […] students should receive consideration over colleges.*" (Gale and Shapley 1962, 10). A market design point of view confirms this: a world where students propose is optimal for the students. Optimality refers to a situation with Pareto efficiency, meaning that every applicant is as well off under this assignment as they would be under any other stable assignment (Gale and Shapley 1962, Theorem 2, 14). This condition gets a lot of relevance in the DA mechanism.

3.1.5. Best and worst matches

A big problem in matching markets is that agents do not reveal their true preferences, but have incentives to behave strategically. This causes instability, because if not everyone reveals their true preferences, then no market mechanism can match agents to its real preferable choices. In a scenario where agents reveal their true preferences Chinese students can get at the best one match, while US-American students can get at the best as many matches as universities they applied.

The best match a Chinese student can get is being admitted to her highest ranked college, and therefore automatically denied from all her other choices (Chen and Kesten 2017, 107-

108). A second-best match for the same student is being admitted to her second listed college and denied from her first choice and all choices below. This procedure is the same at every level, so that for a Chinese senior the worst match is to not be admitted to any college at all. Consequentially the second-worst match is to be admitted to the last listed choice and denied from any college above. In the USA seniors apply directly to any desired university and the universities admit students independently from each other. The best and worst matches for a US-American senior would be similar to what I described above for a Chinese senior, with the difference that prospective students in the USA do not submit preference lists and an admission at any college does not influence the chances of being admitted or denied from another college.

On the other side of the market there are universities that can get also good and bad matches. Since probably all of them prefer the "good students", the bad case for them is being match only to "bad students", because the "good" ones did not even consider applying or preferred to enroll somewhere else after being admitted. This situation is more likely to happen in the USA, where many other aspects, other than the ranking play a role in a student's decision to apply, e.g. funding, state and distance from home. In China, the cultural education fever plays a major role, meaning that good students would rarely not apply to the good colleges. Here is a positive assortative matching more likely to happen, meaning a situation where matches have higher chances to occur with alike agents (Becker 1973, 825). In our context this refers to the situation where good students are mostly matched with good universities and the matching occurs with both parties being similarly ranked. The contrary to this situation is random matching, which here does not refer to random matches, but random characteristics of both agents. I present more of assortative matching in section 4.1.

3.1.6. Clearinghouses

To make market transactions easier to occur, markets can take advantage of clearinghouses. Instead of everyone proposing and rejecting individually, as we know from the marriage market, a market can let a third party manage this interactions, with the final decision always taken by the agents. Clearinghouses can take the form of independent institutions to lower transaction costs. They facilitate transactions between agents, meaning the admissions, and accelerate the exchange of information, meaning the submission of applications and communication of rejections.

In China, the allocation of study places goes through a centralized clearinghouse run by the Ministry of Education of each province. The universities get to choose the criteria of admission, like a high *Gaokao* score, but the matching itself occurs inside the provincial

Ministry of Education. This should not be confused with the Ministry of Education deciding who gets into which institution. The clearinghouses in the provinces use different types of mechanisms, which can change the chances of getting into college depending on the province of residence (Chen and Kesten 2017).

The opposite is the decentralized matching procedure in the United States. Here there does not exist a clearinghouse, but private platforms. The Common App is one of these platforms that lower transaction costs, but do not get involved in the matching mechanism. Many colleges do not take part in the Common App or other platforms, so for them seniors need to apply individually. From the side of the university engaging in such a platform increases the competition with other universities, but it also increases the volume of applications, which results in a higher enrollment, and may have other benefits like an increase in the diversity of the prospective students applying and prevent positive assortative matching (Ehrenberg and Liu 2009).

3.2. Immediate Acceptance mechanism (IA)

The sequential mechanism (IA) is an application-rejection mechanism that assigns college seats based on the time of application and prioritizes students who ranked the university first (Chen and Sönmez 2006, 203-204). It is also known as the Boston mechanism, since it was first identified as the standard algorithm that allocated high school seats in the city of Boston. The algorithm operates on a "first ranked, first judged" principle.

The way the sequential mechanism works is the following. Every student submits her preference list and the clearinghouse (or the institution itself) starts by only looking at the first ranked institution of every student. If the institution would like to have one of the students that ranked it first then she becomes immediate admission, if the institution does not want to have her, she receives immediate rejection. When all admissions and rejections of the first ranked institutions of every applicant have concluded, then the algorithm goes to the second level and now it repeats the procedure with the second ranked institutions, but only with those institutions that still have empty spots. The procedure is repeated at every level with the next ranked institution until every student has been matched or rejected to an institution in her preference list. The mechanism only considers the highest ranked institution before jumping to the next one listed (Chen and Kesten 2017, 106). At this point, this mechanism may seem very intuitive because it is widely used among many types of matching markets that we face every day, but has many flaws, which is the reason it has been majorly substituted with DA and PA.

3.2.1. Manipulation incentives and blocking pairs under IA

One of the general problems of the IA mechanism is that a student choosing a good strategy when ranking her preferences may have better chances of being matched to any of her choices, than a student that scores high but fails to rank the college preferences in a favorable order. The Boston mechanism used to be the standard in China until 2001. Back then, a student with a high score in the *Gaokao* who would fail to be matched to her first choice could then fail to be matched to any of her choices. The reason for that is, that at the time the mechanism would consider the students second or third choice, the institution would already have filled up all of her available seats (Chen and Kesten 2017, 101). Under IA many seniors with high scores in the central examination in China would stay unmatched and would have to repeat once again the senior year of high school (Chen and Kesten 2017, 101). In college admissions using the sequential mechanism, a high school senior can be better off when not stating her true preferences, meaning by „gaming the system". This means that she rises her chances of being admitted when taking strategic decisions based on what she believes may get her the best outcome. IA gives high incentives to be manipulated (Roth 2015, 10-11).

The manipulation can take the form of strategizing the preference lists, which leads to a high amount of blocking pairs, or other forms like individuals trying to transact outside of the defined market. The Boston mechanism is not Pareto efficient and does not produce the highest social welfare, since not every student and university are matched to her highest possible preference. If individuals state their true preferences under IA, then the amount of blocking pairs reduces dramatically and the outcome becomes Pareto efficient (Chen and Sönmez 2006, 206-208). Since it is a dominant strategy for the students listing their choices to misrepresent their preferences, the Boston mechanism is not as suitable for the optimal, meaning stable (envy-free), allocation of college seats as the two other algorithms, DA and PA (Chen and Sönmez 2006, 208).

3.3. Deferred Acceptance mechanism (DA)

It is impossible to talk about Market Design without talking about the famous Gale-Shapley Deferred Acceptance (DA) mechanism. This algorithm has been majorly adopted as an efficient alternative to the Boston mechanism, because it does not make the misrepresentation of preferences a dominant strategy. Instead, under DA it is safe for the individuals to state their true preferences. The algorithm was first presented by David Gale and Lloyd Shapley in an article called "College Admissions and the Stability of Marriage" published in the *The*

American Mathematical Monthly in 1962. The authors noticed that under the Boston mechanism applicants could hurt their chances of getting into college if the institution would notice that they did not list them first.

The way the DA mechanism works is the following. In a first step, every senior applies to her highest ranked institution. The institution or the clearinghouse reviews all applications and rejects all participants that it would not like to admit. In this first step, the institution does not admit the applicants that it likes from the first pool of applicants but it does not reject them either. Instead, the ones it likes are kept waiting. In theory, at every level, an institution would only hold back as much applicants as it has places for them, so no more than its class quota. The already rejected applicants then apply to their second choice. Every institution reviews the new applicants and compares them to their waiting pool of applicants from last step, and then it rejects the least preferred ones of the first and second pool of applicants, again until filling its quota. This step is repeated at every level until all applicants have applied to all of their choices. In theory, the algorithm ends when every individual is matched to an institution (Gale and Shapley 1962, 13). Since in reality some applicants stay without any admission, the algorithm has been expanded by matching individuals to themselves, meaning they could not get a spot at any university they considered, thus leaving empty spots in a college, that is, those institutions preferred to not fill their seats before admitted a not preferred applicant (Roth and Sotomayor 1990, 125-128).

The Deferred Acceptance mechanism is Pareto efficient, meaning every applicant is as well off with this algorithm as they would be with every other algorithm that produces a stable outcome, meaning an outcome without blocking pairs, which is not the case for IA (Balinski and Sönmez 1999, 75-76). We know that DA produces only (and in practice mostly) stable pairs, because if any senior would like to be admitted to a college to which she is not matched and that college would like to have that particular senior too, then that student would have been admitted previously. Under the student-proposing DA, whenever a student is not matched to a higher preferred university it means that this university was not willing to accept her either. There is no better strategy for the student than to apply to their truly preferred institutions, this is also referred to as the „student optimal“ assignment (Gale and Shapley 1962, 14).

3.3.1 Early applications - The equivalent to DA in the USA?

In the original article about the Deferred Acceptance by Gale and Shapley (1962), the authors explain the mechanism by presenting two hypothetical situations: marriage proposals and college admissions. After them, plenty of authors have carried out research regarding both

challenges. Nevertheless, as far as I am aware today, there is something forgotten: college admissions, at least for the USA, has not been widely analyzed in a practical manner. Instead it has been used as a mathematical model to explain (and sometimes also to solve) real-world problems, like the school choices taken by parents in Boston and New York, and the matching mechanism pairing medical students to residency programs at hospitals around the United States (Roth 2015). These two examples share one thing: both of them run through a centralized clearinghouse in charge of pairing both sides of the market according to their preferences. But as we have seen before, in the USA college admissions run in reality decentralized and without students requiring to submit a preference list, meaning that preferable choices are unknown to anyone besides the students and the selection committees itself. Since a centralized matching procedure is part of the Chinese college admissions, it is possible to find many studies about the real pairing procedure in China, because the centralized clearinghouse give researchers the opportunity to observe a real massive functioning matching procedure. However, as in the USA there is no clearinghouse, the Common Application merely acts as a platform to lower transaction costs (Chade et al 2014, 974). Therefore, the question that arises is: What is the matching mechanism running in the US-American college admissions? The short answer is that there is none. Every institution decides how to admit their students, but there is a major trend that many institutions follow.

Such above-mentioned trend is the Early Admission (EA), which in practice divides into two types of early admission rounds called Early Action and Early Decision. For simplification both will be treated in this thesis as equal, but in practice they do produce different outcomes. Colleges in the USA usually allow applications until January 1st in a regular decision round and send out admission letters typically on April 1 (Ross and Moody 2020). Although some institutions have different deadlines, the majority of schools accept their students under this regular decision deadline, which in a conglomerate works as a „one-round“ sequential algorithm. Every student sends out applications and receives admissions or rejections, and this happens once per year. However, a major trend of early admissions started in the 1970's in the Ivy League schools and MIT to attract a highly selective set of applicants and lower the uncertainty of the entering class size (Avery and Levin 2010, 2127). Today, the majority of schools run some form of early admissions round, which usually takes place with the applications sent until November, while admission decisions come out from December to January. The general way EA works is by students applying by the early admission deadline, with most universities requiring them not to apply elsewhere during this period (restrictive EA). Therefore, this is a strong signal of interest for the potential college and is why many seniors

take this opportunity to leverage their chances of getting into their highest preferred school. If the institution would like to admit that particularly student then she is admitted early and both sides gain by reducing the uncertainty of their potential pairs. But if the university isn't completely sure, then the student gets deferred to the regular application pool to be compared against the applicants from Regular Decision, notifying them in April in the regular decision round (Reingold 2004, 19-20). Any student can be rejected or admitted at any of both rounds, with the possibility of the school deferring her to the second round. Although we cannot define the mechanism of every institution in the USA, in a conglomerate they work together similar to the Gale and Shapley deferred acceptance algorithm, with the particularity of only two admission rounds existing (a minority amount of schools may have an additional third and even fourth round, e.g. University of Chicago).

Contrary to China, there are some schools in the USA that also offer rolling admissions, which refers to schools that allow students to apply anytime and get immediate response until all of their places are filled (Ross and Moody 2020). This clearly constitutes to the IA mechanism, but this method is not representative in the country, so in broad perspective, college admissions in the United States run in a two-round version of the deferred acceptance mechanism.

3.4. Parallel Acceptance mechanism (PA)

The Parallel acceptance mechanism is a hybrid of the sequential and deferred mechanisms, proposed initially by the former director of undergraduate admissions at Tsinghua University, Zhenyi Wu (Chen and Kesten 2017, 101). The IA and DA mechanisms can be seen as the extremes of the family of application-rejection market algorithms and PA is in the middle of them. How similar PA can be to IA or to DA depends on one factor: the band size. When switching from the sequential algorithm to the deferred acceptance mechanism, the pairing of colleges and students becomes Pareto efficient and less manipulable. Therefore, today almost all provinces in China have left the Boston mechanism and shifted to the Parallel Acceptance (PA) mechanism. It is important to notice, that just as in the USA every college is in charge of their admissions and we look at the big picture to decide which algorithm predominates, in China every province is responsible for its own admissions procedure and we look at all of them together to analyze which trend is majorly followed.

In the former admissions system in China (under IA) a student with a high score could remain unmatched, because of a bad strategy when listing colleges. This was partially also caused because the mechanism used to review applications in the tiers decreasing order. Today

tiers still exist to classify the universities, but the PA gives the student the opportunity to list colleges in decreasing preference in parallel bands. The algorithm goes through each band in order, starting with band 1, where a student can choose a certain amount of colleges to list. Inside a band, choices are treated as they belong in the same level of preference, like in the deferred acceptance mechanism. However, each band is revised in the same order as the immediate acceptance mechanism does. Only after a student has been rejected of all her choices inside a band, the algorithm jumps to the next band of choices. The mechanism follows the same pattern until the student is matched to a university or the algorithm has gone through every college in every band of a student's parallel preferences (Chen and Kesten 2019, 84-85).

3.4.1. Band sizes

Moving from IA to DA causes the pairing to become stable, because revealing the true preferences suddenly becomes a dominant strategy. What happens then in the hybrid version (PA) used in CCA? Well, here students list their choices in bands of decreasing order, but in contrast to IA, inside a band students do not lose their score priority, so that the risk of choosing a poor strategy decreases as low as in DA, depending on the band size. However, between every band, students still need to strategize like in IA, since bands are taken into consideration one after the other. The parallel mechanism gives Chinese students the opportunity to play safe and risky strategies at the same time. Inside the same band, students can list their true preferences, but still list a couple of high ranked universities that would be otherwise too risky to list in the old matching mechanism (Chen et al. 2020). In a recent study on college admissions in the Sichuan province the shift to PA has shown a 5% increase of students listing the most prestigious colleges in their lists (Chen et al. 2020). This shows that students are willing to sacrifice one of their choices they would have listed under IA to get the chance of being admitted to a top program. For good ranked students this represents an opportunity, since they can compete with other students without playing it too risky as under IA, but for the otherwise average or under average students listing tier 1 colleges would be only like playing the lottery. Nevertheless, overall is a shift from IA to PA a Pareto improvement.

The difference between the three algorithms lies on the band size, meaning how many choices a prospective student can list for the algorithm to go through before decisions are made final (Chen et al 2020, 2). On one extreme, IA has a band size of one, which means that the algorithms goes through it in order, meaning choice per choice. This makes every assignment after each step final. DA on the other extreme has a band size from infinity, meaning the algorithm takes all preferences as being on the same level and only makes assignments final

after all have been considered. In the middle of both lies PA, in which the band size is between two and infinity, and then the algorithm follows the same logic as previously stated (Chen and Kesten 2017, 103-104). The difference from PA to DA is that the algorithm runs through multiple bundles of preferences[1], instead of taking all of them as equal. Without the PA mechanism is the discussion about band sizes not essential.

3.4.2. Timing of application

At this point, two things are clear: every province in China is in charge of managing its own college admissions and every application carries a list of preferences in decreasing order, mostly listed in bands after the Parallel Acceptance mechanism. The questions then are, when are preferences submitted and when should they be submitted for optimal results?

In the United States seniors apply to universities as early as in November of their last year in high school, and as late as April. From the perspective of the university, this broad period can be very risky, because a student has not even completed the last year of high school and cannot signal with certainty how the performance is going to be at the end. Universities could of course wait until the end of the academic year to allow applications, but with schools ending in July and colleges starting in Mid-August in the USA, there would not be enough time for a proper admissions procedure. Besides that, a single university changing the timing of admissions would only lose applications against those institutions that did recruit early. This is what Alvin Roth (2015) calls a market that acts too soon, meaning before being able to screen the full potential of her candidates. In Germany, for example, universities allow applications only after seniors have graduated and are able to submit their final grades. This reduces the errors of admitting a not preferred student, because the admissions office overestimated her potential scores or performance. A combination of these two extremes, meaning the timing of application submission, is what seniors in China experience depending on their province of residence.

According to Binzhen Wu and Xiaohan Zhong (2014), in China high school seniors submit their scores to the Ministry of Education in three possible situations, depending on their province of residence. The first situation is called “pre-exam”, which refers to the seniors submitting their preference lists before even taking the *Gaokao* examination. The second one is “post-exam but pre-score”, here seniors have already taken their central exams, but submit their preference lists before knowing the results. This is similar to the seniors in the USA, who

[1] See the Appendix A for a visual representation of band sizes and the three algorithms.

do not know their final results, but are still active in determining them. The third one is "post-score" and refers to the seniors submitting their preferences after taking the exam and after knowing the results, just like in Germany.

In the "pre-exam" situation, students know their preferences and their self-expected score, which is highly influenced by a student's ability to do a critical self-valuation (Wu and Zhong 2014, 199). In this situation the uncertainty for both sides of the market, colleges and students, is high. The preferences of a student under "pre-exam" will not only depend on where she wants to go to college, but where she thinks that she can go to college. In the other two "post-exam" situations, students can better adapt their preferences to its true abilities (*Gaokao* Score), but do not know what the scores of the other students are (Wu and Zhong 2014, 199). Here again, agents in CCA deal with a market with incomplete information.

Under the PA mechanism, students that submit their preferences before taking the *Gaokao*, primarily choose their universities based on their school grades, which are better to signal aptitudes during high school than a three-day exam. The Parallel Acceptance mechanism is *ex-ante unfair and* [Pareto] *inefficient, although it is strategy-proof and ex-post fair and* [Pareto] *efficient* (Wu and Zhong 2014, 210). Fairness means here that students with high scores are matched to high ranked institutions (Wu and Zhong 2014). Taking into account the already defined optimality, meaning that matchings are stable, the desirable situation among the three is the "post-score". Here students can list preferences based on real results and not on speculation, but with the trade off, that some form of strategizing takes places, comparing on the situation where students do not know their scores and submit their preferences based on where they truly want to go. In all cases, PA gives students the possibility to back up their chances with an insurance-strategy, meaning listing safe and risky options, in comparison to the IA, where students lose their chances by poorly strategizing their choices and assessing their abilities.

4. Further approaches in the matching market for college admissions

"*Communication, like decision making, is always imperfect. No individual ever fully communicates perfectly what he knows to another.*" (Sah and Stiglitz 1986, 717).

In this section, I present situations in which both sides of the market, students and colleges, do not have complete information about each other or fail to communicate their own characteristics to the other side of the market. I present two further approaches: assortative matching and error types. These approaches highlight another perspective in market design, which complements what the three mechanisms themselves do in the college admissions market. In this section, the

focus is on what happens after students have applied and which outcome create the institutional framework and the mechanisms presented before.

4.1. Assortative Matching

Gary Becker was the first to introduce the concept of Assortative Matching in his paper series "A Theory of Marriage" (1973, 1974). In this series, he analyzes the marriage market and explains how economic theory applies in a married couple. When talking about the market for college admissions, the discussion about the marriage market is somehow very important too. The reason for this is that both markets share similar characteristics. Students apply to colleges; individuals propose marriage to other individuals. The difference between both markets relies on the capacity of the agents to accept proposals. While the pairing in the marriage market is one-to-one, in the college admissions market it is many-to-one. Multiple students need to be matched to one university. Every university has a different capacity (the size of the admitted class), in contrast to the marriage market, where the capacity is equal to one. The reason I am making this brief comparison between marriage proposals and college applications, is that in this section I will take the principles of assortative matching in the marriage market and apply them to the thematic of college admissions. Just as I did in the last section when transferring the stability of marriage to the stability of college admissions (Gale and Shapley 1962).

Positive assortative matching is the pairing of agents with similar characteristics. Negative assortative matching, on the other hand, is the mating of agents with dissimilar characteristics. Random assortative matching lies between positive and negative assortative matching, and refers to the situation, where the characteristics of the paired agents do not correlate with each other, and therefore, can be described as random. In the context of signaling characteristics, a situation where nobody is signaling causes a random matching outcome (Hoppe et al 2009, 268). This is not so much the case in college admissions, where both sides are trying to signalize they are the best agents in the market. In this section, I am going only to refer to the first two situations: positive and negative assortative matching.

In theory, colleges and students choose each other only if the match maximizes each agent's payoff (Becker 1973, 825), taking into account only the possible pairs that the exogenous given matching algorithm produces. This means that a university only admits students if it is convinced that a particular student (or a bundle of students) is going to maximize its own benefit. A university's utility may come from having an excellent class, preparing the leaders of the future, acquiring early the best researchers, having a diverse class, recruiting individuals with the potential to make high donations in the future, or whatever other reason a

university has for admitting students. From the side of a student, she chooses the best university (among all universities that admitted her) based on which one is going to give her the highest return. Once again, this payoff can take many forms, such as where the student maximizes her network, where she gets the best paid job later, which university has the best sport facilities, proximity to hometown, and even where are friends going to study. A study by Cortes and Lincove (2019) confirms that these among other factors influence in the United States a student's decision to attend a particular university besides its place in a ranking. These examples seem to be more the case in the United States than in China, where as I presented before, a Chinese student maximizes her utility by attending the best-ranked university, with other factors being of lower priority.

From what I presented in section 3 about matching mechanisms, one could conclude that it is desirable for a matching algorithm to pair the best students with the best universities, if the criteria to admit students is based on the student's quality. This case is true for China, where an academic mismatch is seen as a mistake in the algorithm. An academic mismatch is when the percentile of the score of a student highly differs from the percentile to which the college is ranked (Dillon and Smith 2017, 46). This is the case when a high score student ends up in a low-ranked university (More of mismatching and errors in the selection process is the topic of Section 4.2.). Nevertheless, in the United States a difference in the students score (e.g. SAT) with a university's place in the ranking cannot be directly attributed to a certain type of assortative matching, since it may be in the interest of a university to admit low-score students. For example, if the university is seeking a diverse class or the student has over performed in other areas besides the school grades and the test scores. One could imagine also the opposite situation, that it is desirable for a matching algorithm to produce negative assortative pairs. Although this is not the case in reality, from a normative point of view, it could cause that good students improve the quality of low-ranked universities, and that good-ranked universities improve the aptitudes of low-scoring students. With this in mind, a situation where students are paired to colleges of dissimilar characteristics (negative assortative matching) could enter into the agenda of policy makers. At the end, the purpose of the allocation of study places is decided by the social values, which in our market society it has been "reserve the best spots for the best students". Nevertheless, in assortative matching, the talk is about the characteristics of the agents matched, and this can be identified regardless any normative statement.

4.1.1. Costly signals

In the market for college admissions agents need to signalize their characteristics to the other side of the market. Signaling costs are transaction costs, and this type of costs causes friction between applications and admissions. In the DA mechanism presented by Gale and Shapley (1962), agents do not face any form of transaction costs and are perfectly informed about the characteristics of every other agent in the market. Therefore, an outcome produced by DA is stable, but in reality, students and colleges face high costs for transacting. Signaling characteristics is costly, especially when from signaling highly depends who is admitted to which university. A very good applicant failing in signaling outstanding characteristics may lose many spots at its preferred colleges, and colleges failing to signalize its valuable program, campus and faculty face a potential loss in student applications. The competition to signalize causes strategic behavior, where agents can involve in activities not for individual interest, but to signalize more characteristics to the other side of the market.

As I mentioned above, depending on the characteristics, two different pairing outcomes are possible, positive or negative assortative matching. Although most agents know their individual strengths and weaknesses, it is often costly to signalize positive characteristics, and failing to do so may signalize weaknesses too. Especially in the market for college admissions, signals for both sides of the market are of high cost. Universities need to invest in assets that may not be of particular interest for the current researchers and enrolled students to signalize high quality in areas such as education, campus life, and even to compete with other colleges. US-American universities have invested billions of dollars in the last decade to expand their campuses. This includes giving money away in fancy laboratories and beautiful gardens (Hoppe et al 2009, 254), that do not get even used by undergraduate students (The Economist 2007). What has driven high spending at US-American colleges has been a big debate in the country, but one source of this spending is for sure coming from the high competitiveness among colleges. "[…] *with more students entering university, there are also more desirable applicants, a fact that encourages universities to try and expand the number of highly qualified students they can attract*" (The Economist 2007). As it is often the case, in the other side of the market, the students suffer from costly signals too. Some of them I have presented already, such as the opportunity costs, the application fees and the central examinations. However, costly signals go beyond that. According to Hoppe et al. (2009), students get involved in activities with high costs years before applying to college to signal aptitudes. Such activities go from attending prestigious private high schools to engage in particular sports (e.g. American football in the

hope of getting a sport scholarship in the USA) and learn music instruments. For these signals, parents often burn valuable resources, both in time and money (Hoppe et al 2009, 254).

The same question as before arises. Is under costly signaling the trend to positive assortative matching socially desirable? Well, in the sense of preferences, if two agents prefer each other to every other agent in the market, why should anyone intervene in that match? Patrick Legros and Andre Newman (2007) present an example of the recruiting for athletes at US-American colleges that gives a hint to these two questions. In the USA, sports scholarships represent an important funding for student-athletes willing to attend college, and those athletes become later through national competitions an important source of income and prestige for the college who granted the scholarship. Therefore, it is in the interest of universities to get the best athletes, which tends to be also a fight for athletes with high "*revenue-generating capacities* [in] *their respective sports*" (Legros and Newman 2007, 1094). For example, when colleges recruit male athletes to play American Football, the market faces a situation where a college with excellent football reputation and an outstanding student-athlete are matched. This may be Pareto efficient and stable, but represents also an unfair disadvantage for women with the same performance who may be excluded from the recruiting for representing less "potential profit". This situation is particular to the United States, where college football is a billion dollar industry. A solution to this problem has been partially solved by a policy in the US that reduces public funding for state universities if the public funding is not distributed in activities that benefit men and women equally (Legros and Newman 2007, 1094). With this example, I showed that even though agents engage in costly signaling activates and even though both are willing to transact with each other (due to the exogenous given valuation of characteristics) a pairing of agents with similar characteristics (positive assortative matching) is not always desirable.

4.1.2. Negative assortative matching caused by financial need

Financial resources can improve an institution's facilities, teaching, and research quality, but it cannot so easily acquire reputation, which is what primary attracts applicants. A family's financial resources cannot buy aptitudes and favorable characteristics for their kids, but it can buy access to a better and broader education. Wealthier families can get access to private tutoring for the *Gaokao* examination, or activities that admission teams like to see in their applicants, like being a member of the local water polo team or the school's big band. Indeed, a country's welfare and a family's financial resources have a huge impact in the outcome of the college admissions market. A negative assortative matching may be high correlated to a bad

distribution of wealth along the population. Dissimilar characteristics defined here as "good" students that are not matched to the "good" institutions. The reason for this is that with a bad distribution of income many good students do not have the chance to access the right tools for academic success at school, and end up being under-matched.

Cortes and Lincove (2019) found out that in the USA most students prefer to assist colleges where the fellow peers share similar characteristics, both demographic and socioeconomic. This explains why sometimes a positive assortative matching is inevitable, since many students feel more comfortable in a class with similar aptitudes and economic background. There are also many students who have the required characteristics to assist a "good" college, but do not consider applying, because of a misinformation of their chances to enroll there. This happens primary to low income students, and causes that higher income students tend to be overmatch, due to their willingness to apply to better colleges (Cortes and Lincove 2019). A solution to this problem was proposed by an automatic admission policy in the US-American State of Texas, that offers with certainty a spot in a given state university in Texas to qualified high school seniors from underrepresented groups and minorities (Cortes and Lincove 2019, 120). This place is offered with a less bureaucratic admission process and requires less costly signals, than the traditional application. With such a program, the gap between students gets smaller. For the college admissions market to be fair, any prospective student should be able to compete equally. The information asymmetries caused by the student's family background are potentially solved by such state policies that offer advantages to these usually under-matched high-qualified seniors. With this example, I showed that there is also from a public policy perspective the need to reduce negative assortative matching. There is not one correct answer and one preferable outcome when choosing to avoid one of the types of assortative matching. It is just a matter of how a given society defines the preferable characteristics in the agents and what type of outcome (stable, fair, etc…) is desirable.

4.2. Errors in the selection process

When testing a hypothesis in statistics, rejecting a true hypothesis corresponds to a type I error, and not rejecting a false hypothesis corresponds to a type II error. Sah and Stiglitz (1986) use this principle of statistic as an analogy to describe the selection process of good and bad work projects and the acceptation or rejection of those projects. In this section, I am going to apply the analogy of Sah and Stiglitz (1986) to the thematic of college admissions in the context of the decentralized system in the USA and the centralized system in China. The overall problem is that in the market for college admissions there are "good" and "bad" students, which actually

means students that are or are not desired to a particular institution. A given university judges a prospective student based on the characteristics that were signalized in the application process.

In the theoretical mechanisms I presented previously in section 3, one of the assumptions was no errors in the admission process. This means, that an admitted or rejected senior is assumed to be actually desired or not desired by the college that took the decision. However, in the real admissions process in both countries there is the possibility of two errors to happen. This is different to the over-matched and under-matched problem of assortative matching from the last section, where the situation presented was not an error in the selection process (from the side of the institution), but an error in the application process (from the side of the student). The type I error in the market for college admissions is rejecting an applicant, besides being a "good" or desired student, and the type II error consequentially is admitting an applicant, besides being a "bad" or not desired student. What I will do in this section is compare the errors in the selection process of the decentralized and centralized systems. Sah and Stiglitz (1986) refer to this as the architecture of the decision-making, which they categorize under polyarchies and hierarchies. In the case of the decentralized admissions process in the USA the choice-architecture is a polyarchy, because institutions take the admission-rejection decisions independently from each other. The situation is exactly opposite to the admissions process in China, where the choice-architecture is a hierarchy, because decisions are taken dependently of each other, for example when considering admissions in order of tiers.

4.2.1. Centralization vs Decentralization

"Without perfect screening, the architecture of the economic [here: admissions] *system determines the conditions under which a project* [here: student] *gets selected and, hence, it affects the system's output."* (Sah and Stiglitz 1986, 718). In the college application market, there are limited methods for students to signal interest and aptitudes to universities. The task of the selection committee is to screen the applicants (Sah and Stiglitz 1986, 717). For seniors to communicate all of their positive characteristics to the admissions committee in an institution is difficult, but just as difficult as it is for the institution to judge individuals based only on papers and scores. Consequentially, errors in the selection process are inevitable, but depending if the system is decentralized or centralized the process of selection looks quite different and causes also a different probability of error type I or error type II to occur.

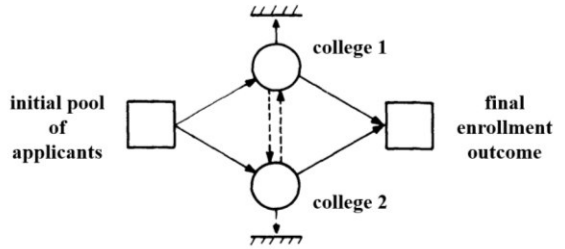


FIGURE 1. POLYARCHY
Decentralized college admissions in the USA

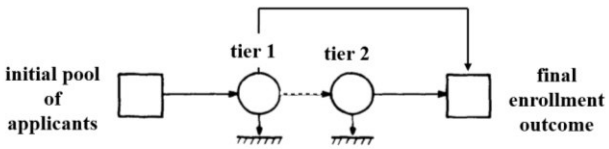


FIGURE 2. HIERARCHY
Centralized college admissions in China

Source Figure 1 and Figure 2: Sah and Stiglitz (1986)*, p. 718.

*Adaptations in the titles to match the context and in the arrows in Figure 2 to visualize the admission process through tiers.

In Figure 1 and Figure 2, I adapted the basic model of Sah and Stiglitz (1986) to explain the problem of centralization vs. decentralization in the market for college admissions, both in the USA and in China. The model classifies students into two categories "good" for desired and "bad" for not desired, which also means admission or rejection. The probability of any student to pass the selection process is higher if she signalizes strong characteristics. The signals itself do not ensure that the student is actually "good" or "bad". The error therefore is to classify the student in a category she does not belong.

In a poliarchy (Figure 1), hence in the decentralized US-American college admissions, a senior applies to all her desired universities with parallel applications. Each university screens the student independently and rejects her or offers her admission. In Figure 1, the dotted arrows symbolize the parallel application, in which decisions of admission and rejection are taken independently. If an applicant is rejected by any of the colleges, then she is removed from the list of that particular institution ( ). The final enrollment outcome is defined by the admitted and rejected students, and for the students that got more than one admission it is defined by where she finally enrolls. Figure 1 also approximates the application-rejection process of the deferred acceptance algorithm (Gale and Shapley 1962), with the difference that it does not display the process the algorithm goes through before making decisions final.

In a hierarchy (Figure 2), hence in the centralized Chinese college admissions, the senior submits her preference list and is evaluated in order of preference, or like it is in practice, in order of university tiers. Since the admissions mechanism in China is a hybrid version with aspects of the sequential algorithm, the students profiles are reviewed in order of listed preferences (or of listed choice bands). The dotted arrow in this case symbolizes that "tier 2" (or choice band B) is only allowed to see the profiles of the students that have already being rejected by "tier 1" (or choice band A). An admitted student in tier 1 becomes directly part of

the final enrollment outcome. Figure 2 primary visualizes the application-rejection process of a sequential algorithm. A hybrid version of both figures would approach more the situation of the parallel acceptance mechanism used for college admissions in Chinese provinces.

4.2.2. Chances of mismatching

There is a higher chance of a type II error to happen in decentralized college admissions system, and there is a higher chance of a type I error to occur in a centralized system (Sah and Stiglitz 1986, 719). In practice this means, that there is a higher chance in the USA to admit a "bad" (or not desired) student, and there is a higher probability that a Chinese university rejects a student, besides being "good" (or desired). The reason for this is not only explained by the process of application of the model visualized in Figure 1 and Figure 2, but also by the signals applicants are required to send in the application process.

In China, a senior prepares for months, and sometimes up to two years, to take a 3-day examination. This means that regardless of the preparation a prospective student puts into taking the *Gaokao*, a bad sleep or sickness at the day of exam are enough to ruin or sink the applicant's score. Therefore, there is a high chance that many good prepared seniors end up with bad *Gaokao* scores. The selection process afterwards would only take into consideration the scores, without considering a student's effort or other characteristics, and end up rejecting a higher portion of good seniors (type I error).

The opposite situation happens in the USA, where seniors can put a lot of effort when writing their essays (or even acquire a ghostwriter from many companies that offer such a service), and through their parents or personal network get powerful recommendation letters, besides not being as good as such signals would show. Seniors in the USA are also able to take the SAT or ACT examination a couple of times before submitting them with their applications. This means that having a "bad day" can be solved by taking the exam again. The signals seniors send in the application can be corrected or influenced by external factors before submission. That causes that the probability of admitting a bad senior is higher (type II error) in a polyarchy.

In a massive centralized college admission system in a country like China, it may not be a big problem that type I errors are produced, as long as the relative amount of students selected and rejected correctly is high. It may be of higher relevance in China to produce more highly qualified individuals in the masses. In the United States, with a decentralized college admissions system where individual institutions take the final admission decisions, it may not be that big of a problem to choose wrong at the beginning if the individual can be taught to be better during college. This is confirmed by Sah and Stiglitz (1986, 726). The authors state, that

in hierarchical choice-architectures, like in China, the system faces higher costs in the selection process, if they try to avoid more type I errors. Higher costs meaning here not only higher screening costs, but also rejecting more good students, when trying to avoid that mismatched students get assorted correctly. In polyarchical choice-architectures, more not-desired students get through the selection process, so that the institutions would face higher costs when conducting better screening, which again could avoid admitting more of the good applicants.

5. Closing remarks and the future of education

"*Economics is about the efficient allocation of scarce resources"* (Roth 2015, 4). In this thesis, I analyzed the problem around study places, which are scarce resources. These places are traded in a market where the "sellers" and "buyers" are universities and students. Other actors play a major role in college admissions, such as the government regulating and framing the market, private and public organizations funding the colleges, and the parents of the applicants that burn their own scarce resources to give their children a chance of competing for higher education.

The aim of this thesis was to conduct a deep comparison of the matching market for college admissions in China and the USA. I conducted this analysis from the broad to the specific. I presented the general process students in both countries go through in order to apply to college. This included an explanation about the *Gaokao* and about the SAT and other crucial steps in the process. Then I presented the major focus of this thesis: matching algorithms. This included the technical aspects of the mechanisms and its application in the real college admissions in China and the USA. At the end, I presented two further approaches that explain other points of view in market design, such as the architecture of choices and how the admission-rejection mechanisms works different in practice than in theory.

Both college admission systems are different and somehow unique too. It is hard to say which system is desirable, since both serve the purposes defined by the culture and the values of the society in which they operate. Both countries shifted their systems away from the Sequential mechanism (IA) to less manipulative mechanisms, like PA and DA, to solve some of the issues with strategic behavior and instability. In practice, some degree of strategic behavior always remains, because students face a restriction in the amount of applications they can submit, either because of the limited amount of preferences they can list in China (Cao 2020, 274), or because of the constraints of sending additional applications in the USA. However, even the errors in the selection process can have a positive impact on students and universities, since some amount of academic mismatching may cause positive peer effects on a more diverse admitted class (Dillon and Smith 2017, 64).

Education is evolving and adapting to this digitalized century and the already started fourth industrial revolution. With that is the market for college admissions going to change in the next couple of years too. I wrote this thesis in the middle of a world pandemic, which cannot be ignored as a big challenge of this decade, just as we cannot ignore the changes the financial crisis of the last decade brought to the world. I observed how universities and students digitalized in a matter of days to continue engaging in education under the crisis. This affected college applications so fast as no change did in the last decades. Suddenly students in the USA were able to take tests online and at home, and universities made exemptions when not fulfilling all application requirements. In China *Gaokao* was postponed for a month, something that happened for the last time in 2008 in only one province after a natural disaster. With high schools going online and seniors staying at home, the educational inequality became more noticeable in China as many children lacked the technological equipment to continue learning and preparing for the national central examinations (Kologrivaya and Shleifer 2020).

What happens in the college admissions market affects the job market and that later affects the world economy. With that in mind, the two biggest economies by GDP, China and the USA, will face big challenges in the coming decade if they want to give more students access to higher education and what is more important, to offer an equal access to education and fair competition for the spots in college among the population (Cao 2020, 274).

This thesis exposes two markets in two countries. Some questions that go beyond the scope of this analysis remain open. For example, what effect has provincial and minority quotas on the Chinese college admission market? Moreover, how does high tuitions in the USA affect the decision of attending college? In addition, how do other credentials required in the job market, like a vocational training, affect competition in the market for college admissions?

The future is going to bring new forms of education, and for students not pursuing academic careers a college degree may lose some relevance in the coming decade. The coming times are going to be about "life-long education", since with the speed that technology is evolving, what a student learns during her degree may lose relevance by the end of the decade (Marr 2020). The supply side, the universities, are adapting. The world's best education institutions are now offering complete online degrees, continued education, and micro-certifications. Changes in what the job market is looking for is going to affect the college admissions in the coming decade as well, and even the preferences from the demand side, the students, are adapting to this new trends.

6. List of references

01 Abdulkadiroğlu, A., Parag A. Pathak, and Roth, A. (2005). *The New York City High School Match.* The American Economic Review, Vol. 95 (2), pp. 364-367.

02 Avery, C., and Levin, J. (2010). *Early Admissions at Selective Colleges*. The American Economic Review, Vol. 100 (5), pp. 2125-2156.

03 Balinski, M., and Sönmez, T. (1999). *A tale of two mechanisms: Student placement.* Journal of Economic theory, Vol. 84 (1), 73-94.

04 Becker, G.S. (1973). *A theory of marriage. Part I.* Journal of Political Economy, Vol. 81 (4), pp. 813–846.

05 Becker, G.S., (1974). *A theory of marriage. Part II.* Journal of Political Economy, Vol. 82 (2), pp. S11–S26.

06 Cao, Yuan (2020). *Centralized assignment mechanisms and assortative matching: Evidence from Chinese universities.* Journal of Economic Behavior & Organization, Vol. 177, pp. 255-276.

07 Chade, H., Lewis, G. and Smith, L. (2014). *Student portfolios and the college admissions problem.* Review of Economic Studies, Vol. 81 (3), pp. 971-1002.

08 Chen, Y. and Kesten, O. (2017). *Chinese college admissions and school choice reforms: a theoretical analysis*. Journal of Political Economy, Vol. 125 (1), pp. 99–139.

09 Chen, Y. and Kesten, O. (2019). *Chinese College Admissions and School Choice Reforms: An Experimental Study.* Games and Economic Behavior, Vol. 115, pp. 83-100.

10 Chen, Y., Jiang, M., and Kesten, O. (2020). *An empirical evaluation of Chinese college admissions reforms through a natural experiment.* Proceedings of the National Academy of Sciences.

11 Chen, Y. and Sönmez, T. (2006). *School choice: an experimental study.* Journal of Economic theory, Vol. 127 (1), pp. 202-231.

12 Cortes, K. E., and Lincove, J. A. (2019). *Match or mismatch? Automatic admissions and college preferences of low-and high-income students.* Educational Evaluation and Policy Analysis, Vol. 41 (1), pp. 98-123.

13 Dillon, E. W., and Smith, J. A. (2017). *Determinants of the match between student ability and college quality.* Journal of Labor Economics, Vol. 35 (1), pp. 45-66.

14 Ehrenberg, R.G. and Liu, A.Y.H. (2009). *The Common Application: When Competitors Collaborate*. Change: The Magazine of Higher Learning, Vol. 41(1), pp. 48-54.

15 Ergin, H., and Sönmez, T. (2006). *Games of school choice under the Boston mechanism.* Journal of public Economics, Vol. 90 (1-2), pp. 215-237.

16 Feng, Y. (1999). *National College Entrance Examinations: The Dynamics of Political Centralism in China's Elite Education.* The Journal of Education, Vol. 181 (1), pp. 39-57.

17 Gale, D., and Shapley, L. (1962). *College Admissions and the Stability of Marriage.* The American Mathematical Monthly, Vol. 69 (1), pp. 9-15.

18 Hafalir, I.E., Hakimov, R., Kübler, D., Kurino, M. (2018). *College admissions with entrance exams: Centralized versus decentralized.* Journal of Economic Theory, Vol. 176, pp. 886-934.

19 Hoppe, H. C., Moldovanu, B., and Sela, A. (2009). *The theory of assortative matching based on costly signals.* The Review of Economic Studies, Vol. 76 (1), pp. 253-281.

20 Hurwitz, M., and Kumar, A. (2015). *Supply and Demand in the Higher Education Market: College Admission and College Choice.* Research Brief, College Board.

21 Kologrivaya, E. and Shleifer, E. (2020). *Gaokao in the Time of COVID-19*. The Diplomat. Retrieved on 30.12.2020, from: https://thediplomat.com/2020/04/gaokao-in-the-time-of-covid-19/.

22 Kowarski, I. (2019). *Colleges With the Highest Application Fees.* U.S. News & World Report. Retrieved on 14.11.2020, from: https://www.usnews.com/education/best-colleges/the-short-list-college/articles/colleges-with-the-highest-application-fees.

23 Legros, P., and Newman, A. (2007). *Beauty is a beast, frog is a prince: Assortative matching with nontransferabilities.* Econometrica, Vol. 75 (4), pp. 1073-1102.

24 Marr, B. (2020). *The Future Of Jobs And Education.* Forbes. Retrieved on 30.12.2020, from https://www.forbes.com/sites/bernardmarr/2020/12/11/the-future-of-jobs-and-education/?sh=4476f02c3d9f.

25 NCES. (2019). *Number of higher education institutions in the United States in the academic year of 2018/19, by state [Graph]*. Statista. Retrieved on 12.10.2020, from: https://www.statista.com/statistics/306880/us-higher-education-institutions-by-state/

26 Qin, X. and Buchanan, R. (2019). *Policy and Public Preferences Regarding the University Enrollment Quotas System across Chinese Provinces.* Higher Education Policy, pp. 1-21.

27 Reingold, D. (2004). *How to Humanize the College Admission Game.* Journal of College Admission, Vol. 184, pp. 18-22.

28 Roth, A. (1982). *The Economics of Matching: Stability and Incentives.* Mathematics of Operations Research, Vol. 7 (4), pp. 617-628.

29 Roth, A. (2015). *Who gets what—and why: The new economics of matchmaking and market design.* Houghton Mifflin Harcourt, New York.

30 Roth, A. and Sotomayor, O. MA. (1990). *Two-sided Matching: A Study in Game-Theoretic Modeling and Analysis.* Econometric Society Monographs, Cambridge University Press.

31 Ross, K.M. and Moody, J. (2020). *A Complete Guide to the College Application Process.* U.S. News & World Report. Retrieved on 15.11.2020, from: https://www.usnews.com/education/best-colleges/articles/college-application-process.

32 Sah, R. K., and Stiglitz, J. E. (1986). *The architecture of economic systems: Hierarchies and polyarchies*. The American Economic Review, Vol. 76 (4), pp. 716-727.

33 The Economist. (2007). *Construction on Campus —Just add cash.* Article, retrieved on 13.12.2020, from: https://www.economist.com/united-states/2007/11/29/just-add-cash

34 Wu, Binzhen, and Zhong, Xiaohan. (2014). *Matching mechanisms and matching quality: Evidence from a top university in China.* Games and Economic Behavior, Vol. 84, pp. 196–215.

35 Yu, Lan and Hoi K., Suen. (2005). *Historical and Contemporary Exam-driven Education Fever in China.* KEDI Journal of Educational Policy, Vol. 2 (1), pp. 17-33.

7. Declaration of authorship

I hereby confirm that my work does not violate core principles of scientific integrity.

„Ich versichere durch eigenhändige Unterschrift, dass ich die Arbeit selbstständig und ohne Benutzung anderer als der angegebenen Hilfsmittel angefertigt habe. Alle Stellen, die wörtlich oder sinngemäß aus Veröffentlichungen (auch aus dem Internet) entnommen sind, habe ich als solche kenntlich gemacht. Ich weiß, dass bei Abgabe einer falschen Versicherung die Arbeit als mit 'nicht ausreichend' (1 Bewertungspunkt gemäß § 16 Abs. 2 Allgemeine Bestimmungen, Note 5, ECTS-Grade F) bewertet gilt.“

Jonathan Hauff Ortega - 08.01.2021

Appendix A: Graphic model of IA, DA, and PA

This thesis is the first accomplishment of many steps that I will need to undertake to make a successful contribution to science, but I still want to use this opportunity to propose something of my own creation. There is a high risk involved when proposing something and claim it as my own, therefore I want to make clear at this point that my creation is just the visualization of the mechanisms presented in this thesis in the graphics below.

This graphic simplifies the mathematics behind the three mechanisms from the diverse authors presented and helps further students visualize the procedure the mechanisms go through before making assignments final.

Figure 1 – IA
Immediate Acceptance mechanism

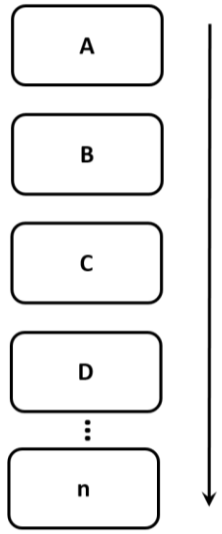


Figure 2 – DA
Deferred Acceptance mechanism by Gale and Shapley (1962)

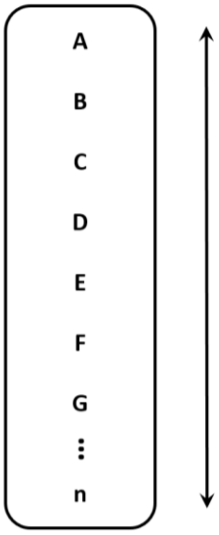
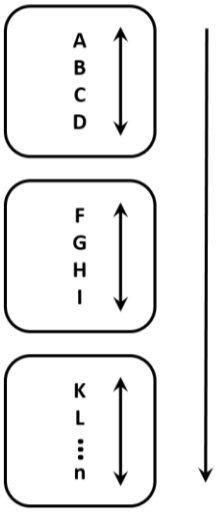


Figure 3 – PA
Parallel Acceptance mechanism as described by Chen and Kesten (2017, pp. 102-104)



The boxes in Figure 1-3 are filled with college choices in order of preference A to n (high to low). The arrows show the direction the algorithm checks the boxes or the choices inside the boxes, meaning the arrows show the order in which applications are revised. In IA (Figure 1) the band size equals 1 and therefore the algorithm makes each match final after going through each box. In DA (Figure 2) no match is final until the algorithm has revised all college choices (applications), the band size is equal up to infinity, and therefore there is only one large box. PA is a hybrid of both algorithms (Figure 3). Under a PA mechanism students can list many colleges inside a band, where preferences are treated as in DA, and they can also list colleges in other bands (or tiers) of decreasing preference, where bands, regardless of its size, are treated as in IA. In the USA students face in practice a special version of DA. First, there is

a single choice in the Early Admission round that is treated as in IA, then Students can be deferred or apply directly to the regular decision round, where applications are revised with a DA mechanism.

Appendix B: Closing letter and acknowledgments

This thesis symbolizes the end of my Bachelor of Science in Economics and with that the end of my stay at the city of Marburg. After submitting this thesis, there will only be three exams left for me to call myself an Economist. During the past two and a half years of my undergraduate studies plus one year of preparatory courses at the Philipps-Universität Marburg I met plenty of awesome people and collected memories that will stay with me forever.

I would specially like to thank Prof. Dr. Elisabeth Schulte for introducing me last summer to Market Design. This is not only the topic of my thesis, but an area of Economics that I can see myself specializing in the future. I am also very grateful with Professor Schulte for being my thesis supervisor and for investing a lot of time in me. I will always remember the very interesting discussions we had over Zoom, at her office, and even while walking around Marburg and tasting "Zimtsterne".

I am grateful with Professor Yan Chen from University of Michigan (USA) for answering all my questions about Chinese College Admissions over a Zoom meeting, and for providing me many useful resources about the topic.

A very special appreciation goes to my two friends, Leon Alleke and Ricardo Skewes, who took the time to read my thesis, provided me feedback and suggested grammar corrections.

I also want to thank Yuan Cao from the Capital University of Economics and Business (China) for granting me access to her research paper "Centralized assignment mechanisms and assortative matching: Evidence from Chinese universities" (2020).

I am very grateful with every person that made my time in Marburg an awesome experience. I want to thank my parents and sister for motivating me and specially for supporting my decision to come to Germany to pursuit a bachelor degree. I want also to thank Renata Juhasz, my German teacher during the Studienkolleg, who cheered me up and rescued me when I was about to quit in the first semester.

Thanks to the Philipps-Universität Marburg for admitting me twice. The first time in 2017 for the Studienkolleg, and the second time in 2018 for my bachelor degree. I will miss this incredible institution, the passionate professors, and the campus spread around the beautiful city of Marburg. I will be a proud Alumnus of this institution in the next stage of my life.