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ABSTRACT

Telling the Truth May Not Pay Off: An Empirical Study of Centralised University Admissions in Germany*

We investigate the matching algorithm used by the German central clearinghouse for university admissions (ZVS) in medicine and related subjects. This mechanism consists of three procedures based on final grades from school ("Abiturbestenverfahren", "Auswahlverfahren der Hochschulen") and on waiting time ("Wartezeitverfahren"). While these procedures differ in the criteria applied for admission they all make use of priority matching. In priority matching schemes, it is not a dominant strategy for students to submit their true preferences. Thus, strategic behaviour is expected. Using the full data set of applicants, we are able to detect some amount of strategic behaviour which can lead to inefficient matching. Alternative ways to organize the market are briefly discussed.

JEL Classification: C78, D02, D78, I29

Keywords: matching, university admissions, strategic behaviour

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1. Introduction

The German system of university admissions is characterized by the coexistence of two diametrically opposed mechanisms. For the majority of subjects, universities decentrally select the students themselves. However, in six subjects there is a centralised matching scheme that is administered by the clearing house ZVS (*Zentralstelle für die Vergabe von Studienplätzen*). This coexistence provides the opportunity to study the advantages and shortcomings of both systems at the same time.

In this paper we take a closer look at the centralised matching scheme that is currently employed in Germany.[4] While the German case is of some stand-alone interest for policy makers in Germany, central clearinghouses for university admissions also exist in other countries (e.g. Turkey, Sweden, the Netherlands, United Kingdom). Our analysis can thus be understood as a contribution to the reform process that the university admissions system is undergoing in many countries.

To investigate the efficiency of the current matching mechanism, we first show that it is not strategy-proof, i.e., revealing one's true preferences is not a dominant strategy. Then, we study whether the preference lists submitted by students reflect their true preferences or, alternatively, whether students submit manipulated lists for strategic reasons. The rationale for focusing on strategic behaviour is that it can lead to inefficient matching.[5]

Centralized matching algorithms are useful to study even if no centralised mechanism is used. To see this, consider the recent experience in Germany. After many years of centralised admissions through the ZVS, universities were granted more rights in selecting their students in 2005. This has been advocated by many, and is an important step towards more competition among German universities.[6] Although long awaited, the experience with decentralised admissions has been disillusioning in some respects. The new freedom has led to a number of problems that are typical for decentralised matching markets. Every year more than 300 000 applicants have to be handled by the not yet professionalized admissions offices of the universities. In addition, most students send their applications to a number of universities. After being admitted to some of them, students do not immediately reject their less preferred offers. Thus, universities get rejections rather late and then have to send out offers again. Many students are accepted only when the first term is already well under way.[7]

[4] The rules of the matching scheme have often changed in the past. We chose to focus on the rules used in 2006 which is the most recent year of our dataset.

[5] See Ergin and Sönmez (2006) for an analysis of the "Boston mechanism" which shares central features with the mechanism used by the ZVS.

[6] E.g. the German Scientific Council (*Wissenschaftsrat)*, an advisory board to the German Federal government and federal states, in its statement on the reform of university admissions in Germany (2004), stipulates that universities become more active in the admissions process to ensure a better match between the qualifications of applicants and the specific requirements of the programs (p.49).

[7] This problem has received wide coverage in the press. See e.g. Spiegel special, 24.4.2007, Nr. 2, or UniSPIEGEL 5/2007.

In addition, the universities often cannot fill all their spaces.[8] These are typical symptoms of a congested market where universities find that they do not have sufficient time to make all offers they would like to make. Many universities are already reacting to this problem by moving application deadlines to earlier dates. This unravelling process implies earlier and more dispersed offers, which creates other inefficiencies.

In the light of this experience and of the study of other matching markets, the usefulness of a well-designed central clearinghouse is evident. It can serve as an instrument to generate an efficient and stable matching, based on the preferences of universities and students. Thus, it is by no means necessary to move from a centralised to a decentralised system in order to strengthen the role of the universities in the admissions process. To the contrary, a well designed central mechanism can be a helpful tool for universities to be able to admit their most preferred students.

Of course, markets do not have to be organized through a central clearinghouse. But the study of matching algorithms, and in particular the deferred acceptance algorithm (Gale and Shapley 1962), has led to insights about what is necessary to avoid congestion, instability, unravelling etc. Attempts to deal with these problems can be observed in many decentralised markets such as Undergraduate College Admissions as well as Graduate School Admissions in the US. In these markets, central institutions attempt to regulate, e.g., application deadlines, the possibility to make exploding offers (i.e. offers with a short deadline for acceptance) or the possibility to force students to make binding acceptances early.[9]

The new initiative of the German KMK (the group of ministers of education from the federal states) to use the ZVS as a central platform for the admission process is a step into this direction.[10,11] The plan is to assign the ZVS a service function within a decentralised admission process. The board of ministers recommends to the universities the conferral of all administrative tasks within the admission process on the ZVS. The idea is that the ZVS will then be in the position to speed up the admission process: If an applicant accepts an offer, this will lead to an immediate rejection of potential other offers. Hence, the advantage of such a moderated decentralised admission is that rejected slots can instantaneously be offered to someone else. Notice, however, that the process leading to an efficient match is rather complex. It is not sufficient to use the ZVS as a central platform to secure timely rejections after a student has accepted an offer. For example, to achieve an optimal matching it must be possible for universities to make second and later round offers. And if a student has received a preferred offer later (because his preferred university was rejected by an applicant

[8] See Die Zeit 11/2007, p.39, UniSPIEGEL 5/2007 or Der Tagesspiegel Nr. 19476, 02.03.2007, p.3.
[9] See Avery, Fairbanks and Zeckhauser (2003) for a thorough analysis of College Admissions in the United States.
[10] See Handelsblatt Nr.043, 01.03.07, Tagesspiegel Nr.19474, 28.02.07 and Nr.19476, 02.03.07.
[11] Also the Wissenschaftsrat (2004) has proposed to reorganise the ZVS according to the British Universities and Colleges Admissions Service (UCAS), see p.51-52.

in the first round) he should be able to reject the offer he had first accepted and accept this new offer instead.

The plan of the paper is as follows. In the next section, we describe the rules currently applied by the ZVS and analyze the incentives of applicants to misrepresent their true preferences. In Section 3, we describe the dataset used, and in Section 4 we employ various tests designed to understand whether subjects do indeed behave strategically. In Section 5 we discuss policy issues and briefly sketch an alternative matching mechanism, the deferred acceptance algorithm. Section 6 concludes.

2. The Student Mechanism

In Germany, admission to university for all medical subjects is centrally administered. Nationwide all prospective students of biology, medicine, pharmacy, psychology, animal health and dentistry have to apply at the ZVS.[12]

The ZVS assigns students according to the following three procedures:

1. *Abiturbestenverfahren* (procedure for those who are top of class). Around 20% of all seats are supposed to be allocated through the *Abiturbestenverfahren* [ABV].
2. *Wartezeitverfahren* (quota for those who have been waiting for some time). Around 20% of all seats are supposed to be allocated through the *Wartezeitverfahren* [WZV].
3. *Auswahlverfahren der Hochschulen* (selection procedure of universities). Around 60% of all seats are supposed to be allocated through the *Auswahlverfahren der Hochschulen* [ADH].

For each of these procedures, applicants are asked to submit a preference ranking of universities. They are allowed to rank no more than six universities. Only in the WZV they have the option to add all other universities to the bottom of their list without ranking them.

Universities do not submit preferences for individual students. Rather, the allocation rule in the ABV and WZV assumes that students who rank a university higher are preferred to students who rank it lower on their preference list. For students with the same rank, other criteria (e.g. final grades in the ABV or social factors in the WZV) are used to break ties.[13]

[12] In the past, every federal state had different regulations concerning admission to university. This led to juridical insecurity and to the so-called “Numerus-clausus” decisiongment of the Federal Constitutional Court. Due to the necessity of concerted criteria and a central service admitting applicants to university, the federal states founded the ZVS in the "*Staatsvertrag über die Vergabe von Studienplätzen*" on 20th of October in 1972 (ZVS 1998). Today, the ZVS has the mission to admit applicants, to support universities in selecting their students and to establish uniform criteria for the determination of the number of admitted applicants.

[13] These rules can either be interpreted as representing the preferences of the universities or as mere devices to allocate scarce seats. In the first case, it is a two-sided game with universities and students as players while in the second case we have a one-sided clearing house with only the students as players. See Abdulkadiroglu et al. (2005, 2006).

All of the three procedures are **two-stage procedures**. At the first stage, applicants are selected ("selection"). At the second stage, the selected applicants compete for admission to one of their preferred universities ("admission"). While the sequence is identical in the three procedures, they differ concerning the criteria applied. All three procedures and the optimal application strategies of students will be described in more detail in the following.

After having administered all three procedures, the ZVS publishes detailed information on the application characteristics of admitted candidates for every university-subject combination. This includes average grades, waiting times and social criteria. Hence students applying with the ZVS can learn about the popularity of the different subjects and universities and about their chances of being admitted at a specific university within the different procedures. We therefore suspect that at least some applicants take this information about the past into account and compare their characteristics to historical thresholds. This helps them to make the right strategic choices.

2.1 Abiturbestenverfahren (ABV)

The ABV rewards excellent average grades in the *Abitur* (final grades from school).

Therefore, those applicants with the best average grades are selected at the first stage.[14] Whether an applicant is selected or not only depends on his characteristics, i.e. the final grade in the *Abitur* and possibly on subordinated criteria.[15] It cannot be influenced by his stated preferences. That is why we will concentrate on the second stage at which selected applicants compete for admission to one of their preferred universities and where stated preferences matter: First, a candidate's first preference is considered. If there are more applicants for this university than can be assigned, those with the best average grades are admitted. Social criteria and (subordinately) lotteries are used to break ties. Once all first preferences have been considered, remaining applicants are admitted according to their second preference – if there are still seats left after the first round.

The admission algorithm of the ABV can be generalised as follows:

Step *1*: In step *1* only the 1^{st} preferences of the applicants are considered. For each university, admit the selected applicants who have ranked it as their 1^{st} choice until there are no seats left or until all candidates ranking the university as their 1^{st} choice have been

[14] Due to the federal structure of the German educational system, every federal state in Germany has its own *Abitur* with its particular combination of subjects and grading system. In order to guarantee equal chances of admission to universities in spite of this federal school system, competition for admission is not nationwide but takes place only among applicants who have passed their *Abitur* in the same federal state. A detailed description for this can be found in Braun and Dwenger (2007).

[15] Subordinate criteria for selection are waiting time for being admitted, service and lottery.

admitted. If there are more candidates giving priority to a university than can be admitted, those applicants with the best grades in the *Abitur* are admitted.

Step *k*: In step *k* only the k^{th} preference of the still unassigned applicants is considered. For each university with available seats admit the selected applicants who have ranked it as their k^{th} choice until there are no seats left or until all candidates ranking the university as their k^{th} choice have been admitted. If there are more candidates giving the rank *k* to a university than can be admitted, those applicants with the best grades in the *Abitur* are admitted.

The algorithm stops after step *k* when every selected applicant is assigned or when all *k* preferences have been considered. This means that some applicants may have been selected but remain unassigned even though there are still open seats at some universities. This is the case when universities with open seats have not been listed by the unmatched applicants.

Let us assume that there are four universities $U=\{u_1,u_2,u_3,u_4\}$ where $n=\{1,1,2,1\}$ is the respective number of available seats. Every university *u* prefers applicants who rank university *u* higher to applicants ranking it lower. Furthermore, universities use average grades to break the ties among students who have given it the same rank.

The set of selected applicants consists of $A=\{a_1,a_2,a_3,a_4,a_5\}$ and their respective average grades are denoted by *g*. For simplification reasons let us assume that students are allowed to rank no more than three universities. Applicants state the following preferences:

$$P(a_1)=u_2;\ldots \qquad g(a_1)=1.3$$
$$P(a_2)=u_1;\ldots \qquad g(a_2)=1.0$$
$$P(a_3)=u_1;u_2;u_3 \qquad g(a_3)=1.2$$
$$P(a_4)=u_2;u_3;\ldots \qquad g(a_4)=1.4$$
$$P(a_5)=u_1;u_2;u_3 \qquad g(a_5)=1.1$$

Step 1: In step 1 only the first preference of the applicants is considered. Applicant a_2 is assigned to university u_1. Applicant a_1 receives an offer from university u_2. Applicants a_3, a_4 and a_5 cannot be admitted in the first step.

Step 2: As applicants a_3, a_4 and a_5 are still unassigned, their second preference is considered. While applicant a_4 can be admitted to university u_3, applicants a_3 and a_5 are still left without an offer after round 2: all spaces have already been taken at their second preferred university (u_2).

Step 3: Applicants a_3 and a_5 are still unassigned and hence their third preference is considered. Applicant a_5 can be admitted to university u_3. Applicant a_3 by contrast, cannot be admitted. He remains unassigned even though there is one seat left at university u_4.

In our example it becomes clear that applicants have an incentive to misrepresent their preferences. Applicant a_3, for instance, could have obtained an offer. He could have been assigned to his second preferred university by changing his (stated) university ranking: A space at university u_2 would have been secured by stating this university as the most preferred one.

Hence, the student mechanism in the ABV is **not strategy-proof**. It is not a dominant strategy to state one's preferences truthfully. This is not per se problematic. We only have to worry when applicants' strategies influence the matching outcome. Unfortunately, this is true for the allocation mechanism. In the ABV (and in the WZV, too, as we will see in the following), an applicant ranking a university on k^{th} position is admitted before applicants ranking a university on $(k+1)^{th}$ position are considered – independently of her qualification. Average grades and social criteria are only used as tie-breakers among those applicants who have given it the same rank. Hence, the ranking decision can be decisive for the success of an applicant, and it may be advantageous to manipulate one's true preference ordering.

In a leaflet, the central clearing house (ZVS) points out that the chances of being admitted depend on the rank-order submitted:[16]

"If you could not be admitted to your top university, the ZVS considers your second preferred university. However, at this university priority is given to all those applicants who top-ranked this university. This means that your chances of being admitted at a lower ranked university are worsened depending on the overall demand."

2.2 Wartezeitverfahren (WZV)

The WZV rewards the number of terms an applicant has been waiting for admission since the *Abitur*.[17]

First, applicants are selected depending on their waiting time (selection). At the second stage, admission is organized similarly as in the ABV. The admission process follows the preferences that have been stated by the applicants. Differences between ABV and WZV are due to the criteria applied to break the ties between applicants giving the same rank to a university that does not have enough seats left to admit all of its applicants. In the WZV, emphasis is put on social criteria. By this means, students are priority ordered in the following way:

[16] ZVS (2006a). Translated by the authors.
[17] Note that years of study are not accepted as waiting time.

1. Severely disabled applicants,
2. applicants with spouse/child having their main residence next to the wanted university,
3. applicants with especially mandatory links to the top-ranked university town,
4. applicants registered at their parents' / foster parents' house and who want to study at the closest university,
5. other applicants.

Average grade and (subordinately) lotteries are used to break the ties within each group. Once all first preferences have been considered, remaining applicants are admitted according to their second preference – if there are still seats left after the first round. This implies that the procedure in the WZV is **not strategy-proof** either. As applicants endogenously determine their rivals' chances of being admitted, strategic behaviour pays out.

Hence, stated preferences do matter in the WZV. The ZVS indirectly advises some strategic behaviour:[18]

"In practice, some universities are regularly over-demanded. That is to say a large number of applicants want to study at a famous university or in an attractive university town. Many applicants therefore state one of these universities as their first preference even though this university is not the nearest one offering the desired subject; in this case these applicants are of priority order 5 for universities which are far away. This means that a large number of applicants living with their own family or with their parents and having stated the nearest university will be considered with priority. Most applicants have little chance to be admitted outside their catchment area."

To see why the manipulation of preference lists can lead to inefficient outcomes, consider an example.[19] For a given subject (e.g. medicine), there are three universities A, B, and C. Each of them has 100 slots and 100 students in its vicinity for whom the university is the closest university offering medicine. Assume that none of the applicants fulfils social criteria 1 to 3, such that criterion 4, i.e. living close to the university, becomes decisive. Suppose that university C is the least preferred university from the perspective of all students. In every area, 50 students prefer university A over B and 50 students prefer university B over A.

Consider a student who lives in the vicinity of university A, but who prefers B over A. If she lists B first on her list, she loses priority at A. Thus, if she does not get a seat at university B, it will be difficult to get a seat at A, and she will possibly end up at C. The safe strategy in this situation is to rank A first where the student has priority. Notice that the more students from area B rank university B first, the more advisable it becomes for the student living in A not to list B first, but play safe and choose A. It is an equilibrium in the WZV for each student to list her home university first. In this equilibrium, every student is assigned to her home university.

[18] ZVS (2006b), p.3. Translated by the authors.
[19] See Ergin and Sönmez (2006).

But in our example, it is possible to allocate all students living in the vicinity of university A or B to their first choice. Thus, all students who prefer university A but live in the area of B are offered a seat at A, and conversely, all students who prefer university B but live in area A are offered a seat at B. This allocation Pareto-dominates the allocation where every student is assigned to her home university as it increases the welfare of some students while leaving the welfare of others unchanged.

2.3 Auswahlverfahren der Hochschulen (ADH)

The ADH guarantees German universities to select most of their students according to a mixture of their own criteria and the average grade in the Abitur.

In the ADH universities may preselect their applicants before deciding about admission.[20] For this preselection, a mixture of different criteria is applied, which potentially includes the preference rank the applicant has given to the university.[21] After the preselection stage, which universities can delegate to the ZVS if they want to do so, universities decide over the preselected applicants. Unlike in the ABV and the WZV, strategic choices can mainly be expected in the (pre)selection process (1st step), not in the admission process (2nd step). This is due to two features of the procedure: First, some universities only preselect those students who give the university top priority. Second, applicants are allowed to renew their preference ordering for the universities they have been preselected for, once preselection is accomplished. This means that students may give first priority to a university only for being preselected – and then move the university down on the list before admission takes place.[22] This sort of strategic behaviour can be illustrated by an example taken directly from the official ZVS brochure:[23]

"*University "A" determines that only those applicants are preselected who have an average grade of 2.5 or better and who give top priority to university "A". Admission is therefore excluded if you rank this university as your second or third choice – even if you have an average grade of 1.0!*

Once preselection is accomplished (…) applicants have the chance to re-order the preference ranking of the universities they have been selected for. (…) It turned out that applicant Antje K. has been preselected for her first, second and fifth preferred universities. As she had only given top priority to university "A" for being preselected, she had had to rank her truly desired top university "B" as second preference. Now she can rearrange her preference ordering. Antje K. now puts university "B" as first and university "A" as second preference. University E (originally her fifth choice) moves forward to rank three."

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[20] Note that unlike the selection process in the other two procedures preselection in the ADH is not compulsory for the universities.

[21] Other criteria that can be observed are: weighted average of grades which reflect necessary qualifications for the subject, result in a subject specific scholastic test, apprenticeship relevant in respect of content and other criteria that are permitted by federal state legislation.
If preselection is delegated to the ZVS, the ZVS shortlists applicants by considering the preference rank the applicant has given to the university and the average grade in the *Abitur*.

[22] Admission takes place according to a bunch of criteria, where the average grade in the *Abitur* is predominant. Other criteria are: weighted average of those grades which reflect necessary qualifications for the subject, result in a subject specific scholastic aptitude test and apprenticeship relevant in respect of content.

[23] ZVS (2006), p.11. Translated by the authors.

2.4 Strategic behaviour due to the combination of the three procedures

There may be some strategic behaviour caused by the interdependence of the three procedures described. The following sequence of the three procedures is used: First, the ABV is administered. Once applicants are admitted or rejected, the WZV takes place for those applicants who are still unassigned. Finally, those candidates who have not been admitted either through the ABV or through the WZV can participate in the ADH. Figure 1 illustrates the sequential ordering of the three procedures. As described above, there may remain seats untaken in the ABV if not all selected applicants can be admitted to one of their preferred universities. These remaining seats (x) are additionally administered through the WZV.

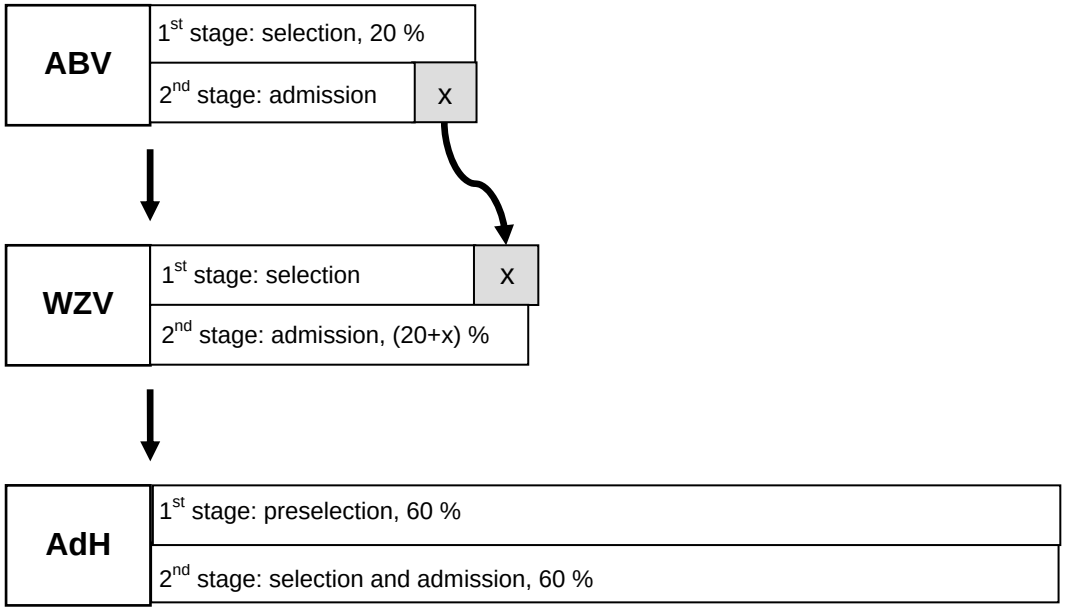

Figure 1: Admission Procedures – Sequential Order and Percentage of Seats Allocated

It is important to note that the **procedures are not** completely **independent**: Applicants who have been admitted in the ABV (or in the WZV) are not allowed to take part in the ADH. This means that applicants not only have to behave strategically *within* one procedure but also *between* the three procedures. This problem is especially severe for applicants with a very good grade in the *Abitur*.

Let us exemplify this with Stefan who is top of his class. At first, he takes part in the ABV, where he is selected because of his excellent average grade. Stating his preferences for the ABV, his considerations are twofold. On the one hand, Stefan would like to be admitted in the ABV, in order to ensure that he will get admitted at all.[24] On the other hand, Stefan knows

[24] It is possible that very qualified students remain unassigned. An extreme case we found in the data is the following: A student with a final grade of 1.1 applies to study medicine. He is selected in the ABV, but does not receive his first choice university because the tie is at a final grade of 1.1 *and* social criterion 4 (living close to the

that he has a good chance of being admitted in the ADH because of his very good average grade. Thus, he does not want to be admitted through the ABV to a university that ranks lower in his preference list than a university he would be admitted to through the ADH. Thus, we anticipate that his stated preferences in the ABV contain more truthful preference revelation than without the second chance of the ADH in the sense that he can risk to rank only very popular universities. For the same reason, he might even prefer to submit a truncated list of preferences in the ABV if he thinks that he has a good chance to receive one of his first preferences through the ADH. I.e. he prefers not being admitted through the ABV to receiving a university that is rather low on his preference list.

3. Description of the Data

We have access to a database of the ZVS covering all applications for the winter term 2006.[25] The following six subjects are centrally administered and part of our dataset: biology, medicine, pharmacy, psychology, animal health and dentistry. The dataset records all information provided by the applicants. This includes data on individual characteristics such as age, sex, and the place of living. Applicants also report the average grade of their Abitur, their waiting time since completing secondary school, information on military or social services, and potentially social criteria important to the selection process. Furthermore, the database provides information on the type(s) of admission procedure a prospective student has participated in as well as his or her preferences concerning the subject and the place of study that have been stated for the different procedures. For each of the admission procedures, success or failure of the application is reported. Applicants that have been selected in the first stage of the selection procedure (but were not necessarily admitted) can be identified by applying the selection criteria made public by the ZVS (2006c). Additionally, we create a dummy for each stated preference indicating whether the applicant has chosen an over-demanded university for her or his subject of choice.

Definition: A university is **over-demanded** for a given subject and within a given procedure if only selected applicants that have ranked the university as their first choice have a chance of being admitted.

Note that whether or not a university is over-demanded may depend on both the subject considered and the admission procedure. Information about whether the university was over-demanded for a certain subject in previous years is publicly available from the ZVS (2006c).

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university town). As the student has not chosen his hometown university, he loses out in the social criteria and remains unassigned after the first round. His second and third choices are over-demanded. In the WZV, he is not selected as he has no waiting time. In the ADH, the four universities on his list select their students themselves, and the person does not get selected. As a result, this person does not get a seat at all. This student could have been assigned a seat at his second preferred university if he had submitted a list in the ABV with his second-ranked university first.

[25] Individual data have been made anonymous.

After excluding those applicants who received their university entrance diploma not in Germany, we are left with a total number of 65,254 observations.[26] Almost every applicant has submitted a preference list for each of the three procedures. In fact, 61,317 prospective students have chosen to take part in the ABV, 60,935 in the WZV and 62,758 have supplied a preference list for the ADH.

For each application procedure the descriptive statistics in Table 1 contrast the characteristics of those applicants that have been selected at the first stage with those of the unsuccessful candidates.[27] The results illustrate the different selection criteria applied in the three procedures. Applicants selected in the ABV have received extraordinarily good grades in their *Abitur*. While candidates successful in the ADH performed somewhat worse, they still distinguish themselves from the rejected applicants by their good final grades. On the contrary, students selected in the WZV are characterised by a relatively poor performance in school, but they all have been waiting for a long time. The table also shows that the largest share of applicants are potential medical students, and that subject preferences matter for the success probability of an application.

	ABV		WZV		ADH	
	Selected	Not Selected	Selected	Not Selected	Accepted	Rejected
Personal Characteristics						
Age (Years)	20.20	21.27	25.86	20.91	20.20	21.70
Female	.7236	.6723	.6142	.6743	.7068	.6592
Grade	1.198	2.330	2.606	2.292	1.802	2.472
Waiting Time (Semester)	.6732	2.21	9.035	1.649	.7350	2.817
Subject Preferences						
Biology	.1371	.0778	.1755	.0653	.1925	.0316
Medicine	.4411	.4992	.4122	.5107	.3763	.5491
Pharmacy	.0944	.0574	.0945	.0531	.0974	.0435
Psychology	.1915	.2024	.2055	.1983	.2074	.1965
Animal Health	.0565	.0795	.0466	.0848	.0544	.0895
Dentistry	.0794	.0836	.0657	.0877	.0720	.0898
N	3,274	58,043	6,024	54,911	17,470	45,288

Table 1: Descriptive Statistics, by Admission Procedure

[26] In section 4.3 we make use of the fact that in the WZV the proximity of an applicants' place of living to the preferred university is used as an (subordinated) admission criterion which may induce strategic behaviour. Since this criterion can – by definition – not be fulfilled by most foreigners, we have restricted the dataset as described.

[27] Since the preselection step is not obligatory in the ADH, the characteristics of accepted and rejected students are compared for this procedure.

4. Empirical Evidence of Strategic Behaviour

As a first step towards evaluating the performance of the assignment mechanism, the stated and received preferences of the selected candidates can be compared. We can simply count the number of times where the first preference of an applicant is satisfied, the number of times the second preference is satisfied etc. Table 2 shows that in the ABV 58.33 % of the selected students are admitted to their first preference. In the WBV this percentage is somewhat higher at 61.80 %. Notice that the second to sixth preference are only rarely satisfied in both procedures. This is a direct effect of the assignment mechanism used by the ZVS which gives priority to those students who have listed a university as their first choice. However, stated and true preferences may not coincide, which greatly reduces the value of stated preferences as a measure of success.

	ABV		WZV	
	Number	Per cent	Number	Per cent
1st Preference	1,909	58.33	3,723	61.80
2nd Preference	214	6.54	395	6.56
3rd Preference	80	2.44	198	3.24
4th Preference	54	1.65	114	1.89
5th Preference	57	1.74	104	1.73
6th Preference	27	0.82	61	1.01
Other Preference	-	-	447	7.42
Unassigned	933	28.48	982	16.30
	3,274	100.0	6,024	100.0

Table 2: Preference Received By Applicants Fulfilling Selection Criteria

In what follows, we shed some light on the sources of preference misrepresentation and use the data to show that observed behaviour is consistent with the incentives to act strategically. The main difficulty for studying strategic behavior empirically is the unobservability of the students' true preferences. We therefore have to use indirect measures to investigate whether students reveal their preferences truthfully or whether they behave strategically.[28] In the following, three such indirect measures are presented. First, we argue that applicants have an incentive to truncate their preference lists in the ABV (but not in the WZV) and show that a number of selected students behave accordingly. Next, the observed instability of preferences across procedures provides further evidence for strategic behaviour in the application procedure. Finally, we exploit the fact that it is a (weakly) dominated strategy to state an over-demanded university at any preference rank other than the first one. A proportion of students takes this feature of the mechanism into account and adjusts their preference orderings strategically.

[28] For a related analysis based on data from school choice in Boston see Abdulkadiroglu et al. (2006).

4.1 Truncated Preference Lists

A considerable number of students remain unassigned in ABV and WZV, although they fulfil the selection criteria. This number is particularly high in the ABV where more than one quarter of the selected students are not admitted to any university. This observation is in line with the incentive to go for the top choice in the ABV and in case of no success hope to be admitted in the ADH. In fact, 716 (or 76.74 %) of the selected students who have remained unassigned in the ABV procedure have obtained their top choice in the ADH.

Table 3 displays the percentage of students who list only one university, only two universities etc. in the ABV and in the WZV. Note that almost all students supply a preference list for the ABV and the WZV, even if their final *Abitur* grade is by far not good enough or even if the number of semesters they have waited will not be sufficient to be selected. The second and fourth columns show that the majority of students list all six universities. Even if all applicants are considered, significantly more prospective students truncate their preferences lists in the ABV. A t-test reveals that the difference is statistically significant at any conventional level However, we are mostly interested in behaviour of those students who are finally selected, i.e. those students who can expect to be assigned through the ABV or the WZV, respectively, and therefore try to make a smart choice when listing their preferences. In the ABV (third column) more than a quarter of the selected students only list one university. These students obviously understand that they should not try to get matched by all means in the ABV, but that they should rather try to get their top choice either through the ABV or through ADH.

Now consider the last column in table 3 for those students who get selected in the WZV. The percentage of students listing only one university is much higher in the ABV than in the WZV. In the WZV no analogous incentive exists as in the ABV because the successfully selected students in the WZV usually have so poor grades that they have no chance of being admitted through the ADH.

Number of Universities Ranked	ABV		WZV	
	All Applicants	Selected Applicants	All Applicants	Selected Applicants
1	11.05 %	26.11 %	8.85 %	17.16 %
2	6.11 %	9.65 %	4.07 %	6.51 %
3	7.46 %	11.79 %	4.29 %	5.89 %
4	5.52 %	8.03 %	2.62 %	3.20 %
5	9.62 %	8.06 %	8.16 %	5.10 %
6	60.23 %	36.35 %	72.01 %	62.13 %
N	61,317	3,274	60,935	6,024

Table 3: Number of Universities Ranked by Applicants

The strategic choice to rank only one's first preference(s) in the ABV has an important side-effect. Around 28% of the slots the universities plan to fill through the ABV are not taken in

the ABV because certain universities do not get listed often enough by applicants. These slots are then filled through the WZV. This implies that some universities receive by far more than 20% of their students through the WZV. Thus, they admit weaker students due to the strategic choices in the ABV than if applicants submitted a complete list of their true preferences (if at least some of the true preference lists contain universities that are not over-demanded).

4.2 Stability of Preferences across Procedures

If applicants revealed their preferences truthfully, stated preferences should not vary across the three procedures. However, the criteria employed by the ZVS to admit applicants differ between procedures and it can therefore pay off for an applicant to submit different preference lists. In particular, if there are too many applicants for one university who all satisfy the selection criterion, a number of social criteria are employed in the WZV. No such assignment rule exists in the ABV. Thus, we can ask whether these different selection criteria lead to differences in the preference listings. Similarly, the universities have their own criteria for the ADH which can slightly diverge from the criteria of the ABV.

Table 4 reports the discrepancies between the preference lists applicants submit in the different procedures. Discrepancies at a certain preference rank can result either from naming different universities or from not stating a preference in one list but stating one in the other list. The results show that a considerable number of subjects submit different lists in the three procedures. This can be ascribed to strategic considerations. Furthermore, the consistency between stated preferences is generally higher for higher ranks of the preference list than for lower ranks, no matter which procedures are compared to each other. First, this is a logical consequence of the fact that certain changes like removing one university from the list automatically lead to changes at lower ranks. But it is also in line with the strategic incentives. Of course, subjects might already misrepresent their first choice in an attempt to get the preferred university for which the best shot is the first priority. But for later ranks, it is clear that additional strategic issues arise, e.g. because applicants have an incentive to truncate their list in the ABV but not in the WZV as argued above. Consistent with this, we find that for lower preference ranks the discrepancy between the lists increases to up to 58%

In the ADH, applicants have the possibility to state a preference list for the preselection process at the first stage and, once preselected, to modify their preference ordering for admission. As we have shown earlier, strategic behaviour in the ADH is expected to take place at the first stage because some universities only preselect candidates top-ranking them. When comparing stated preferences for the preselection and admission process it is

evident that the majority of applicants understands this and rearranges preferences after being preselected.[29]

	ABV vs. WZV	ABV vs. ADH	WZV vs. ADH	ADH: preselection vs. admission*)
1st Preference	24.43 %	26.90 %	31.15 %	61.29 %
2nd Preference	32.87 %	38.46 %	42.75 %	76.48 %
3rd Preference	37.55 %	43.25 %	48.09 %	85.39 %
4th Preference	42.66 %	46.75 %	52.88 %	89.19 %
5th Preference	45.49 %	47.24 %	55.05 %	93.67 %
6th Preference	49.05 %	48.65 %	57.96 %	93.98 %

*) As preselection in the ADH is only administered by the ZVS for a subgroup of universities, we do not have information on all applicants. Hence, in the third column we restrict our analysis to applicants for whom we have preference lists for both preselection and selection. There is no obvious reason why those universities relying on the ZVS for preselection differ from the other ones in a way that is related to our focus on strategic behaviour.

Table 4: Discrepancy between Preference Lists

Let us now turn to the WZV. The quantitatively most important (subordinated) criterion for admission is whether a student who is registered at his parents' house applies to the closest university. While this information is not directly provided in the dataset, we can identify the university closest to the place of living of an applicant. We then compare the number of applicants in the two procedures listing the closest university. Strategic behaviour would lead to a higher number of such applications in the WZV than in the ABV.[30] This is exactly what we observe (see Table 5) although at first glance the differences are not large.[31] However, notice again that the difference is strongest among the selected applicants, i.e. the group of students with a real chance of being assigned in the respective procedure, ABV or WZV, and, hence, a strong motive to optimise their preference ordering. This finding is again consistent with a number of applicants choosing strategically.

	1st Preference	2nd Preference	3rd Preference
ABV			
All Applicants	52.07 %	16.65 %	8.50 %
Grade ≤ 2.0	49.37 %	16.07 %	9.07 %
Selected Applicants	49.88 %	14.77 %	8.94 %
WZV			
All Applicants	53.33 %	17.09 %	8.60 %
Waiting Time ≥ 6	63.49 %	18.73 %	7.62 %
Selected Applicants	65.27 %	18.95 %	8.16 %

Table 5: Fraction of Applicants with Preference for Closest University

[29] Note, however, that some of the discrepancies reported here will not reflect strategic behaviour. In particular, prospective students who are not preselected for all of their stated choices are forced to change their preferences in the second step of the admission procedure. But as the criteria applied to preselect applicants are made public in advance and are not determined endogenously as the selection criteria in ABV and WZV, most applicants do not have to change their preference ordering for this reason.

[30] We implicitly assume here that applicants in the two procedures are alike with respect to their inclination to move away from their home town.

[31] The difference between the proportion of students choosing a home university as their first preference in the ABV and in the WZV is statistically significant even if all applicants are considered.

Finally, Table 6 displays the number of cases where students switch preferences from their home university (as defined above) to a university away from home or in the opposite direction in the ABV and WZV procedures. For this table we only look at applicants who state different preferences in the ABV and the WZV. Note that by analysing the behaviour of one candidate in different procedures we circumvent the problem that candidates selected in the two procedures may systematically differ from each other in terms of their mobility.

Concerning the first preference, the number of cases where applicants switch their preference lists according to the strategic incentive, i.e. choosing their home university in the WZV and some other university in the ABV, is five percentage points higher as in the opposite direction. The difference is statistically significant, but relatively small. The small difference may have to do with the fact that only very few candidates have a chance to be admitted in both the ABV and the WZV (and, hence, have a motive to behave strategically in both procedures). When restricting the analysis to this group only, the gap indeed widens markedly to about 14 percentage points. Again, this shows that a number of applicants adjust their preference lists to the criteria used in the selection procedure and that preference lists cannot be taken to represent true preferences in all cases.

	All Applicants		Applicants with Grade ≤ 2.0 & Waiting Time ≥ 6	
	Number	Per cent	Number	Per cent
Away University ABV → Home University WZV	2,256	27.19	35	34.65
Home University ABV → Away University WZV	1,835	22.11	21	20.79
No Change between Procedures	4,207	50.70	45	44.55
	8,298	100.0	101	100.0

Home University: University is among the universities that are located closest to the place of living of an applicant.

Table 6: Strategies of Applicants Changing their Preferences between ABV and WZV

4.3 Strategic Preference Ordering

Next, we exploit the fact that under the priority matching mechanism it is a (weakly) dominated strategy to state an over-demanded university at any preference rank other than the first one. The reason is the following: By the definition above, the number of applicants ranking an over-demanded university as their first choice exceeds its number of seats. Thus, it is never successful to rank this university second or lower. Consider two different possible strategies by the applicants. Under Strategy I we summarize all preference lists with an over-demanded university as first and second preference. Strategy II covers all cases where an over-demanded university is ranked first, but a university that is not over-demanded is

ranked second. While the percentage of first preferences received is almost the same for both strategies, there is a notable difference for the second preference (see table 7). Both in the ABV and the WZV, Strategy I is never successful for the second preference, while more than a quarter of students receive their second preference if it is not over-demanded (Strategy II).[32] These results are not surprising given the priority matching mechanism, but they show very clearly that listing an over-demanded university as second preference is (weakly) dominated.

	ABV		WZV	
	Strategy I	Strategy II	Strategy I	Strategy II
1st Preference	47.68 %	42.78 %	46.49 %	49.91 %
2nd Preference	0.00 %	29.75 %	0.00 %	34.29 %
3rd Preference	6.68 %	2.55 %	7.28 %	2.26 %
4th Preference	4.87 %	0.99 %	4.44 %	0.78 %
5th Preference	5.10 %	1.13 %	4.15 %	0.52 %
6th Preference	2.38 %	0.42 %	2.37 %	0.43 %
Other Pref.	-	-	17.34 %	3.13 %
Unassigned	33.30 %	22.38 %	17.94 %	8.68 %
N	883	706	1,794	1,152

Strategy I: over-demanded university ranked as first and second choice
Strategy II: over-demand university ranked as first, not over-demanded university as second choice

Table 7: Preference Received by Strategies (Selected Applicants Only)

We can now study whether applicants are aware of this property of the mechanism and adjust their preference lists accordingly. An interesting aspect in this regard is that the ZVS makes applicants aware of the fact that stating an over-demanded university as second or third choice never pays off. In an information brochure of the ZVS it reads:[33]

"Applicants with very good marks should not bet to become admitted at their preferred university at all costs. For instance, if there are 50 free seats at a university which is very popular and which has thus been ranked on position one by the student, 10 seats can be allocated by the ABV. If there are many applicants ranking this university at position one, only the ten best applicants will be admitted; this possibly means that not even all selected applicants stating this university as their first choice will be admitted. As a consequence of the described admission process by stated preferences, applicants stating this place of study as their second or third choice cannot be admitted all the less."

Do applicants behave accordingly? Consider first an example. In 2006, among all applicants for medicine in the ABV, 2,551 students listed the Charité in Berlin as their first preference. Only 812 listed it as their second preference and 776 as their third. As the Charité is over-demanded, this drop between the first and the second preference on the list can be explained by strategic considerations. An alternative explanation is that preferences for the

[32] Note that Strategy II is not necessarily successful for the second preference as this preference could be over-demanded when applicants ranking it first and second are considered.
[33] ZVS (2006b), p.2. Translated by the authors.

Charité are by coincidence characterized by a large number of students whose first preference it is and a much smaller number of students with the Charité as their second or third preference. In order to test for this alternative explanation, we will now look at all universities.

Table 8 presents the percentage of over-demanded universities at each rank of the preference list for both the ABV and WZV. First, notice that selected applicants choose over-demanded universities more often than all applicants together. This effect is particularly strong in the ABV with 46.95 % of all applicants and 67.56 % of the selected applicants ranking an over-demanded university first. If the selected applicants are a random sample with regard to their preferences, then this hints at strategic considerations of the applicants who submit a list of preferences that depends on their own grade in the ABV.

An alternative explanation would be that preferences of students vary systematically between talented and less talented students such that talented students prefer over-demanded (possibly more or less demanding) universities. However, given that the state exam is generally the same at all universities in medicine, pharmacy etc., there is no obvious reason why this should be the case. Still, we cannot exclude this alternative explanation and therefore only conclude that the observed pattern is consistent with subjects stating preferences strategically.

	ABV		WZV	
	All Applicants	Selected Applicants	All Applicants	Selected Applicants
All Applicants				
1st Preference	46.95 %	67.56 %	67.00 %	72.00 %
2nd Preference	39.93 %	54.73 %	63.27 %	66.67 %
3rd Preference	39.53 %	53.16 %	61.62 %	63.40 %
4th Preference	40.56 %	50.38 %	59.11 %	59.93 %
5th Preference	38.97 %	44.09 %	57.00%	57.53 %
6th Preference	40.42 %	47.23 %	56.78 %	57.31 %
Applicants who have ranked 6 universities				
1st Preference	44.44 %	67.56 %	64.20 %	69.33 %
2nd Preference	37.98 %	55.97 %	60.04 %	64.71 %
3rd Preference	37.67 %	54.12 %	58.84 %	61.31 %
4th Preference	39.97 %	51.00 %	56.63 %	58.30 %
5th Preference	39.71 %	46.39 %	56.74 %	58.06 %
6th Preference	40.42 %	47.23 %	56.78 %	57.31 %

Table 8: Fraction of Over-demanded Universities in Stated Preferences

Table 8 also reveals that the selected applicants in both the ABV and the WZV choose an over-demanded university very often as their first preference. For the second preference there is a clear drop, e.g. from 67.56 % to 54.73 % in the ABV. The differences between second and third, third and fourth etc. are much smaller than the drop between first and

second preference.[34] This is consistent with a proportion of students understanding that they should never rank over-demanded universities at the second to sixth place.

An alternative approach to the question of how often over-demanded universities are ranked second or lower is to take every subject-university combination as a unit of observation. We do this in Table 9 which shows the average number of applications per university for a given subject that is either over-demanded (first column) or not over-demanded (second column) at the university considered. Over-demanded universities are ranked clearly more often as first preference than as second or third preference. In contrast, universities that are not over-demanded are ranked about equally often as first and second preference. Again, if some students understand the sub-optimality of ranking an over-demanded university second or lower, this is the pattern that would result.

	ABV		WZV	
	Over-demanded Universities	Not Over-demanded. Universities	Over-demanded Universities	Not Over-demanded Universities
1st Preference	475.68	356.39	458.81	326.51
2nd Preference	354.33	365.10	389.90	337.07
3rd Preference	320.81	331.80	363.26	334.08
4th Preference	309.72	302.60	330.05	337.47
5th Preference	282.74	283.23	318.99	327.54
6th Preference	261.91	270.11	311.44	320.86
All Preferences	2005.19	1909.23	2172.45	1983.54
Observations	57	82	80	59

The subject animal health was excluded since applicants can only chose between five universities.

Table 9: Applications per University in a Given Subject

The observation of a significant drop in the number of over-demanded universities ranked as first and second preference does not necessarily imply strategic behaviour. First, a university might receive a significantly larger number of applications ranking the university first than applications ranking it second because the university is over-demanded and, hence, prospective students understand the strategic advantage of giving it first priority. Alternatively, the observed drop may simply hint at a large number of applications ranking the university at position one, which, by definition, causes the university to be over-demanded. In the following we will use instrumental variable regressions in order to analyse the issue of causality more thoroughly. The results for the ABV and the WZV are reported in tables 10a and 10b.

[34] This observation also rules out that the observed drop simply results from the fact that once an over-demanded university is chosen at the first preference rank, the pool of over-demanded universities shrinks and, hence, the likelihood of choosing an over-demanded university at the second rank decreases as well. In particular, similar drops should then also be evident for ranks further down the list. Importantly, the pool of over-demanded universities is quite large. In fact, at about 41 % (57.6 %) of all university-subject combinations are over-demanded in the ABV (WZV). Hence, even after choosing an over-demanded university the applicant is left with a considerable number of potential choices that are over-demanded as well.

The difference between the number of applications ranking university *i* for subject *j* at position *k* normalised by the total number of applications at the two adjacent ranks is used as the dependent variable. Accordingly, the variable to be explained is bounded by ± 1 and takes a value of 0 in case of a balanced number of applications at the two ranks considered. The normalisation ensures that the dependent variable is not influenced by the size of a university. Otherwise, we would risk biased estimates given that the probability of a university to be over-demanded may be related to its size. The dependent variable is regressed on a dummy indicating whether or not subject *j* is over-demanded at university *i*. Furthermore, a full set of subject dummies is included.

	Dependent Variable: $(Pref_{ijk} - Pref_{ijl}) / (Pref_{ijk} + Pref_{ijl})$				
(k,l)	(1,2)	(2,3)	(3,4)	(4,5)	(5,6)
OLS Estimation					
Over-demanded	.1391***	-.0060	.0145	-.0106	.0029
	(.0428)	(.0283)	(.0252)	(.0135)	(.0151)
Constant	.0244	.0835*	.0716*	.0717***	.0612***
	(.0388)	(.0445)	(.0366)	(.0177)	(.0177)
Subject Dummies	Yes	Yes	Yes	Yes	Yes
R^2	.1287	.0171	.0301	.0453	.0275
N	144	144	144	144	139
2SLS Estimation					
Over-demanded	.3126**	-.0458	-.0944	.0145	.0401
	(.1542)	(.1056)	(.1073)	(.0431)	(.0358)
Constant	-.0431	.1089	.1278*	.0612**	.0433
	(.0830)	(.696)	(.0722)	(.0284)	(.0271)
Subject Dummies	Yes	Yes	Yes	Yes	Yes
N	122	122	122	122	118
Diagnostic Tests (p-values)					
Overidentification	.1070	.6430	.8893	.3162	.9810
Endogeneity	.1002	.9676	.2046	.6120	.2063
F-Test of Instruments	.0000	.0000	.0000	.0000	.0000

***, **, *: statistically significant at the 1, 5, 10 percent level.
$Pref_{ijk}$: Number of Applications Ranking University *i* for subject *j* at position *k*.
Standard errors, robust to heteroscedasticity and intra-group correlation, are reported in parentheses.
The null hypothesis of the test of overidentifying restrictions (Sargan-Hansen test) is that the instruments are valid instruments.
Under the null hypothesis of the endogeneity test the over-demand variable can actually be treated as exogenous.

Table 10a: Preference Discontinuities - Regression Results, ABV

We start with estimating our regression model by conventional OLS. As expected, the estimated coefficient of the dummy for over-demand is positive and highly statistically

significant in the regression on the difference between ranks 1 and 2. This applies to both application procedures but not to ranks further down the preference list.[35]

	Dependent Variable: $(Pref_{ijk} - Pref_{ijl}) / (Pref_{ijk} + Pref_{ijl})$				
(k,l)	(1,2)	(2,3)	(3,4)	(4,5)	(5,6)
OLS Estimation					
Over-demanded	.0952***	.0315	.0485*	.0128	.0024
	(.0315)	(.0255)	(.0256)	(.0174)	(.0165)
Constant	-.0016	.0267	.0054	.0131	.0344
	(.0489)	(.0450)	(.0346)	(.0233)	(.0376)
Subject Dummies	Yes	Yes	Yes	Yes	Yes
R^2	.0703	.0162	.0310	.0245	.0082
N	144	144	144	144	139
2SLS Estimation					
Over-demanded	.3944*	.1345	-.0389	-.0492	-.0238
	(.2230)	(.1100)	(.1169)	(.0669)	(.0817)
Constant	-.2165	-.0312	.0860	.0534	.0426
	(.1915)	(.0848)	(.1048)	(.0544)	(.0800)
Subject Dummies	Yes	Yes	Yes	Yes	Yes
N	122	122	122	122	118
Diagnostic Tests (p-values)					
Overidentification	.5653	.0603	.9314	.5128	.7976
Endogeneity	.0580	.1203	.4890	.4982	.8444
F-Test of Instruments	.0001	.0001	.0001	.0001	.0001

***, **, *: statistically significant at the 1, 5, 10 percent level.
$Pref_{ijk}$: Number of Applications Ranking University *i* for subject *j* at position *k*
Standard errors, robust to heteroscedasticity and intra-group correlation, are reported in parentheses.
The null hypothesis of the test of overidentifying restrictions (Sargan-Hansen test) is that the instruments are valid instruments.
Under the null hypothesis of the endogeneity test the over-demanded variable can actually be treated as exogenous.

Table 10b: Preference Discontinuities - Regression Results, WZV

In a next step, we tackle the endogeneity issue by instrumenting the dummy for a university being over-demanded. A valid instrument should be correlated with the explanatory variable but uncorrelated with the error term. Three instruments are proposed that arguably fulfil these criteria. First, the average value of the over-demand dummy of university *i* in all subjects $i \neq j$ is used as an instrument for subject *j* at university *i*. Intuitively, universities that are very popular in a given subject should be more likely to be popular in the subject under consideration as well. For instance, knowing that biology at LMU Munich is in high demand should also reveal information about the popularity of the respective medical faculty since

[35] The dummy is also significant at the 10 per cent level in the regression on the difference between ranks 3 and 4 in the WZV. However, the coefficient is comparably small and no such effect is found for the other application procedure.

common factors should affect demand for both subjects. However, being in over-demand for subject *i* should not have a direct effect on the difference between the number of applicants ranking a university as their first or as their second choice in subject *j.*

As further instruments we utilise the (yearly) population growth of the city a university is located in and a dummy indicating a population size of above 500,000 inhabitants. Both variables are meant to proxy the attractiveness of the city environment, which is likely to play a major role in determining whether or not a subject at a university is over-demanded. Neither population growth nor population size should be directly related to our dependent variable. The lower part of tables 10a and 10b reports 2SLS estimation results. For both application procedures the dummy for over-demand still enters with a positive sign and is statistically significant in the regression on the difference between ranks 1 and 2. The point estimate of the dummy (but also the standard error) increases markedly for both procedures.

Turning to the diagnostic tests, a standard Sargan-Hansen test cannot reject the null hypothesis that our instruments are uncorrelated with the error terms and, hence, valid.[36] Moreover, in both estimations the instruments are jointly significant in the first step regression at any conventional significance levels. Thus, the instruments are indeed correlated with the endogenous variables thereby also fulfilling the second requirement for an instrumental variable. Since the 2SLS estimator is generally less efficient than its OLS counterpart, the latter is preferred over the former in the absence of an endogeneity problem. Perhaps surprisingly, the null hypothesis that the over-demand variable can actually be treated as exogenous could not be rejected for the ABV (p-value of 0.1002). The result indicates that it may not be necessary to resort to instrumental variable techniques. However, evidence for endogeneity is found in the estimation referring to the WZV. As anticipated, endogeneity is not an issue in the regressions involving ranks further down the preference list.

In summary, the difference between the number of applicants ranking a university as their first or as their second choice is significantly higher when the corresponding subject is over-demanded than when it is not over-demanded. This is consistent with applicants refraining from stating an over-demanded university second on their list, while it can be perfectly rational to state it as a first choice. Causation indeed seems to run from a university-subject combination being over-demanded to the corresponding (strategic) application behaviour.

[36] In the estimation for the ABV (difference between rank 1 and 2) the p-value of the Sargan-Hansen test is 0.1070 and, hence, close to the 10 per cent significance level. However, dropping the instrument for population size would increase the p-value considerably (0.2244) without changing the qualitative results.

5. Policy Implications and Concluding Remarks

In summary, this paper shows that the allocation mechanism used in the German centralised university admission system is not strategy-proof. In fact, applicants may have an incentive to misrepresent their preferences. Using a comprehensive dataset of the ZVS, we have evidence that a sizable number of prospective students understand the mechanism and behave strategically when submitting their preference lists. First of all, the data is consistent with many students engaging in strategic preference ordering within the different procedures. Second, applicants truncate their preference lists in accordance with the incentive provided by the allocation procedures. Third, we have shown that preferences are not stable across procedures hinting again at some degree of strategic behaviour. Since strategic preference lists may imply inefficient matches, these results lead to the question of how the current mechanism could be improved. We will sketch one small change of the current mechanism to illustrate how one of its shortcomings can be remedied. But we will also argue that a more fundamental change might be warranted in order to get rid of other more severe shortcomings of the mechanism.

A simple change in the mechanism that could be advocated concerns the allocation of seats between the three procedures. Currently, unfilled spaces from the ABV are moved to the WZV. Due to strategic behaviour of applicants who truncate their preference lists in the ABV, this happens often. A simple measure to prevent the inflation of the number of spaces allocated through the WZV is to move open spaces from the ABV to the ADH instead. In this way, universities get students from the same pool as in the ABV, namely those students with good final grades.

However, many problems of the current mechanism remain unsolved by minor changes of this kind. As we have shown the ZVS currently applies priority matching within each of the three procedures. Algorithms based on priority matching are generally prone to strategic preference manipulations and can thus lead to inefficient matchings.[37] We will briefly sketch the Gale-Shapley mechanism which is central to the literature on matching algorithms. It was first described by Gale and Shapley (1962) although similar ideas had already been used since the 1950's in the US clearinghouse for the first jobs of doctors.[38] In the last years, the algorithm (with necessary adaptations to the special requirements of each market) has been implemented for example in central clearinghouses for admissions to high schools in New York City and to public schools in Boston as well as in the market for medical fellowships in the US and medical labour markets in Canada and Great Britain.[39] The Gale-Shapley

[37] See Roth (1991).
[38] See Roth (forthcoming).
[39] See Abdulkadiroglu, Pathak, Roth (2005) as well as Abdulkadiroglu, Pathak, Roth (2006) for NYC high school admissions and Abdulkadiroglu, Pathak, Roth, Sönmez (2006) as well as Chen and Sönmez (2006) on the Boston public school system. For an overview see Niederle and Roth (2007).

mechanism can also be used to match students to universities. As several applicants are assigned to each university, the application procedure creates a many-to-one matching problem in a two-sided market. In a two-sided market, e.g. with students and universities, individuals on each side have preferences over those with whom they are matched and are (potentially) strategic agents.

The Gale-Shapley student optimal mechanism selects the student optimal stable matching.[40] This deferred acceptance algorithm leads to a stable matching in the sense that everybody prefers his match over no match at all, and that there is no student and university who are not matched but who would both prefer to be. In addition, it is the mechanism that leads to the stable matching that is preferred to all other stable matchings by the students. This student proposing deferred acceptance algorithm works as follows:

Step *1*: Each applicant proposes to his *1st* choice university. Each university tentatively assigns its seats to its proposers one at a time following their rank ordering. When all seats are taken, any remaining proposers are rejected.

Step *k*: Each applicant who was rejected in the previous step proposes to his next choice. Each university considers the applicants it has been holding together with its new proposers and tentatively assigns its seats to these students one at a time, following its rank ordering. When all seats are taken, any remaining proposers are rejected.

The algorithm terminates when no student proposal is rejected. Each student is assigned to his final tentative assignment. If a student is rejected by all universities to which he has applied, the student remains unassigned.

What can be gained by adopting the Gale-Shapley student-optimal mechanism? Ergin and Sönmez (2006) point out the efficiency problems of a priority matching mechanism similar to the one used in the ABV and the WZV.[41] They analyze the so-called Boston mechanism which shares the property of the ABV and the WZV at the admission stage that students who have ranked a school higher are strictly preferred by this school to students who have ranked it lower. In their paper, the equilibria of the Boston mechanism are compared to the outcome of the student-optimal stable mechanism, and it is shown that the outcome of the latter is equal to or Pareto dominates the Nash equilibrium outcomes of the Boston mechanism. Thus, a transition to the student-optimal mechanism can lead to significant efficiency gains.

[40] Analogously, the Gale-Shapley college optimal mechanism selects the college optimal stable matching.
[41] See also Roth (1991) who shows that priority matching systems can produce unstable matchings and that it is not a dominant strategy to reveal one's true preferences.

However, the Gale-Shapley student optimal mechanism requires a consolidated preference list on both sides of the market. This is simple for the applicants. If strategic behaviour does not pay out, applicants do not suffer from having to submit one single list (instead of three in the current mechanism). A single preference ordering for every university, however, is more difficult to realise: The current German system has a number of special features such as quotas for students with long waiting times. These priorities must be taken into account when reorganizing the system of university of admissions. On the basis of our analysis, we can only make some cautious first suggestions.

1. Our data show that the ABV and the ADH procedures do not differ much in terms of the characteristics of students admitted through them. In fact, the majority of students selected but not admitted through the ABV get a seat through the ADH procedure. It therefore seems conceivable to merge these two procedures into one.[42] Universities could submit preference lists that are either based on one single criterion (e.g. the final grade) or on their own set of criteria. Given also the preference lists of students, the Gale-Shapley student-optimal mechanism could then be applied to secure a stable matching that is optimal for students. This mechanism is strategy-proof for the students, and it is the only mechanism which combines a number of other desirable properties.[43]

2. We also see in our data that the groups of students admitted through ABV and ADH on the one hand and the WZV on the other hand are (almost) disjunct. This could be useful when considering maintaining two different procedures, each using the Galey-Shapley mechanism with one based on social criteria and the other based on academic achievement and preferences of the universities. Strategic considerations could be minimal due to the difference in focus groups, but this remains to be analyzed carefully.

Of course, a change of the mechanism must be accompanied by a political discussion about the importance of the various criteria. On the other hand, we have shown that the present mechanism leads to preference manipulations, inducing an inefficient matching outcome. Thus, independently of the criteria applied, the current mechanism can be made more efficient. Finally, it should be mentioned that even though the current mechanism is not strategy-proof it is rather successful in filling all available seats compared to many non-regulated decentralised markets.

[42] This has also been suggested by the Wissenschaftsrat (2004) in a statement highlighting the important role of the final grade as a predictor of academic success. After mentioning the possibility of allocating a number of slots directly to those with the best final grades (as in the ABV), it is explicitly mentioned that a combined procedure where the final grade plays a dominant role might be especially effective (p. 48).

[43] See Gale and Shapley (1962), Roth (1985), Roth and Sotomayor (1989). For the related student placement problem where the priority at schools is determined by e.g. exam scores see Roth (1982), Alcalde and Barberà (1994) as well as Balinski and Sönmez (1999).

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