Simultaneous Screening and College Admissions*

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Abstract

We develop a decentralized two-sided matching model with an imperfect screening device, the entrance examination, to analyze a problem of simultaneous screening in competition among top schools. The model predicts that the second best school could attract better students by choosing the same examination date as the best one only when they have similar prestige. We then test the model with a unique data set in Taiwan. Moreover, we identify departments' optimal choices based on revealed preferences and find that student quality was improved with such choices.

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1. Introduction

In many markets, participants simultaneously search and screen multiple potential options, but can only settle with one match. Their optimal static strategy, as demonstrated in Chade and Smith (2006), is to choose a portfolio among all possible options that balances marginal benefits and costs of adding options to the portfolio.[1] In some circumstances, however, participants' choices are also endogenously limited by actions of option providers. For example, firms compete for workers by setting job offer deadlines; schools compete for students by providing early decisions or choosing the same entrance examination dates; producers compete for consumers by announcing new products simultaneously. We are interested in studying whether such limitations could be a useful strategy of the option providers. In particular, we show that when participants have private information, option providers may screen desired matches by limiting participants' choice set because their choices partially reflect personal characteristics.

In this paper, we focus on a simultaneous screening problem that schools choose the same entrance examination dates as strategies to maximize the expected quality of enrolled students. The conflict of examination dates is a common phenomenon in Asian countries, such as China, Japan, Korea, and Taiwan. Their schools use entrance examinations to screen student quality, and students only can apply to one school when many have examinations on the same date. For example, in 2011, two top universities in Taiwan, the National Taiwan University (NTU) and National Cheng Kung University (NCKU), implemented the examinations of graduate programs on the same date.[2] In responding to public complaints, Chi-Chuan Hwang, the Provost of NCKU, said "Choosing the entrance examination on the same date is a strategy for the school to enroll high quality students."[3] To our knowledge, this claim has not been verified in academic research. Thus, we investigate the simultaneous screening problem of whether schools could compete for better students by choosing the same examination dates.

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[1] Chade and Smith (2006) introduce the simultaneous search problem that decision makers simultaneously choose costly portfolios of ranked stochastic options. Chade, Lewis, and Smith (2011) extend the simultaneous search to an equilibrium model in which students costly apply to colleges and colleges set admission standards to fill their capacity.

[2] Similarly, in 2012, two top universities in China, Peking University and Tsinghua University, had the same examination date for the undergraduate programs.

[3] The original statement is in Chinese and we translate it in English. It can be found in the United News on February 20, 2011, http://mag.udn.com/mag/campus/storypage.jsp?f_ART_ID=302578.

We develop a decentralized two-sided matching model of students with unobservable quality and schools with different prestige. Two schools decide the entrance examination dates sequentially and a conflicting strategy of the second school is defined as implementing the examinations at the same date as the first school. Students then decide to apply for which schools. Students can apply to at most one school if the examination dates conflict, otherwise they can apply to both schools. Finally, the score rankings of students are governed by a plausible joint distribution, so that the equilibrium can be solved according to expected payoffs. The equilibrium analysis shows that, in some cases, using the conflicting strategy cannot attract better students for the second best school. However, when the prestige of the second one is very close to the best school, students face a coordination problem and hence the conflicting strategy can be justified in the equilibrium. That is, when schools have similar prestige, the second best one could compete for better students by using the conflicting strategy.

The simultaneous screening problem is similar to the early decision problem in the early admissions models of Lee (2009), Avery and Levin (2010), and Kim (2010). In the last two decades, early admissions programs are widely used at selective colleges and universities in the U.S. and the common type is the early decision program in which students have to commit to enroll once they are accepted by the college.[4] In the simultaneous screening problem, students also have to decide the school to which they apply in the early stage of application.[5] Regarding school competition, one stylized fact of early admissions programs is that lower ranked (but still selective) colleges typically use early decisions (Avery, Fairbanks, and Zeckhauser, 2003). Avery and Levin (2010) provide an explanation called competitive effect that relatively lower ranked colleges could enroll some highly desired students who are uncertain about their abilities in the early decision program. This competitive effect seems to justify the aforementioned claim because NCKU indeed has lower rank compared to NTU.

Nevertheless, empirical investigations of Jensen and Wu (2010) and Chapman and Dickert-Conlin (2012) find no evidence that students from early decision programs have

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4 The other type is the early action program in which students are not committed to enroll if they are accepted by the college.

5 However, schools admit students according to the rank of scores in the simultaneous examination problem, whereas colleges admit students based not only on SAT scores but other signals such as enthusiasm about attending in the early decision program.

better academic performance in liberal arts colleges. The competitive effect, if any, is not significant in their samples, i.e., Hamilton College in Jensen and Wu (2010) and two unknown colleges in Chapman and Dickert-Conlin (2012). To our knowledge, there is no other empirical research on measuring the competitive effect at other selective colleges or universities with different rankings. In our model, such competitive effect should be a function of school's prestige or rankings. Specifically, a relatively lower ranked college could enroll some highly desired students only if its prestige is closed to the best one. Thus, one might have different empirical results about competitive effect from samples with various rankings. This explanation could unify theoretical implication of Avery and Levin (2010) and empirical findings of Wu (2010) and Chapman and Dickert-Conlin (2012) in early decision programs.

We test the model with a unique data set from Taiwanese graduate programs. NTU is generally considered the best university in Taiwan. In 2008, other four top universities jointed an alliance called the University System of Taiwan (UST), which is considered the second best one in Taiwan. Since then the examination dates implemented by UST are always conflicted with NTU. However, each departments of UST, still have the option to hold its own examination dates, which are different dates from NTU. Thus, within UST, we have some departments conflicting with NTU but the others do not conflict with it. Moreover, before 2008, the examination date is given by schools, and therefore exogenous to departments, while after 2008 it becomes an endogenous choice for UST departments. This provides a unique opportunity to test the model and control endogenous problems.

We then collect the examination dates of NTU and UST during 1998-2011 and use retardation rates to measure the quality of enrolled students per year. The retardation rate is defined as the proportion of students that are not qualified to graduate within the regular years in a department. Thus the retardation rates among departments can be served as a proxy for measuring student quality in our testing, after controlling for departmental specific factors.

The empirical results suggest that the second best school on average will have lower student quality if it conflicts with the best one on the examination date. However, for some departments with similar prestige to the best one, their students' quality is improved by applying the conflicting strategy. Moreover, because departments are allowed to choose whether to conflict with NTU after 2008, we also identify departments' optimal choices based on revealed preferences and find that student quality was improved with such choices. That is, departments at UST which decided to adopt a conflicting strategy when they had the freedom to choose the examination dates after 2008 did attract better students. In addition, those departments which previously conflicted with NTU but decided to avoid confliction after 2008 could have had better students if they had not been constrained to adopt the conflicting strategy before 2008. Those empirical results are consistent with the model predictions.

The rest of the paper is organized as follows. Section 2 presents the model and finds equilibria under different conditions. Section 3 tests the model with a unique data set from Taiwanese graduate programs and identifies the effect of conflicting strategy. Section 4 concludes.

2. Model

The two-sided matching model consists of two schools and three students. The timeline of the model is illustrated in Figure 1. First, schools decide whether to implement the entrance examinations on the same day or not. Second, after knowing the examination dates, students decide to apply for which schools and then take the examinations. Finally, the score rankings of students in the examinations are stochastic but governed by a particular joint distribution, so that we can solve the equilibrium according to expected payoffs of agents.

2.1 Environment

There are two schools and three students with different types in the model. The set of students is $S = \{s_i \colon i = 1,2,3\}$, where i is the unobservable type and only the student s_i know its own type i. The set of schools is $G = \{A, B\}$, and, for simplicity, each of them only enrolls one student. Both schools have the same preference over S that $s_1 \succ_j s_2 \succ_j s_3$ for $j = A, B$. This preference is represented by the utility function of

$$v_j(s_i) = v_i, \text{ where } v_1 > v_2 > v_3 \text{ for } j = A, B \text{ and } i = 1,2,3. \tag{1}$$

For students, they also have common preference over G that $A \succ_i B$ for all i and it is represented by the following utility function:

$$u_i = \begin{cases} a \text{ if } s_i \text{ is enrolled by } A \\ b \text{ if } s_i \text{ is enrolled by } B \\ 0 \text{ if } s_i \text{ is not enrolled} \end{cases}, \text{ where } a > b > 0 \text{ for } i = 1,2,3. \quad (2)$$

Although students' types are unobservable, they can be imperfectly screened by an examination. An examination is a random mapping from students to the pseudo types, i.e., $S \to T = \{t_k : k = 1,2,3\}$ such that

$$(s_1, s_2, s_3) \to (t_1, t_2, t_3) \text{ with probability 1/3;} \quad (3)$$

$$(s_1, s_2, s_3) \to (t_2, t_1, t_3) \text{ with probability 1/3;} \quad (4)$$

$$(s_1, s_2, s_3) \to (t_1, t_3, t_2) \text{ with probability 1/3.} \quad (5)$$

Once an examination is implemented, the realization of t_k, the pseudo types, is observed by schools. For example, if (5) is the outcome, schools will rank the students as (s_1, s_3, s_2) according to the realized pseudo types, and this rank will be the order to determine the admissions for students. In addition, if only one or two students take an examination, the outcomes and associated probabilities of the pseudo types are still governed by (3)-(5).

2.2 Strategies of students

If A and B choose different examination dates, then all students will apply for both schools because each of them has a positive probability to be enrolled by A or B. For example, if $(s_1, s_2, s_3) \to (t_1, t_3, t_2)$ is the outcome for both examinations, A and B will respectively choose s_1 and s_3 as their enrolled student. Note that B cannot enroll s_1 because the student prefers A to B. In addition, if $(s_1, s_2, s_3) \to (t_2, t_1, t_3)$ is the outcome, then A and B will enroll s_2 and s_1, respectively. Thus, when the schools choose different examination dates, we have the following proposition.

Proposition 1. *When A and B choose different examination dates, all students will apply for both schools.*

When A and B choose the same examination date, a conflicted examination date, who will apply to which school becomes a simultaneous game among students. In this game, we focus on the pure-strategy Nash equilibrium. Let $\tilde{s}_i \in \{A, B\}$ be the pure strategy used by s_i for $i = 1,2,3$. In principle, we have to verify $2 \times 2 \times 2 = 8$ strategy profiles in determining the Nash equilibrium. However, the best response for s_3 is never to apply for the same school to which s_1 apply. This is because the probability that s_3

has a higher rank of pseudo type than s_1 is zero. Once s_3 and s_1 apply for different schools in this game, the probability of s_3 being enrolled become positive in all cases that $\tilde{s}_2 = A$ or $\tilde{s}_2 = B$. Hence, we have the following lemma.

Lemma 1. *When students face a conflicted examination date, any strategy profile in which s_3 and s_1 apply for the same school, i.e., $\tilde{s}_3 = \tilde{s}_1$, cannot be an equilibrium.*

On the other hand, s_1 only cares about which school s_2 applies for because s_1 always outperforms s_3 in the examination. For example, s_1 is indifferent between $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, B)$ and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$. Therefore, the game can be reduced to a two person normal-form game as in Figure 2, where s_1 and s_2 decide to apply for A or B given that s_3 applies to a different school than that of s_1. The payoffs in Figure 2 are the expected utilities calculated by students according to the possible outcomes and associated probabilities in the examination. For example, if $\tilde{s}_1 = A$ and $\tilde{s}_2 = B$, then $E[u_1] = (1/3)(a + a + a) = a$ and $E[u_2] = (1/3)(b + b + 0) = 2b/3$ are the expected utility for s_1 and s_2, respectively. Notice that $E[u_2] = 2b/3$ because in this case s_3 also applies B as its best response.

The Nash equilibrium in this game depends on the relative values of a and b. It is easy to find the Nash equilibrium given different conditions for b. Table 1 reports the corresponding Nash equilibria under different cases of b. First, if $b \in (0,\ a/2)$, the Nash equilibrium is $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, A, B)$. Second, if $b \in (a/2,\ 2a/3)$, the Nash equilibrium is $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$. Finally, if $b \in (2a/3,\ \mathrm{a})$, we have two Nash equilibria that $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$ and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$. Note that s_1 applies to B in the Nash equilibrium only when b is close to a, i.e., $b \in (2a/3,\ \mathrm{a})$. For this reason, we call $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$ the inverse sorting equilibrium and others are sorting equilibrium. Those possible equilibrium strategies used by students can be summarized in the following proposition.

Proposition 2. *When students face a conflicted examination date, under different values of b, the possible strategy profiles predicted by the Nash equilibrium are $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$, $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, A, B)$, and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$. In particular, if $b \in (2a/3,\ \mathrm{a})$, there are two Nash equilibria that $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$ and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$.*

Note that B can enroll the best student only in the inverse sorting equilibrium. This is because in cases of $b \in (2a/3,\ \mathrm{a})$, two schools provide similar values to students, so that s_1 and s_2 face a coordination problem that not to apply for the same school is the best result for them. Since those possible outcomes and equilibria in the game of students are also known by the school A and B, Proposition 1 and 2 therefore provide a basis for the schools to determine their examination dates.

2.3 Strategies of schools

Based on the equilibrium-strategy profiles in Proposition 1 and Proposition 2, we now investigate the interaction of schools in the game of choosing examination dates. There are some available dates, $D = \{D_1, D_2, \cdots, D_M\}$, for schools to implement the examinations. Let $\tilde{d}_j \in D$ be the pure strategy used by the school for $j = A, B$. We further assume that this is a sequential game in which A chooses $\tilde{d}_A$ first and then B determines $\tilde{d}_B$ after knowing the public information of $\tilde{d}_A$. Thus, we focus on the pure-strategy subgame perfect Nash equilibrium (SPNE) in the game for schools.

According to Proposition 1, when A and B choose different examination dates, i.e., $\tilde{d}_A \neq \tilde{d}_B$, all students will apply for both schools. The probabilities that A enrolls s_1, s_2, and s_3 are 2/3, 1/3, and 0, respectively. Similarly, the probabilities that B enrolls s_1, s_2, and s_3 are 1/3, 1/3, and 1/3, respectively. Hence, the expected utilities for A and B are

$$E[v_A \mid \tilde{d}_A \neq \tilde{d}_B] = \frac{2}{3}v_1 + \frac{1}{3}v_2, \tag{6}$$

$$E[v_B \mid \tilde{d}_A \neq \tilde{d}_B] = \frac{1}{3}(v_1 + v_2 + v_3); \tag{7}$$

when they choose different examination dates.[6]

By Proposition 2, when A and B choose the same examination date, i.e., $\tilde{d}_A = \tilde{d}_B$, the equilibrium strategy profiles used by students could be $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$, $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, A, B)$, and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$ under different values of b. We thus calculate the expected utilities for schools in various ranges of b and corresponding equilibrium strategies of students. The result is summarized in Table 2. For example, under $b \in (a / 2,\ 2a / 3)$ and corresponding equilibrium strategies of $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$, v_1

[6] We calculate these expected utilities by assuming that the realized outcomes of two examinations are the same. The interpretation for this is that the state of the world should be stable in a short period during two examinations. If we assume the two outcomes being independent, we still obtain the same implication but need more complicated calculations.

and $(2/3)v_2 + (1/3)v_3$ are respectively the expected utilities for A and B. In such a case, A enroll s_1 for sure, and the probabilities that B enrolls s_1, s_2, and s_3 are 0, 2/3, and 1/3, respectively.

By comparing (7) and Table 2, it is easy to find the SPNE under different cases of b. First, if $b \in (0,\ a/2)$, the SPNE are $(\tilde{d}_A, \tilde{d}_B) = (D_l, D_l^c)$, where $D_l \in D$ and D_l^c is the complement of D_l. That is, B chooses $\tilde{d}_B \neq \tilde{d}_A$ to obtain higher expected utility. Second, if $b \in (a/2,\ 2a/3)$, SPNE are also $(\tilde{d}_A, \tilde{d}_B) = (D_l, D_l^c)$, for $D_l \in D$. Finally, if $b \in (2a/3,\ \mathrm{a})$, we have two equilibrium strategies of students that $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$ and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$ could be possible outcomes. In this case, we assume that $\pi(b)$ and $1 - \pi(b)$ is the probability of $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$ and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$ being the equilibrium outcome of students, respectively. We further assume that $\pi(b)$ is increasing, i.e., $\pi'(b) > 0$, and then $\pi(b \to 2a/3) = 0$ and $\pi(b \to a) = 1/2$ because $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$ cannot be an equilibrium outcome as $b < 2a/3$. Hence, there must exists a $b^* \in (2a/3,\ a)$ such that

$$E[v_B \mid \tilde{d}_B = \tilde{d}_A] = (1 - \pi(b^*))(\frac{2}{3}v_2 + \frac{1}{3}v_3) + \pi(b^*)(v_1) = E[v_B \mid \tilde{d}_B \neq \tilde{d}_A]. \qquad (8)$$

We therefore have an interval for $b \in (b^*, a)$ that $E[v_B \mid \tilde{d}_B = \tilde{d}_A] > E[v_B \mid \tilde{d}_B \neq \tilde{d}_A]$ because of $\pi'(b) > 0$. As a result, when $b \in (b^*, a)$ the SPNE is $(\tilde{d}_A, \tilde{d}_B) = (D_l, D_l)$ for $D_l \in D$; on the other hand, when $b \in (2a/3,\ b^*)$ the SPNE is $(\tilde{d}_A, \tilde{d}_B) = (D_l, D_l^c)$ for $D_l \in D$. That is, the model predicts that the school B will choose the same date as $\tilde{d}_A$ when the prestige of two schools are close enough, i.e., $b \in (b^*, a)$. The SPNE can be summarized in the following proposition.

Proposition 3. *When the two schools have similar prestige that $b > b^*$, B have an incentive to conflict with A on the examination date because the expected quality of enrolled students will be higher. In other cases of $b < b^*$, B will never conflict with A.*

In other words, when the prestige of two leading schools are very close, i.e., $b \in (b^*, a)$, the conflicting strategy can be justified in the equilibrium. The claim that a second best school can enroll higher quality students by conflicting with the best one could be true in such situation. Since the model prediction depends on the prestige difference between schools, it needs to be empirically tested to identify the effect of conflicting strategy.

3. Empirical testing

We test the model by examining the effect of conflicting strategy on student quality for top universities in Taiwan. We first describe the uniqueness of the data, and then provide a proxy called retardation rates to measure students' quality. The empirical results of panel regressions are consistent with the model predictions. They suggest that the second best school on average will have lower student quality if it uses the conflicting strategy. However, for some departments with similar prestige to the best one, the second best school could have better students by conflicting with the best one on the examination date. The finding is robust with estimations dealing with possible endogenous problems.

3.1 Simultaneous screening problem in Taiwan

On the entrance mechanism of graduate schools in Taiwan, most students have to take examinations for schools they applied and the rankings of scores will determine who can be enrolled. Those examinations are individually implemented by schools. In 2011, there are 163 universities and colleges in Taiwan and most of them have graduate programs.[7] In practice, schools choose their own examination days, but the feasible set of dates, however, is typically the weekends from late February to May, which are only about 14 weekends. Therefore, we must have some schools implementing entrance examinations on the same date and such conflict of date is a crucial issue in Taiwan over the years.

In 2006, the government announced the list of top eleven universities in Taiwan and gave them an additional subsidy of 50 billion NT dollars in total, about 1.67 billion US dollars, during 2006 and 2011.[8] According to the relative amounts of the subsidy, the top six schools are orderly NTU, NCKU, the National Tsing Hua University (NTHU), National Chiao Tung University (NCTU), National Central University (NCU), and National Yang-Ming University (NYMU). Hence, NTU is the best university and the others are second best ones from this view. In the past decade, we always have top universities that choose the same examination date as that of NTU.

In particular, NTHU, NCTU, NCU and NYMU jointed an alliance called UST in 2008.

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[7] Details can be found in the statistics of the Ministry of Education in Taiwan, R.O.C. The website is http://www.edu.tw/statistics/.

[8] In 2011, the government announced a new list of top universities in Taiwan. It consists of the old eleven schools and a new one. The total subsidy is still 50 billion NT dollars over the next five years. Details can be found in http://epaper.edu.tw/e9617_epaper/news.aspx?news_sn=4074.

Since then some departments of the four universities have taken the examination implemented by UST, which are always conflicted with NTU before 2011; on the contrary, other departments of them have taken examinations in different date from NTU. Therefore, within one university of UST, we have some departments conflicted with NTU but the others did not conflict with it in the same period. Moreover, we also have all departments at NTHU that had always been conflicted with NTU before 2008 (except the year of 2006). This provides a unique opportunity to test our model implications.

To our knowledge, Kao and Lin (2012) is the first study on similar issue in Taiwan. They develop a Hotelling (1929) type model for enrollment competition and test the implications by the panel data of the number of applications for schools from 2001 to 2011. The results show that the market segmentation is well developed after the government announced the list of top universities. Nevertheless, Kao and Lin (2012) do not investigate the problem here because their model focuses on the conflicting effect of applications for schools in different market segments. In contrast, the task of simultaneous screening problem is to explore the conflicting effect on the quality of enrolled students for schools within the same market segment. As a result, we emphasize how to measure the quality of students among schools, not the quantity of student applications in Kao and Lin (2012).

3.2 Estimating conflicting effect by retardation rates

We use the retardation rates of students studying for more than 2 years as a proxy for measuring student quality. This is because students in Taiwan usually can complete their master degrees after studying the program for two years, and hence the retardation rates capture the proportion of students in a department that are not qualified to graduate in the regular years. The raw data we obtained contains the number from 1st-year graduate to 4th-year graduate students for all departments at NTU and UST during 1998-2011, respectively.

The data set is from the statistics of the Ministry of Education in Taiwan, R.O.C. According to the department codes defined by the Ministry of Education, we only focus on the departments with the same code that both NTU and UST have. By tracing the number of 1st-year graduate students of the department i in the year t, denoted by $n(g=1)_t^i$, and its following 3rd-year graduate ones in the year $t+2$, denoted by $n(g=3)_{t+2}^i$, we then compute the retardation rate as $n(g=3)_{t+2}^i \,/\, n(g=1)_t^i$ for the students enrolled by the department in the year t.

We then test the simultaneous screening problem by applying the retardation rates as the dependent variable. Specifically, our empirical setting is a fixed effects model as follows:

$$y_{it} = \alpha_i + \mathbf{x}_{it}'\beta + u_{it},\ i = 1,2,...,M,\ t = 1,2,,..,N, \tag{9}$$

where y_{it} is the retardation rates of department i over time, α_i is the intercept of department i, $\mathbf{x}_{it}$ is the vector of independent variables, and u_{it} is the disturbance term. The independent variables we used are as follows. "Conflicting with NTU" is a dummy indicating the years that the department at UST conflicts with UST. "Conflicting with UST" indicates the number of universities of UST that are conflicted with NTU. "Conflicting with other tops" indicates the number of other top universities that are conflicted with the departments at NTU or UST. "Alliance" is a dummy indicating the years that UST has been established. "Number of faculty" is the number of faculty of the department over time. "Time trend" is the time index. Finally, "Unemployment rate" is the average annually unemployment rates in Taiwan. Table 3 summarizes some descriptive statistics for departments at NTU and UST.

The main reason for our specification in (9) is that, others being equal, student quality in a department should be negatively correlated to its retardation rate. We apply a fixed effects model in order to control department-specific effects, such as quality of a department, department's standard for graduation, and so on. In addition, if a department becomes larger, it may have more students who graduate late. We thus use the number of faculty members to control for the size of departments. Finally, we also include time trend and unemployment rate to control for the values of outside options of students.

Table 4 and Table 5 report the conflicting effect on the retardation rates of students at NTU and UST, respectively. As we can see, the retardation rates at NTU are not significantly affected when they take the examination conflicting with UST. In contrast, the retardation rates at UST are significantly increasing if they have the same examination date as NTU. Therefore, the empirical result suggests that, on average, the second best school will have lower student quality if it conflicts with the best one in the examination date. According to our model, it implies that UST as a whole should have a much lower prestige than NTU and thus using the conflicting strategy cannot attract best students for UST.

3.3 Departments with similar prestige

Proposition 3 also says that the conflicting strategy can be justified only if the prestige of two schools are very close. If we can find a group of departments at UST that have similar prestige with parallel departments at NTU, then those departments at UST may have higher student quality when they use the conflicting strategy. In Taiwan, higher education evaluation for departments and universities is implemented by the Higher Education Evaluation and Accreditation Council of Taiwan (HEEACT). According to the up-to-date data from HEEACT, some UST departments in the fields of Electrical Engineering and Computer Science have higher rankings in total research articles and citation rates from the database of Web of Science.[9] In fact, many Taiwanese hi-tech companies locate in the Hsinchu Science Park and they prefer employees graduated from UST, particularly from the nearby NTHU and NCTU. Thus, it is fair to say departments of Electrical Engineering and Computer Science at UST and such departments at NTU have similar or almost the same prestige in Taiwan.

Table 6 and Table 7 report the conflicting effect on the retardation rates of students in departments of Electrical Engineering and Computer Science field at NTU and UST, respectively. Table 6 shows that the retardation rates at NTU are not significantly affected when they take the examination conflicting with UST. Nevertheless, Table 7 shows that the retardation rates at UST are significantly decreasing if those departments have the same examination date as NTU. This suggests that, those departments at UST will have higher student quality if it conflicts with the parallel departments at NTU on the examination date. Such result is consistent with the model implication of Proposition 3. Also note that the retardation rates for those departments at UST are decreasing after the establishment of UST (Alliance dummy). This may be the case that the prestige of those departments is further enhanced by the alliance of UST.

3.4 Identification

The ranking of HEEACT is only an imperfect measure for the prestige of schools since we are interested in not only the ordinal rankings but the actual valuation of the prestige of schools, which is a cardinal measure. Besides the fields of Electrical Engineering and Computer Science, we might have other departments at UST that also have similar prestige

[9] Details can be found in http://wos.heeact.edu.tw/zh-tw/2010/University/All.

to NTU. In order to attract better students, the optimal choice for them is still to conflict with NTU, and we anticipate that the conflicting effect should be close to the result of Table 7, i.e. a negative marginal effect on retardation rates. Similarly, if a department has lower prestige compared to its counterpart at NTU, a conflicting strategy is detrimental to its student quality. This raises a question about how to identify the effect of the conflicting choice because it depends on the school prestige. In this aspect, the specification of (9) may have an endogenous problem that departments' choices are corrected with unobservable prestige.

Fortunately, our data provides an opportunity to control the endogenous problem between departments' choice and their prestige. In fact, for all departments at UST, the examination date is an exogenous variable before 2008; in contrast, after 2008, it becomes an endogenous choice of conflicting with NTU or not. For example, before 2008, all departments at NTHU (one of UST alliance) had been conflicted with NTU while all departments at NCTU (another of UST alliance) had never been conflicted with it. This is because the examination date is determined by the university and the departments have no option to choose the date during this period. However, after the establishment of UST in 2008, the departments in the alliance could have an option to conflict with NTU or not. If departments choose to join the examination implemented by UST, they will conflict with NTU for sure; otherwise, they will have other examination dates by their universities, which are different to NTU after 2008.

We therefore define a new dummy variable called "optimal choice" in the empirical testing. For departments choosing to conflict with NTU after 2008, the optimal choice equals one when they have the same examination date as NTU; otherwise, it equals zero. On the other hand, for departments choosing not to conflict with NTU after 2008, the optimal choice equals one when they have a different examination date to NTU; otherwise, it equals zero. According to the model prediction, the quality of enrolled students should be improved for departments with optimal choice. Since the choice is exogenous before 2008, it could identify the conflicting effect for departments with different prestige at UST.

Although the fixed effects specification of (9) has controlled the department-specific effects, we may have other common trends that are shared with NTU and UST. For example, changes in population structure could affect the quality of students enrolled by NTU and UST as well. In addition, we may have some field-specific effects that should be controlled in the empirical testing. An example is that medical schools had been the first choice for best students in Taiwan but now they are not necessary the first choice. We therefore use the following specification to deal with such problems.

$$\begin{aligned} y_{it} &= \alpha_i + \theta * Optimal_{it} + \mathbf{x}_{it}'\beta + \lambda * t + \gamma * t * UST \\ &+ \sum_{j=1}^{9} \kappa_j * t * Field_j + \sum_{j=1}^{9} \nu_j * t * Field_j * UST + \varepsilon_{it}. \end{aligned} \tag{10}$$

In order to capture common trends shared with NTU and UST, (10) includes variables for departments at both universities over time; where y_{it} is the retardation rates; $Optimal_{it}$ is the optimal choice; $\mathbf{x}_{it}$ has all the independent variables in (9) except "Conflicting with NTU", which is replaced by $Optimal_{it}$; t is the time index; UST is a dummy indicating departments at UST; $Field_j$ are field dummies. According to the department codes defined by the Ministry of Education in Taiwan, the first two digits represent different fields and there are ten fields in our data set.

Table 8 reports the conflicting effect on the retardation rates of departments at NTU and UST from (10). To save the space, we do not present the estimated coefficients of product terms in the table. Clearly, the result shows that the quality of enrolled students is improved for departments with their optimal choices, since the corresponding coefficient is significantly negative. Table 8 also shows that the retardation rates of departments at UST have significantly decreased after the establishment of alliance, and it implies that the prestige is further enhanced by the alliance. The empirical result for optimal choice suggests that for departments avoiding to conflict with NTU after 2008, they would have had better students if they did not use the conflicting strategy before 2008. On the other hand, for departments choosing to conflict with NTU after 2008, they could have applied the conflicting strategy to attract better students before 2008. According to our model, those departments who should choose to conflict with NTU is revealing information about their prestige. In fact, all departments in Table 7 have chosen to conflict with NTU after 2008. The empirical result with optimal choice therefore is consistent with Proposition 3 and the result in the previous subsection.

4. Conclusion

To summarize, we develop a model of simultaneous screening problem and examine its predictions with retardation rates of Taiwanese graduate programs. The empirical results suggest that whether a program can attract better students by a conflicting strategy depends on its prestige. In particular, departments with similar prestige to the best one could have better students by using the conflicting strategy. Moreover, when departments are allowed to set their own examination dates, changes of conflicting strategy correspond to improvement in students' quality, suggesting that departments successfully utilize this opportunity. Those empirical results are in line with our school conflict model.

The model provides a simple decentralized matching framework for the conflicting problem in school competition. It demonstrates how schools, in some cases, could enroll better quality students by choosing entrance examination dates. We believe that this study complements the field of school competition and provides broader thoughts on whether school competition improves achievements of students when schools mainly compete on dimensions besides productivity. Nevertheless, we have not yet addressed the total effect of school conflicting strategy on student performance and whether it leads to a more efficient result. Those issues are beyond the scope of this paper but certainly worth further studying.

There are two limitations in the present study that might be of interest for further research. First, our model is highly stylized and is meant to capture the essential aspect of the simultaneous screening problem. It may not be general enough to cover all possible outcomes, and needs to be extended if one wants to apply the model to other circumstances. Second, while the uniqueness feature of Taiwanese graduate programs allows us to test our model, whether the results are universally applicable still needs further validation. For instance, the school conflict problem is also prevalent in other Asian countries, such as China, Japan, and Korea, and various data sets may be collected from these countries to test the model.

Another interesting avenue of investigation might be to extend the framework to other environments that exhibit simultaneous screening. For instance, in the labor market workers often search multiple jobs simultaneously, and firms may compete for high quality workers by using strategies such as setting job offer deadlines, which has similar purpose to the conflicting strategy of schools. We anticipate that research of conflicting problem in other markets could generate relevant findings of the nature of competition in the time dimension.

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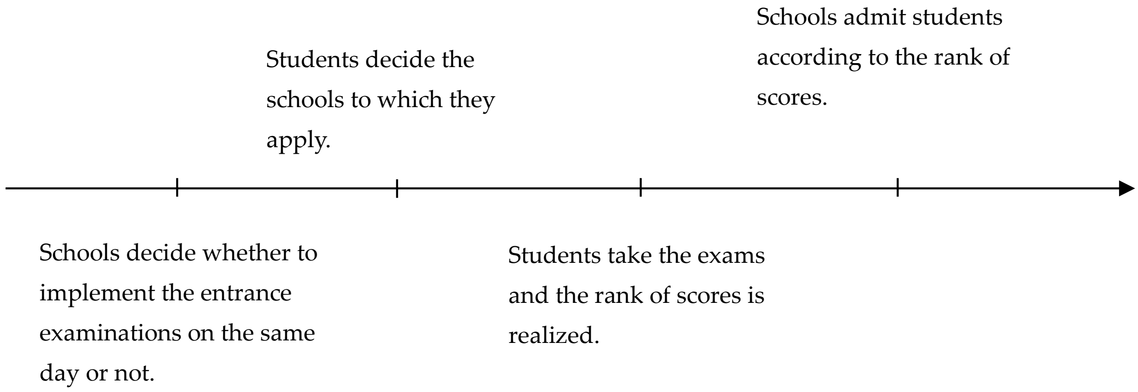

Figure 1. Timeline

		s_2	
		A	B
s_1	A	$\frac{2a}{3}, \frac{a}{3}$	$a, \frac{2b}{3}$
	B	$b, \frac{2a}{3}$	$\frac{2b}{3}, \frac{b}{3}$

Figure 2. The game of students with a conflicted examination date

Table 1. Nash equilibria in the game of students

Relative values of b	Corresponding Nash equilibria
$b \in (0,\ a/2)$	$(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, A, B)$
$b \in (a\ /\ 2,\ 2a\ /\ 3)$	$(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$
$b \in (2a\ /\ 3,\ a)$	$(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$ and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$

Table 2. The expected utilities for schools when $\tilde{d}_A = \tilde{d}_B$

Relative values of b	Equilibrium strategies of students	$E[v_A \mid (\tilde{s}_1, \tilde{s}_2, \tilde{s}_3)]$	$E[v_B \mid (\tilde{s}_1, \tilde{s}_2, \tilde{s}_3)]$
$b \in (0,\ a/2)$	$(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, A, B)$	$\frac{2}{3}v_1 + \frac{1}{3}v_2$	v_3
$b \in (a\ /\ 2,\ 2a\ /\ 3)$	$(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$	v_1	$\frac{2}{3}v_2 + \frac{1}{3}v_3$
$b \in (2a\ /\ 3,\ a)$	$(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, B, B)$	v_1	$\frac{2}{3}v_2 + \frac{1}{3}v_3$
	$(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (B, A, A)$	$\frac{2}{3}v_2 + \frac{1}{3}v_3$	v_1

Note: The cells in the right columns are expected utility for schools under different values of b and corresponding equilibrium strategies of students with a conflicted examination date. For example, v_3 is the expected utility for B under $b \in (0, a\ /\ 2)$ and $(\tilde{s}_1, \tilde{s}_2, \tilde{s}_3) = (A, A, B)$.

Table 3. Descriptive statistics for departments at NTU and UST

	Observations	Mean	Standard Deviation	Minimum	1st Quartile	Median	3rd Quartile	Maximum
NTU retardation rates (%)	393	35.99	32.24	0.00	12.12	20.69	60.00	100.00
UST retardation rates (%)	657	28.71	33.26	0.00	3.57	14.55	40.00	100.00
Conflicting with UST	393	0.47	0.62	0	0	0	1	3
Conflicting with NTU	657	0.31	0.46	0	0	0	1	1
NTU conflicting with other tops	393	0.23	0.51	0	0	0	0	2
UST conflicting with other tops	657	0.34	0.64	0	0	0	1	3
Number of faculty (NTU)	393	22.72	18.73	1	7	16	33	86
Number of faculty (UST)	657	17.69	12.61	1	7	15	27	69

Note: The retardation rates are computed from the statistics of the Ministry of Education in Taiwan, R.O.C. The raw data we obtained contains the number from 1st-year graduate to 4th-year graduate students for departments at NTU and UST during 1998-2011, respectively. According to the department codes defined by the Ministry of Education, we only focus on the departments with the same code. By tracing the number of 1st-year graduate students of the department i in the year t, denoted by $n(g=1)_t^i$, and its following 3rd-year graduate ones in the year $t+2$, denoted by $n(g=3)_{t+2}^i$, we then compute the retardation rate as $n(g=3)_{t+2}^i \,/\, n(g=1)_t^i$ for the students enrolled by the department in the year t. In some cases that the computed retardation rates are greater than 100%, we defined them as 100%. The number of conflicted universities is from Kao and Lin (2011). The number of faculty is from the Ministry of Education in Taiwan.

Table 4. Conflicting effect on the retardation rates of students at NTU

	Retardation rate models		
Independent variables	Model 1	Model 2	Model 3
Conflicting with UST	1.58 (1.11)	1.59 (1.11)	1.62 (1.11)
Conflicting with other tops		0.35 (1.09)	- 0.29 (1.37)
Alliance			1.89 (2.45)
Number of faculty	0.29 (0.19)	0.28 (0.19)	0.26 (0.19)
Time trend	0.12 (0.16)	0.11 (0.16)	0.005 (0.22)
Unemployment rate	0.88 (0.90)	0.93 (0.92)	1.10 (0.94)
Observations	393	393	393
Adjusted R^2	0.019	0.019	0.021

Note: Entries in the same column are from a fixed effects model with corresponding dependent and independent variables. Standard deviations are shown in parentheses. Significances at 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

Table 5. Conflicting effect on the retardation rates of students at UST

	Retardation rate models		
Independent variables	Model 1	Model 2	Model 3
Conflicting with NTU	4.05** (2.03)	4.05** (2.03)	4.01** (2.00)
Conflicting with other tops		0.15 (1.19)	0.46 (1.18)
Alliance			- 8.39*** (2.10)
Number of faculty	0.26 (0.16)	0.26 (0.16)	0.25 (0.16)
Time trend	1.05*** (0.19)	1.06*** (0.19)	1.67*** (0.24)
Unemployment rate	3.66*** (1.04)	3.65*** (1.05)	2.45** (1.08)
Observations	657	657	657
Adjusted R^2	0.06	0.06	0.09

Note: Entries in the same column are from a fixed effects model with corresponding dependent and independent variables. Standard deviations are shown in parentheses. Significances at 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

Table 6. Conflicting effect on the departments of Electrical Engineering and Computer Science at NTU

	Retardation rate models		
Independent variables	Model 1	Model 2	Model 3
Conflicting with UST	-1.32 (1.51)	-1.40 (1.45)	- 1.50 (1.48)
Conflicting with other tops		3.58** (1.67)	2.75 (2.36)
Alliance			2.22 (4.43)
Number of faculty	0.63* (0.33)	0.66** (0.32)	0.69** (0.33)
Time trend	0.92* (0.45)	0.78* (0.44)	0.61 (0.55)
Unemployment rate	2.11 (1.53)	2.62* (1.48)	2.78* (1.54)
Observations	45	45	45
Adjusted R^2	0.430	0.462	0.451

Note: Entries in the same column are from a fixed effects model with corresponding dependent and independent variables. Standard deviations are shown in parentheses. Significances at 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively. The departments of Electrical Engineering and Computer Science at NTU are the Department of Electrical Engineering, the Graduate Institute of Electronics Engineering, the Graduate Institute of Photonics and Optoelectronics, and the Department of Computer Science and Information Engineering.

Table 7. Conflicting effect on the departments of Electrical Engineering and Computer Science at UST

	Retardation rate models		
Independent variables	Model 1	Model 2	Model 3
Conflicting with NTU	- 6.99* (4.16)	- 7.60* (4.16)	- 7.15* (4.10)
Conflicting with other tops		2.12 (1.50)	2.06 (1.47)
Alliance			- 6.81* (3.44)
Number of faculty	0.51*** (0.18)	0.51*** (0.18)	0.43** (0.18)
Time trend	1.17*** (0.41)	1.23*** (0.41)	1.82*** (0.50)
Unemployment rate	2.47 (1.68)	2.13 (1.69)	1.45 (1.70)
Observations	98	98	98
Adjusted R^2	0.371	0.378	0.395

Note: Entries in the same column are from a fixed effects model with corresponding dependent and independent variables. Standard deviations are shown in parentheses. Significances at 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively. The departments of Electrical Engineering and Computer Science at UST are the Departments of Electrical Engineering .at NCU, NCTU, and NTHU), the Departments of Electronics Engineering .at NCTU and NTHU), the Department of Optics and Photonics at NCU, the Institute of Electro-Optical Engineering at NCTU, the Institute of Photonics Technologies at NTHU, the Department of Computer Science and Information Engineering at NCU, and the Department of Computer Science at NTHU.

Table 8. Conflicting effect by controlling common trends and field-specific effects

	Retardation rate models		
Independent variables	Model 1	Model 2	Model 3
Optimal	-7.13*** (2.00)	-7.37*** (2.02)	-5.44*** (2.07)
Conflicting with other tops		0.77 (0.85)	0.76 (0.84)
UST			-7.12*** (1.87)
Number of faculty	0.33** (0.13)	0.32** (0.13)	0.32** (0.13)
Time trend	0.60 (1.10)	0.63 (1.10)	0.62 (1.09)
Unemployment rate	2.49*** (0.69)	2.52*** (0.69)	1.79** (0.71)
Observations	1050	1050	1050
Adjusted R^2	0.122	0.141	0.134

Note: Entries in the same column are from a fixed effects model with corresponding dependent and independent variables. To save the space, we do not present coefficients of product terms in the table. Standard deviations are shown in parentheses. Significances at 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.