Limiting Applications in College Admissions and Evidence from Conflicting Examinations*

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Abstract

We present a college admissions problem in which schools may gain from limiting students' applications and derive conditions that a lower ranked but still selective school can attract desired students by using such strategy. The model is tested by the entrance examination dates of top graduate schools in Taiwan. We measure prestige differences and show that a department with prestige close to the best one tends to set the same entrance examination date to limit applications. Moreover, we identify departments' optimal choices of examination date based on revealed preferences and find that student quality was improved with such choices.

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1. Introduction

In some markets, producers choose to limit consumers' choices and the intention is to attract desired consumers or increase market shares. For example, colleges compete for enthusiastic students by providing exclusive early decision programs as demonstrated in Avery and Levin (2010). In this paper, we present a college admissions problem of whether a school can gain from limiting students' applications by a conflicting strategy of setting the same examination date as another school. Specifically, we derive conditions under which a lower ranked school can attract better students by the conflicting strategy and test the model with the examinations among top graduate schools in Taiwan.

Entrance examinations are primary screening devices for college admissions in many Asia countries. In some cases, examination results are the main criterion to select students and schools sometimes set conflicting examinations on the same date to prevent students from attending multiple examinations. Based on the examination dates of graduate schools in Taiwan, Chen and Kao (2014) present a model that schools may restrict students' applications as a tool to elicit students' private information, which is useful for schools to enroll desired students. Avery, Lee, and Roth (2014) have a similar result for the admissions regime of Korea universities in which a second-ranked school can gain from a single application rule in the examination date. Intuitively, a student's choice of taking one school's examination changes the pool of applicants; and if the resulting pool is more desirable, restricting students' choice set will benefit the school.[1]

In fact, there are other admission procedures that can also restrict students' choices. For example, many colleges in the US adopt the early decision program, which requires students to commit to attending the school if obtain the admissions. According to Lee (2009), students who apply via early decision may be more desirable because they have not been screened by other schools, thus the school can avoid the winner's curse problem. In Avery and Levin (2010), students who apply early have stronger preference toward the school, which could be a

[1] Alternatively, if students' choice set is not limited, schools may have similar pools of applicants and schools have to develop other tools to enroll desired students, e.g., strategic targeting or overweighting non-common measures, as discussed in Che and Koh (2015).

preferable attribute that cannot be revealed through the screening process. In Kim (2010), students who apply early are less financially constrained, thus the school can allocate its scholarship funds more efficiently.

In addition to above reasons, here we provide a complementary channel and shows that school may benefit from limiting applications. We focus on how a regular school competes with a more prestigious school and benefits from limiting students' applications.[2] We define a school to be more prestigious if it has higher common valuation among students. Our result shows that as good (high-ability) students are scarce and the uncertainty about examination result is sufficiently high, there is a threshold of prestige for the second best school above which the conflicting strategy is beneficial. We also highlight the importance of uncertainty by showing that if students can fully anticipate their examination result, then the second best school is at best indifferent and could be hurt by using the conflicting strategy.[3]

Our theoretical prediction is empirically plausible, at least in the context of early decisions. It has been documented that early decisions are typically adopted by lower ranked (but still selective) colleges (Avery, Fairbanks, and Zeckhauser, 2003). Using a signaling model, Avery and Levin (2010) show the competitive effect that relatively lower ranked colleges may enroll some highly desired students who are uncertain about their abilities in the early decision program. However, the competitive effect is not supported by previous empirical studies (Jensen and Wu, 2010; Chapman and Dickert-Conlin, 2012). Nevertheless, Chen and Kao (2014) point out that such effect may be sensitive to the prestige difference between colleges in empirical testing. With a data set containing a

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[2] In contrast, Chade, Lewis, and Smith (2014) show that a higher ranked college could compete with a lower ranked school by strategically increasing application costs and consequently exclude students who are less competent from the pool of applicants. However, a lower ranked school in their model cannot benefit by applying such strategy.

[3] Similarly, based on 1994 admissions reform in South Korea, which shifted the national college entrance test prior to application dates, Avery, Lee, and Roth (2014) document and prove that if students realized the scores of national test before the colleges' individualized examination dates, then second ranked college will avoid to set the same date as the best college's choice.

natural experiment in Taiwan, we can control the college's prestige and identify the competitive effect in the context of conflicting examination dates.

In Taiwan, the National Taiwan University (NTU) is generally considered the best university. In 2007, 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 the UST alliance are always conflicted with NTU. However, every department at UST still has the option to hold its own examination dates, which are different from NTU. Thus, within UST, we have some departments conflicting with NTU but the others do not conflict with it. Moreover, before 2007 the examination dates are given by schools which are exogenous to departments; after 2007 the UST alternative date becomes an endogenous choice for the UST departments. This provides a unique opportunity to test our model and control endogenous problems.

We then collect the examination dates of top universities in Taiwan during 1998-2011. In the university level, only schools having similar prestige to NTU tend to set the same examination date with it. In the department level, we further measure the prestige differences between UST and NTU departments based on scores of a standardized test for college enrollment. Binary models of probit and logit are employed to analyze the decisions of UST departments when they are free to choose the conflicting strategy. The result shows that a UST department with similar prestige to NTU has a higher probability to choose an examination date conflicted with NTU.

Moreover, we compute a retardation rate to measure the quality of enrolled students and it is defined as the proportion of students that are not qualified to graduate within the regular years. The panel regression after control endogenous problems suggests that UST departments which decide to adopt a conflicting strategy when they have the freedom to choose the examination dates do attract better students. In addition, for those departments which previously conflicted with NTU but have decided to avoid confliction after 2007, they could have had better students if they had not been constrained to adopt the conflicting strategy before 2007. In summary, the result indicates that the conflicting strategy is likely to be used by those departments with prestige close to the best one and the quality of their enrolled students is also improved. The evidence is consistent with the model's prediction.

The rest of the paper is organized as follows. Section 2 describes the entrance examinations and patterns of top graduate schools in Taiwan. Section 3 presents the model to illustrate how a school can gain from using the conflicting strategy. Moreover, we demonstrate how to apply the model to analyze the early decision program. Section 4 tests the model with a unique data set from Taiwanese graduate programs and identifies the effect by introducing a variable of optimal choice. Section 5 concludes.

2. Conflicting examinations in Taiwan

On the entrance mechanism of graduate schools in Taiwan, most students have to take examinations for schools they apply and the rankings of scores will determine who can be enrolled. Those examinations are individually implemented by schools. In 2013, there are 163 universities and colleges in Taiwan and most of them have graduate programs.[4] In practice, schools choose their individual examination dates; however, the feasible set of dates is typically the weekends from late February to May, which are about 14 weekends. Therefore, we must have some schools setting entrance examinations on the same date. In addition, Kao and Lin (2015) define top, middle, and lower universities in Taiwan and find those three type universities cluster their examinations during February, March, and April, respectively. Kao and Lin (2015) argue that top universities set early examinations relative to other types in an attempt to raise the probability of enrolling best students.

In this study, we focus on the conflicts of examination dates among top universities in Taiwan. In 2006, the Taiwanese government announced the list of top eleven universities in Taiwan and gave them an additional subsidy of 50 billion NT dollars (TWD) in total, about 1.67 billion US dollars (USD), during 2006

[4] 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/.

and 2011.[5] Table 1 summaries the academic ranking scores of these top universities from the 2013 Shanghai Jiao Tong University's academic ranking of world universities and also the amount of government subsidies to these schools. According to the ranking scores and the relative amounts of subsidy, NTU is always the best university in Taiwan.[6]

In the past decade, we always have some top universities that choose the same examination date as that of NTU. Figure 1 shows the examination dates of NTU and other Top universities during 2001-2011. The NTU dates are represented by dash line and others are represented by circles in which a solid circle means a conflicting examination date with NTU. In particular, NTHU, NCTU, NCU and NYMU jointed an alliance called UST in 2007. As we can see, UST always set the same examination date as NTU. Moreover, NTHU, which has second highest ARWE ranking scores, had also always set the same examination date as NTU before 2006. Finally, NCKU is ranked as top 5 by ARWE but it has second highest amounts of subsidy. After the government announced the list of top universities in 2006, NCKU begins to set the same examination date as NTU in 2008 and 2011.

An interesting fact is that NTHU stop to conflict with NTU after the UST alliance was established. In practice, some UST departments have taken the examination implemented by the alliance, which are always conflicted with NTU; in contrast, other departments have taken individual examinations implemented by their universities which have different date from NTU after 2007. Therefore, we have some UST departments conflicting with NTU and the rest did not during the same period. That is, after the establishment of UST alliance, it provides an option for their departments to freely choose whether to conflict with NTU or not. This gives us a unique opportunity to test our model because we can examine which departments tend to conflict with NTU and also whether such changes in strategy

[5] 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.

[6] Moreover, according to different fields and subjects rankings in 2013 Shanghai Jiao Tong University's academic ranking of world universities (ARWU-FIELD, and ARWU-SUBJECT), NTU is still the best university in Taiwan. Details can be found in http://www.shanghairanking.com.

affect their enrollment results.

3. Model of conflicting examinations

Similar to Avery and Levin (2010), we present a model with two schools and a continuum of students and show that a relatively lower ranked school could compete for better students by choosing the same entrance examination date as that of the best one.

3.1 Model environment

There are two types of students, good and normal. The population of them is normalized to 1 and the fractions of good type and normal type are respectively μ and $1-\mu$. There are two top schools, A and B, with enrollment capacity of k_A and k_B, respectively. We assume that $0 < k_A < k_B$ and $\mu < k_A + k_B < 1$. This means that A is more selected than B and some normal students will also be enrolled by top schools. Schools can screen student type perfectly by entrance examinations and desire to enroll good students as many as possible.

On the other hand, students do not know their types directly. Instead, each student obtains one signal about the type. Good students always obtain signal h and normal students obtain signal h or l with probability of p and $1-p$, respectively. Therefore, a student with l will realize that she is normal type, and a student with h will have a posterior probability of $\pi = \mu \,/\, (\mu + (1-\mu)p)$ to be a good type and of $1-\pi$ to be a normal type. Clearly, when $p=1$, all students obtain signal h and the signal is therefore uninformative. In such case, students indeed do not have any information about their types. By contrast, when $p=0$, students have complete information about their types.

Moreover, each student also has a taste parameter denoted by y, which is private information and only known by herself. For both types, y is independently distributed and governed by a continuous cumulative distribution $F(y)$ with the support of $[-\delta,\ \delta]$ and a density function $f(y)$, where $\delta > 0$. The preferences of students over schools are represented by the utility function of $V_A(y) = a + y$ if enrolled by A; of $V_B(y) = b - y$ if enrolled by B; and of zero if not enrolled.[7] We assume $F(0) < 0.5$ and $\delta < b < a$ to imply that both A and B are prestigious schools but A has higher prestige than B. If $b \to a$, we say that B has similar prestige to A. Thus, students always obtain positive utility of attending one of two schools, but there are more students preferring A to B. Specifically, let $V_A(y) = V_B(y)$, we obtain a cutoff point of $c = (b - a) / 2 < 0$ such that there are $1 - F(c)$ students preferring A to B if they get admissions from both A and B.

For schools, there are two strategies to implement the examination date, one is a conflicting strategy and the other is an avoiding strategy. We assume that if any one of the schools chooses the conflicting strategy, then they will have a conflicted examination date.[8] On the other hand, if both schools choose the avoiding strategy, then they will have different examination dates. For students, they can apply to only one school when schools have a conflicted examination date; they can apply to both schools when schools have different examination dates. In the following subsections, we compare the expected results of two strategies under incomplete information about student types and then find the equilibrium.

3.2 Different examination dates

If A and B choose the avoiding strategy, all students can apply to both schools because the two examinations are implemented on different dates. Since $\delta < b < a$, it implies that all students will apply to A as well as B. Schools can screen student types by examinations and then offer admissions to good students until the enrollment capacities are filled. When the capacity is not filled by good students, the school will continue to enroll normal students for the rest of enrollment. Because schools desire to have good students as many as possible, we focus on the number of good students enrolled by schools in the following analysis.

Let m_A and m_B respectively be the number of good students attending A and B when the avoiding strategy is applied. The values of m_A and m_B depend

[7] We assume that application costs are negligible compared with the utility of being accepted. Chade and Smith (2006) provide a general framework to analyze the case when the application costs are significant.

[8] It is because in practice when one school wants to conflict with the other school, it will wait for the final decision of the other one on the examination date.

on the capacities of schools relative to the number of students who prefer which school. First, in cases of $k_A > \mu\left(1 - F(c)\right)$ and $k_B > \mu F(c)$, both schools will eventually enroll some normal students and hence $m_A = \mu\left(1 - F(c)\right)$ and $m_B = \mu F(c)$. Second, in cases of $k_A < \mu\left(1 - F(c)\right)$ and $k_B > \mu F(c)$, the capacity of A is smaller than good students who desire to attend A and hence A have $m_A = k_A$; and other good students attend school B, i.e., $m_B = \mu - k_A$, given that $k_A + k_B > \mu$. Third, the cases of $k_A < \mu\left(1 - F(c)\right)$ and $k_B < \mu F(c)$ are impossible because we must have $k_A + k_B > \mu$. Finally, the cases of $k_A > \mu\left(1 - F(c)\right)$ and $k_B < \mu F(c)$ are impossible because $k_B > k_A$ implies $k_B > \mu / 2 > \mu F(0) > \mu F(c)$. Thus, define $e^* = F^{-1}(1 - k_A / \mu)$ and $k_A = \mu(1 - F(e^*))$, we can summarize the results of avoiding strategy in the following proposition.

Proposition 1. *When the examination dates are different and $c < e^*$, schools have good students as $m_A = k_A$ and $m_B = \mu - k_A$. However, when the prestige difference between A and B is small enough such that $c > e^*$, schools have $m_A = \mu\left(1 - F(c)\right)$ and $m_B = \mu F(c)$.*

In other words, when A and B apply the avoiding strategy, they will have good students as $m_A = \min\{k_A, \mu(1 - F(c))\}$ and $m_B = \max\{\mu - k_A, \mu F(c)\}$. In particular, when the prestige of B is large enough such that $c > e^*$, we have $m_B = \mu F(c)$.

3.3 Conflicting examinations when $p = 1$

If the conflicting strategy is used, then all students can only apply to one school because the examinations are implemented on the same date. To fix ideas, we first consider the case of $p = 1$. That is, all students receive the same signal h and each of them has a posterior probability of μ to be good type and of $1 - \mu$ to be normal type. The equilibrium strategy profile can be characterized by a cutoff point e such that students with taste $y > e$ apply to A and students with taste $y < e$ apply to B.

Since each student receives the same signal h with probability one, the probabilities of attending schools are equal among students. Therefore, given the equilibrium strategy profile, $\min\left(k_A / (1 - F(e)), 1\right)$ is the probability of attending A and $\min\left(k_B / F(e), 1\right)$ is the probability of attending B for all students. For an interior solution, e is pinned down by the following equation:

$$\min\left(\frac{k_A}{1-F(e)},1\right)\left(a+e\right)=\min\left(\frac{k_B}{F(e)},1\right)\left(b-e\right). \qquad (1)$$

For the corner solution of $e=-\delta$, we have $\mu(k_A/\mu)(a-\delta)+(1-\mu)\times 0>b+\delta$ and hence $k_A>(b+\delta)/(a-\delta)$; and then all students apply to A under this condition.

Let n_A and n_B respectively be the number of good students attending A and B when the conflicting strategy is applied. The cutoff point e gives $n_A=\mu(1-F(e))$ and $n_B=\mu F(e)$. Clearly, n_B is an increasing function of e. If e is large enough such that $n_B>m_B$, then B enroll more good students by using the conflicting strategy. According to Proposition 1, when $c<e^*$, $m_B=\mu-k_A=\mu-\mu(1-F(e^*))=\mu F(e^*)$ and we can have $n_B>m_B$ if $e>e^*$. From Equation (1), $e>e^*$ if and only if

$$\min\left(\frac{k_A}{1-F(e^*)},1\right)\left(a+e^*\right)<\min\left(\frac{k_B}{F(e^*)},1\right)\left(b-e^*\right). \qquad (2)$$

Substituting $k_A=\mu(1-F(e^*))$ into (2) yields $\mu(a+e^*)<\min(k_B/F(e^*),1)(b-e^*)$, and it can be rearranged to

$$b>e^*+\mu(a+e^*)\max\left(\frac{F(e^*)}{k_B},1\right). \qquad (3)$$

Let the right hand side of (3) be b^*. That is, $b^*=e^*+\mu(a+e^*)\max(F(e^*)/k_B,1)$. It says that, in the cases of $c<e^*$, B can gain from using the conflicting strategy if its prestige is large enough such that $b>b^*$.

On the other hand, when $c>e^*$, $m_B=\mu F(c)$ and we can have $n_B>m_B$ if $e>c$. According to Equation (1), $e>c$ if and only if

$$\min\left(\frac{k_A}{1-F(c)},1\right)<\min\left(\frac{k_B}{F(c)},1\right), \qquad (4)$$

which always holds because $0<k_A<k_B$, $k_A+k_B<1$, and $F(c)<0.5$. It says that, in the cases of $c>e^*$, B can surely gain from using the conflicting strategy. Since $c=(b-a)/2$, the cases of $c>e^*$ implies that $b>2e^*+a$. Note that $(2e^*+a)-b^*\geq(e^*+a)(1-\mu)>0$ and b^* is an increasing function of μ. Thus, if

μ is sufficiently small, we can have $b^* < a$ and then the second best school B can gain from using the conflicting strategy when it has similar prestige to A. Therefore we conclude the case for $p = 1$ in the following proposition.

Proposition 2. *For the incomplete information of $p = 1$, the second best school B can gain from using the conflicting strategy if and only if $b > b^*$. The range (b^*, a) is nonempty if μ is sufficiently small.*

3.4 Conflicting examinations when $p < 1$

We now consider the case of $p < 1$ when the conflicting strategy is applied. That is, a student receiving l will realize that she is normal type, and a student receiving h will have a posterior probability of $\pi = \mu / (\mu + (1-\mu)p)$ to be good type and of $1 - \pi$ to be normal type. In this case, the equilibrium strategy profile can also be characterized by two cutoff values (e_h, e_l) such that students with signal h and taste $y > e_h$ (or with signal l and taste $y > e_l$) will apply to A; and students with signal h and taste $y < e_h$ (or with signal l and taste $y < e_l$) will apply to B.

For an interior solution of e_l, the cutoff value is pinned down by the following equation:

$$p_A^l(e_h, e_l)(a + e_l) = p_B^l(e_h, e_l)(b - e_l), \tag{5}$$

where

$$p_A^l(e_h, e_l) = \min\left\{\max\left\{0, \frac{k_A - \mu(1 - F(e_h))}{(1-\mu)[p(1 - F(e_h)) + (1-p)(1 - F(e_l))]}\right\}, 1\right\}$$

and

$$p_B^l(e_h, e_l) = \min\left\{\max\left\{0, \frac{k_B - \mu F(e_h)}{(1-\mu)[pF(e_h) + (1-p)F(e_l)]}\right\}, 1\right\}.$$

Moreover, for an interior solution of e_h, the cutoff value is pinned down by the following equation:

$$p_A^h(e_h, e_l)(a + e_h) = p_B^h(e_h, e_l)(b - e_h), \tag{6}$$

where

$$p_A^h(e_h,e_l) = \pi \min\left\{\frac{k_A}{\mu(1-F(e_h))},1\right\} + (1-\pi)p_A^l(e_h,e_l) \text{ and}$$

$$p_B^h(e_h,e_l) = \pi \min\left\{\frac{k_B}{\mu F(e_h)},1\right\} + (1-\pi)p_B^l(e_h,e_l).$$

Therefore, B can gain from using a conflicting strategy, i.e., $n_B > m_B$, if we have $e_h > e^*$ when $c < e^*$; or if we have $e_h > c$ when $c > e^*$. Conditions under which the second best school can gain from adopting the conflicting strategy are presented in the following proposition.

Proposition 3. *In general, the second best school gains from using the conflicting strategy if its prestige is close to that of the best school, i.e., b is close to a, given that p is sufficiently large and μ is sufficiently small.*

Proof: See Appendix A.

On the other hand, we also find that the uncertainty of examination results to students is essential for the competitive effect to emerge. In the following proposition, we show that the second best school B cannot gain from using the conflicting strategy when $p = 0$.

Proposition 4. *If students are fully aware of the examination result ($p = 0$), then the second best school is strictly worse to adopt the conflicting strategy when the prestige difference is large ($c < e^*$), and is indifferent if the prestige difference is small ($c > e^*$).*

Proof: See Appendix B.

In equilibrium, B will apply the conflicting strategy if $n_B > m_B$, which is generally characterized in Proposition 3. On the other hand, A may also apply the conflicting strategy if the strategy can bring positive gains, i.e. $n_A > m_A$. However, such gains do not exist for A when $k_A < \mu(1-F(c))$. This is because k_A is smaller than the number of good students who desire to attend A, and we already have $m_A = k_A$ when the avoiding strategy is used. In other cases of $k_A > \mu(1-F(c))$, both A and B will eventually enroll some normal students; and if $e_h < c$, we have $n_A > m_A$ and $n_B < m_B$; and if $e_h > c$, we have $n_B > m_B$ and $n_A < m_A$; and if $e_h = c$, we have $n_B = m_B$ and $n_A = m_A$. Thus, under cases of $k_A > \mu(1-F(c))$, either A or B has incentive to use the conflicting strategy, except to the point of $e_h = c$. Note that at $e_h = c$ both schools are indifferent between two strategies.

Generically, the equilibrium outcome is summarized in the following proposition.

***Proposition 5**. In equilibrium, when $k_A > \mu(1 - F(c))$, the conflicting strategy is applied by either school A or B; when $k_A < \mu(1 - F(c))$, the conflicting strategy is only applied by school B as its prestige b is close to a, given that p is sufficiently large and μ is sufficiently small.*

3.5 Conflicting examinations versus early decisions

In this paper, we focus on the strategy of choosing examination dates and the result of student quality. Yet limiting applications can have different forms. In the last two decades, early admissions programs are widely used at selective colleges and universities in the US, and the common type is the early decision program in which students have to commit to enrollment once they are accepted by the college.[9] In the literature, the implementation of early decision programs has been discussed in Lee (2009), Avery and Levin (2010), and Kim (2010), among others. Chen and Kao (2014) point out the similarity between choosing examination dates and implementing early decision programs because both policies are in fact limiting the choice set of students.

Our model differs from the above papers in that we emphasize uncertainty as a crucial factor affecting student's application. We argue that when uncertainty about the examination result is high and the difference of prestige is small, students are more prone to apply to a less prestigious school when they are restricted. That is, when applications are limited, the closer the prestige between the two schools is, the larger the size of the pool of good students who apply to the less prestigious school will be. Limiting applications comes with a cost for the less prestigious school, however. The second best school may still want to enroll those students that have been rejected by the more prestigious school, but when applications are limited, those students cannot apply to the less prestigious school in the first place.

Our model formalizes this trade-off and finds conditions under which the second best school can benefit from a conflicting strategy. To make our channel

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

distinct, we shut down the channels that have been pointed out in the previous studies of early admissions. We assume that schools only concern the ability of students which can be perfectly screened by examinations. Thus there is no winner's curse as in Lee (2009), and in contrast to Avery and Levin (2010) schools here do not care about students' preference to the school per se. In addition, schools are not financially constrained as in Kim (2010), except that enrollment cannot exceed their capacity.

Through the lens of our model, we can compare early decision and conflicting examinations as follows. First, if both schools choose early decision programs, it is equivalent to the case that the entrance examinations are on the same date. This is because students must commit to attending one school under early decision programs. Second, if neither school chooses early decision program, it is equivalent to the case that the entrance examinations are on different dates, because the choice set of students is not restricted. Third, if only one of schools chooses early decision program, students still can apply to both schools; however, they can only attend to the school with early decision even if they receive admissions from both schools.

In early decision, it is also possible that one school chooses early decision and the other does not. For the sake of completeness, we demonstrate how to extend our model to include the third case that only one of the schools chooses early decision program. Assume that school B adopts early decision program (the other case for A can be analyzed symmetrically). Note that it is a weakly dominated strategy to apply only to B because students could fail to receive admissions from B, but they could still receive admissions from A if they apply to both schools. Hence, we only consider the choice between applying to both schools or to school A. We can find two cutoff values (d_h, d_l) such that students with signal h and taste $y > d_h$ (or with signal l and taste $y > d_l$) will apply to A; and students with signal h and taste $y < d_h$ (or with signal l and taste $y < d_l$) will apply to A and B. Let s_B be the number of good students attending B when only school B adopts the early decision program. If $s_B > m_B$, it means that school B have positive benefit from using the early decision program.

4. Testing the model by conflicting examinations in Taiwan

Our model shows that when good students are sufficiently scarce, and the uncertainty for students about their examination result is sufficiently high, a conflicting strategy is beneficial for the second best school if its prestige is above a threshold. In other words, a lower ranked school can attract more good students by using the conflicting strategy when its prestige is close to that of the best one as long as the examination exhibits enough uncertainty for students.

4.1 Prestige differences and conflicting strategy

In this subsection, we test the model's prediction that UST departments with similar prestige to the corresponding NTU ones tend to adopt the conflicting strategy. We find a proxy based on standardized test scores of college enrollment in order to measure the prestige differences between NTU and UST departments. In Taiwan, senior high school students have two major channels to apply undergraduate programs. One is a channel with individual application documents, and the other channel only depends on scores from a nationwide and standardized examination implemented by the college entrance examination center (CEEC). According to the CEEC statistics, about half students choose the channel by CEEC, and the original percentile rank (PR) of the lowest score of enrolled students for every departments is also public available.[10]

We use the method proposed by Zen, Chen, and Lin (2008) to construct a comparable PR among departments. We use such PR as a measure of prestige and then define the PR difference by subtracting a UST department's PR from its corresponding NTU one. We focus on the PR differences after 2007 because the UST departments are able to choose the conflicting strategy since the alliance was established. We finally have 90 samples of PR differences with the average of 7.83, standard deviation of 5.13, maxima of 24.95, and minima of 0.10. That is, all departments at NTU have higher prestige than the corresponding UST ones. Therefore, a UST department with small PR difference implies that its prestige is

[10] The data can be downloaded from http://www.ceec.edu.tw/AppointExam/AppointExamStat.htm.

close but still lower to the corresponding department at NTU. According to Proposition 5, those UST departments with small PR differences would tend to adopt the conflicting strategy.

We define a binary variable which equals one when a department adopts the conflicting strategy and equals zero otherwise. The probit and logit models are employed to estimate the probability of adopting the conflicting strategy for UST departments. The independent variables we used are as follows. "PR differences" is the measure of prestige difference. "Conflicting with other tops" indicates the number of other top universities that are conflicted with the departments at NTU or UST. "Number of faculty" is the number of faculty of the department over time. "Unemployment rate" is the average annually unemployment rates in Taiwan. Table 2 shows that, under all model specifications, the coefficient of PR differences are significantly negative, which implies that a UST department with smaller PR difference will have higher probability to adopt the conflicting strategy. That is, UST departments with similar prestige to NTU tend to choose the examination date conflicted with NTU.

4.2 Estimating the conflicting effect on student quality

In this subsection, 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.

According to the model prediction, 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. That is, in order to attract better students, the optimal choice for them is to conflict with NTU. On the other hand, 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.

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 2007; in contrast, after 2007, it becomes an endogenous choice of conflicting with NTU or not. For example, before 2006, 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 2007, 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; otherwise, they will have other examination dates by their universities, which are different to NTU after 2007.

We therefore define a new dummy variable called "Optimal Choice" in the empirical testing. For departments choosing to conflict with NTU after 2007, 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 2007, 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 2007, it could identify the conflicting effect for departments with different prestige at UST.

We use a fixed effect model to control the department-specific effect, 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. However, 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.

$$\begin{aligned} y_{it} &= \alpha_i + \theta * Optimal_{it} + \mathbf{x}'_{it}\beta + \gamma * t * UST \\ &+ \sum_{j=1}^{9} \kappa_j * t * Field_j + \sum_{j=1}^{9} \nu_j * t * Field_j * UST + \varepsilon_{it}. \end{aligned} \tag{7}$$

In order to capture common trends shared with NTU and UST, (7) includes variables for departments at both universities over time; where y_{it} is the retardation rates; $Optimal_{it}$ is the optimal choice; $\mathbf{x}_{it}$ is the vector of independent variables, and ε_{it} is the disturbance term. The independent variables we used are as follows. "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. "Unemployment rate" is the average annually unemployment rates in Taiwan. Moreover, 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 3 summarizes some descriptive statistics for departments at NTU and UST.

Others being equal, student quality in a department should be negatively correlated to its retardation rate. Table 4 reports the conflicting effect on the retardation rates of departments at NTU and UST from (7). 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 4 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 2007, they would have had better students if they did not use the conflicting strategy before 2007. On the other hand, for departments choosing to conflict with NTU after 2007, they could have applied the conflicting strategy to attract better students before 2007. According to our model, those departments who should choose to conflict with NTU is revealing information about their prestige. The empirical result with optimal choice therefore is also consistent with our model prediction.

5. Concluding Remarks

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) and Chade, Lewis, and Smith (2014), is to choose a portfolio among all possible options that balances marginal benefits and costs of adding options to the portfolio. In some circumstances, however, participants' choices are also endogenously limited by actions of option providers. In the college admissions problem here, colleges as option providers may compete for better students through limiting students' application portfolios by early decision programs or conflicting entrance examinations.

When colleges screen the students they admit, it could create an additional level of strategic interaction. In this paper, we show conditions that such strategic limitations could be a useful strategy for colleges and demonstrate empirical evidence from conflicting entrance examinations in Taiwan. Our empirical result supports the prediction that departments with similar prestige to the best one tend to adopt the conflicting strategy and the quality of their enrolled students is also improved.

In our problem, colleges offer conflicting examinations so that students have to make early decisions to which schools they will apply. In the literature, there is a line of research on unraveling or early contracting in which firms offer jobs early to applicants when firms know little about applicants' ability; see, e.g., Roth and Xing (1994), Li and Rosen (1998), and Li and Suen (2000, 2004), among others. In an unraveling experiment, Niederle, Roth, and Ünver (2013) show that low quality firms can attract high quality applicants by early offers, which is essentially similar to our model and empirical findings. The main difference is that in the college admissions students still face uncertainty to be enrolled or not when they choose one of conflicted examinations; but in the early contracting problem, workers actually face a certain case of choosing one of early contracts and then are hired by firms. Although the issues and models are different, we think the empirical results here may still provide complementary evidence to support the theoretical findings of unraveling.

Finally, 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.

Appendix A

In this Appendix, we show that the second best school B can gain from using the conflicting strategy, i.e., $n_B > m_B$, if its prestige b is close to a given that p is sufficiently large and μ is sufficiently small. Note that from Proposition 2, if $p = 1$ and μ is sufficiently small as

$$\mu < \min\left(1, \min\left(\frac{k_B}{F(e^*)}, 1\right)\left(\frac{a - e^*}{a + e^*}\right)\right),$$

then there exists $b^* < a$ such that $n_B > m_B$ if $b > b^*$. Now we fix μ and b such that the second best school can gain from adopting the conflicting strategy when $p = 1$. Note that $p_A^h(e_h, e_l)$ and $p_B^h(e_h, e_l)$ is continuous with respect to e_h, μ, and p. Moreover, when $p \to 1$, we have

$$p_A^h(e_h, e_l) \to \min\left(\frac{k_A}{1 - F(e_h)}, 1\right) \text{ and}$$

$$p_B^h(e_h, e_l) \to \min\left(\frac{k_B}{F(e_h)}, 1\right).$$

Therefore, we know that $e_h \to e$, and hence $n_B \to \mu F(e) > m_B$ when $p \to 1$. Hence, when μ is sufficiently small, the second best school B can gain from using the conflicting strategy in the case of $p \to 1$.

Appendix B

In this Appendix, we show that the second best school B cannot gain from using the conflicting strategy when $p = 0$. Notice that in this case Equation (6) becomes

$$\min\left\{\frac{k_A}{\mu(1-F(e_h))},1\right\}(a+e_h) = \min\left\{\frac{k_B}{\mu F(e_h)},1\right\}(b-e_h),$$

for interior solutions of e_h. When $c > e^*$, we can verify that

$$\min\left\{\frac{k_A}{\mu(1-F(c))},1\right\}(a+c) = \min\left\{\frac{k_B}{\mu F(c)},1\right\}(b-c),$$

hence $e_h = c$. Therefore, $n_B = m_B$. When $c < e^*$, however, we must have

$$\min\left\{\frac{k_A}{\mu(1-F(e^*))},1\right\}(a+e^*) > \min\left\{\frac{k_B}{\mu F(e^*)},1\right\}(b-e^*),$$

which implies that $e_h < e^*$. That is,

$$\frac{k_A}{\mu(1-F(e_h))} < 1,$$

but then we have $m_B = \mu - k_A > \mu F(e_h) = n_B$. Hence, we conclude that the second best school B cannot gain from using the conflicting strategy, i.e., $n_B \le m_B$, in the case of $p = 0$.

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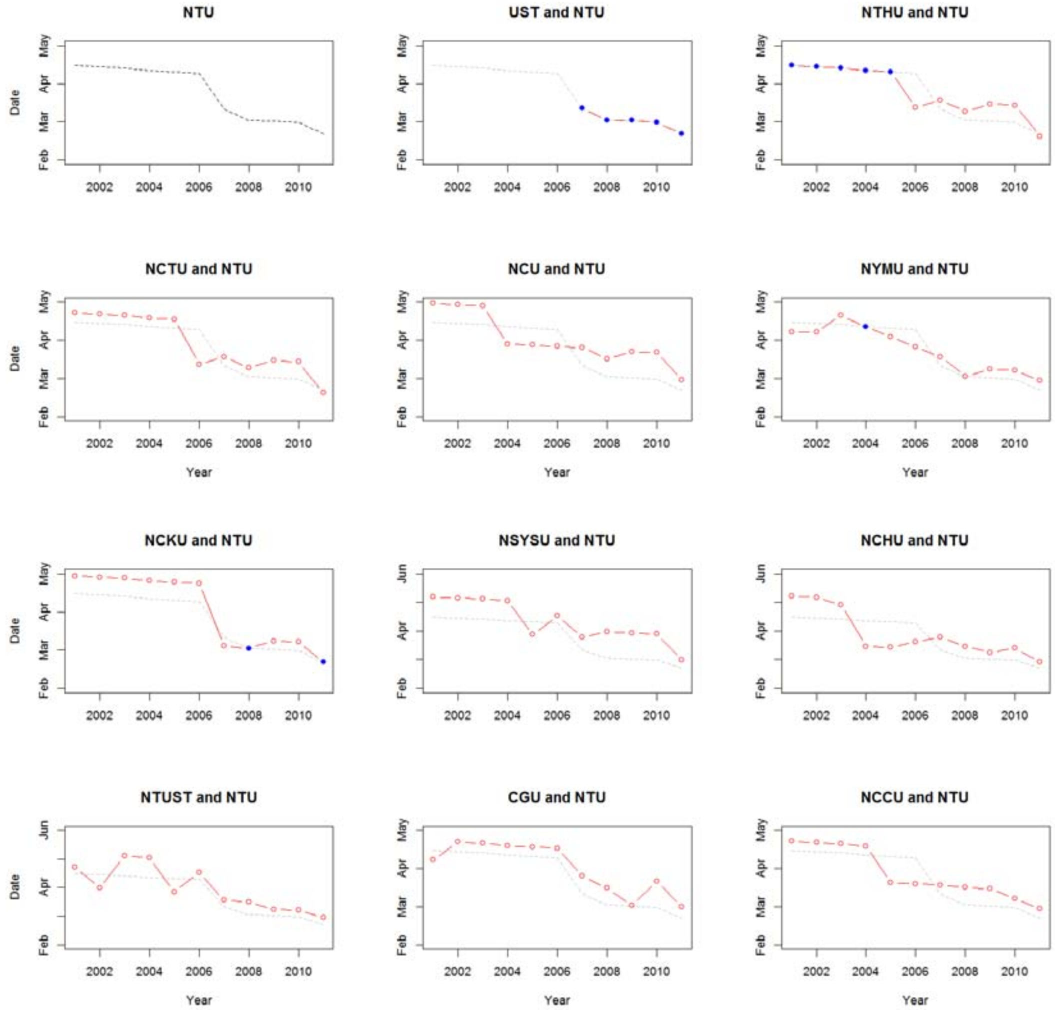

Figure 1. Examination dates of NTU and other Top universities

Table 1. Top universities in Taiwan and their ARWU ranking scores

University	Abbreviation	2013 ARWU ranking scores	Subsidy (TWD billion)
National Taiwan University	NTU	97.5	12.00
National Tsing Hua University	NTHU	91.5	4.40
National Chiao Tung University	NCTU	68.4	3.40
National Yang-Ming University	NYMU	59.0	2.00
National Cheng Kung University	NCKU	53.0	6.80
National Central University	NCU	50.3	2.60
National Taiwan University of Science and Technology	NTUST	45.3	1.00
National Sun Yat-sen University	NSYSU	44.8	2.40
Chang Gung University	CGU	39.3	1
National Chung Hsing University	NCHU	37.1	1.70
National Chengchi University	NCCU	25.4	0.905

Note: The list of top universities here are those who obtained additional subsidy of total 50 billion NT dollars from the government during 2006-2011. The 2013 ARWU ranking scores is the 2013 Shanghai Jiao Tong University's academic ranking of world universities.

Table 2. The conflicting strategy adoption and the PR differences between NTU and UST departments after 2007

Independent variables	Probit models		Logit models	
	Model 1	Model 2	Model 1	Model 2
PR differences	-0.09** (0.03)	-0.08** (0.03)	-0.16** (0.06)	-0.16** (0.06)
Conflicting with other tops		0.16 (0.42)		0.28 (0.72)
Number of faculty	0.02 (0.01)	0.02 (0.01)	0.03 (0.03)	0.03 (0.03)
Unemployment rate	-0.44 (0.64)	-0.36 (0.67)	-0.52 (1.10)	-0.40 (1.15)
Observations	90	90	90	90
AIC	99.97	101.83	99.72	101.57

Note: PR is the percentile rank of the lowest score of enrolled students for a department in a nationwide standardized examination for applying undergraduate programs in Taiwan. A small PR differences implies that the UST department has similar prestige to the corresponding department at NTU. Entries in the same column are from a probit or logit model specification with corresponding dependent and independent variables. Standard errors are shown in parentheses. Significances at 10%, 5%, and 1% levels are denoted by *, **, and ***, respectively.

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 (2015). The number of faculty is from the Ministry of Education in Taiwan.

Table 4. Conflicting effect by controlling common trends and field-specific effects

	Retardation rate models		
Independent variables	Model 1	Model 2	Model 3
Optimal Choice	-7.13*** (2.00)	-7.37*** (2.02)	-5.44*** (2.07)
Conflicting with other tops		0.77 (0.85)	0.76 (0.84)
Alliance			-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.