Reexamining Education Fairness: An Experimental Study of Chinese College Admission Policies

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Outline

1. Background
   - College Entrance Exam (Gaokao)
   - College admission policies (acceptance rules, timing of application)
2. Gaokao Games: Complete Information
3. Pilot Experiment: Complete Information
4. EITM Framework and Quantal Response Equilibrium
5. Gaokao Games and Pilot Experiment: Low Information
6. Gaokao Games and Pilot Experiment: Private Information

Background 1

- **College Entrance Exam (Gaokao, 高考)**
  - An annually nation-wide comprehensive exam on June 7th and 8th.
  - Usually, math, Chinese, and English for all students; history, politics, and geography for the liberal-arts track students; physics, chemistry, and biology for the natural-science track.
  - 87% of universities are public universities.
  - In admitting new students, Chinese universities only consider *Gaokao* scores rather than GPA, recommendation letters, or personal statement.

Background 2

- **College Admissions**
  - Competition for college education is limited within every province because of regional quotas. Local universities favor local students.
  - Universities are highly concentrated in Beijing and Shanghai. College quotas are a source of education unfairness.
  - All universities are officially classified into three tiers. Usually, students can only apply for three universities in each tier, respectively.
  - Following the general instruction of the State Council (executive branch), every province makes its own education policies.
  - Students have to submit their college preferences during the period (3 -5 days) specified by provincial education agencies.
  - Local variations in college admission policies
    - Immediate acceptance/ordered preference (顺序志愿) vs. deterred acceptance/parallel preference (平行志愿)
    - Timing of application with regard to the college entrance exam.

Acceptance Rules 1

- **Immediate Acceptance Algorithms/Ordered Preference** (Roth et al, 2005)
  - "Step 1: For each school, consider the students who have listed it as their *first* choice and assign seats to these students in priority order until either no seats remain or no student remains who has listed it as first choice."
  - "Step k: For each school with seats still available, consider the students who have listed it as their *k*th choice and assign seats to these students in priority order until either no seats remain or no student remains who has listed it as *k*th choice."

Acceptance Rules 2

- **Deterred Acceptance Algorithms/ Parallel Preference** (Gale & Shaple 1962; Roth et al, 2005)
  - "Step 1: Each student "proposes" to her first choice. Each school **tentatively** assigns its seats to its proposers one at a time in their priority order. Any remaining proposers are rejected."
  - "Step k: Each student who was rejected in the previous step proposes to her next choice if one remains. Each school considers the students it has been holding together with its new proposers and tentatively assigns its seats to these students one at a time in priority order. Any remaining proposers are rejected."

Acceptance Rules 3

- **One Example**

Student	Score	Choice 1	Choice 2
A	90	Harvard	UI
B	70	Harvard	UI
C	50	UI	Harvard

Immediate Acceptance

- Step 1

University	Admitted
Harvard	A
UI	C

- Under immediate acceptance rule, first choice is most crucial.

Deterred Acceptance

- Step 1

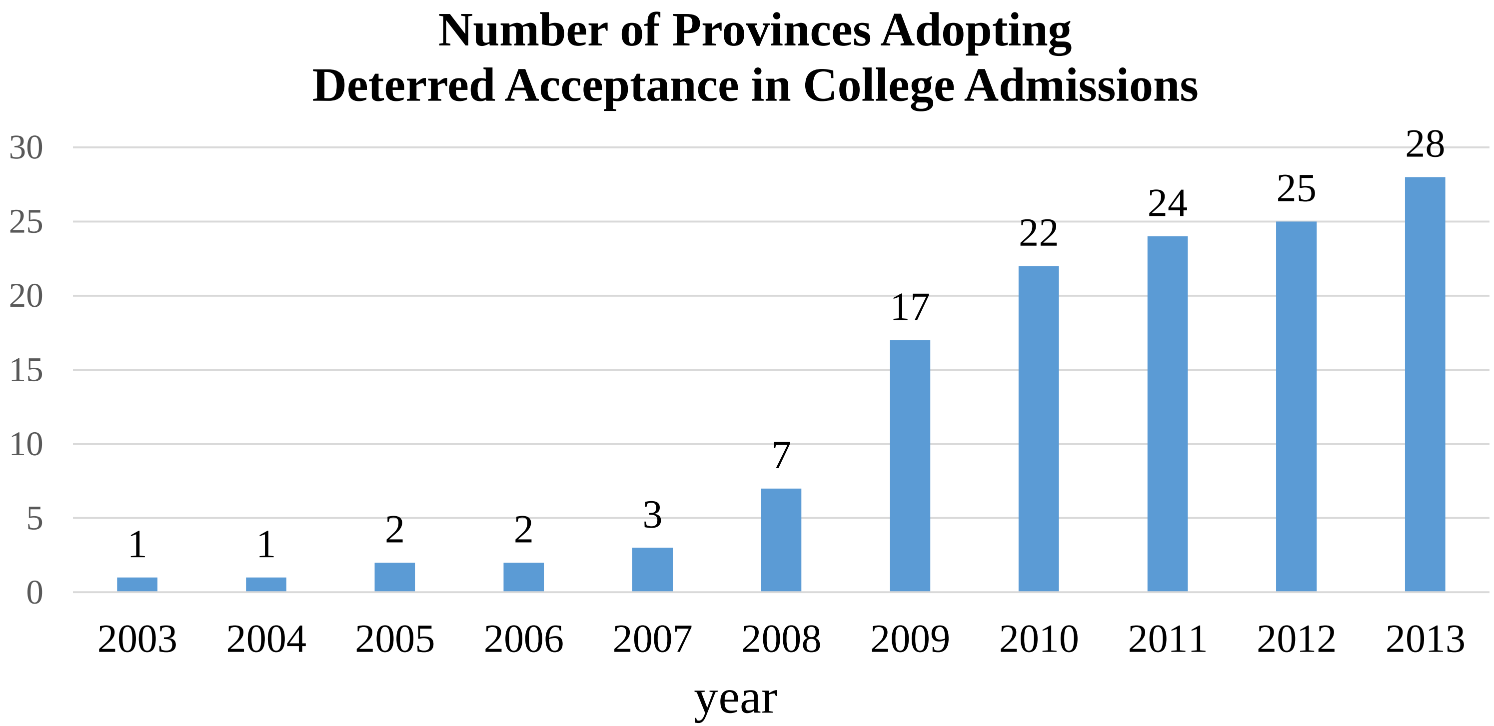
University	Admitted
Harvard	A
UI	C

- Step 2

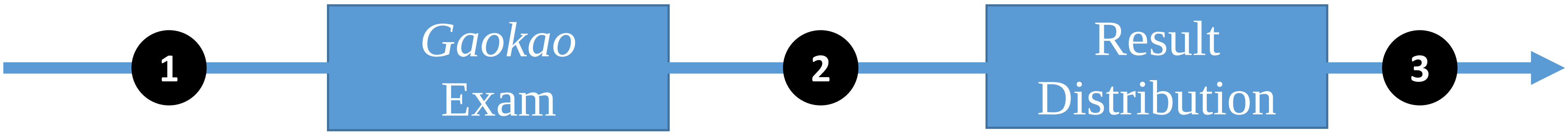
University	Admitted
Harvard	A
UI	B

Acceptance Rules 4

- By 2013, 28 out of 31 provinces have replaced immediate acceptance with deterred acceptance in college admissions except for Beijing, Inner Mongolia, and Qinghai.
- Beijing: Immediate acceptance for the first choice, deterred acceptance for the last three choices (小平行志愿).



Timing of Application



1. **Low Information (考前)**
   - Apply for universities before taking the college entrance exam.
   - Have to estimate your exam result and rank among all students based on previous mimic exams.
2. **Private/Asymmetric Information (估分)**
   - Official answers are distributed right after the college entrance exam.
   - Estimate your exam score based on the official answers but do not know others' scores.
   - On average, estimated score is consistent with the real score.
3. **Complete Information (知分)**
   - The distribution of all students' exam scores are released to the public.
   - Know your real rank among all students.

Research Questions

1. Given immediate acceptance rule, how does timing of application affect students' strategies in choosing universities?

2. Given immediate acceptance rule, how does timing of application affect the distribution of admission outcomes?

Gaokao Games: Complete Information 1

- **Players**
  - **{A, B, C}**
- **Strategies**
  - { Harvard, UI }
- **Payoffs**
  - Admitted by Harvard: 2 dollars.
  - Admitted by UI: 1 dollar.
  - Rejected by both: 0.

Gaokao Games: Complete Information 2

1. **Two Mimic Exams: Common knowledge**

- This prior belief is more critical in private and low information games.

2. **College Entrance Exam**

- Final exam results reflect previous performance: Randomly pick one mimic exam score as the college entrance exam score.
- All possible outcomes

	A	B	C	Rank
1	lo	lo	lo	A B C
2	lo	lo	hi	A C B
3	lo	hi	lo	B A C
4	lo	hi	hi	B A C

	A	B	C	Rank
5	hi	lo	lo	A B C
6	hi	lo	hi	A C B
7	hi	hi	lo	A B C
8	hi	hi	hi	A B C

Rank	Probability
A B C	0.5
A C B	0.25
B A C	0.25

Gaokao Games: Complete Information 3

- Expected rank distribution before taking the college entrance exam

Rank	A	B	C
1	0.75	0.25	0
2	0.25	0.5	0.25
3	0	0.25	0.75

- Ideal/fair distribution of admission outcomes should be consistent with expected rank distribution.

	A	B	C
Harvard	0.75	0.25	0
UI	0.25	0.5	0.25
None	0	0.25	0.75
Expected Utility	**1.75**	**1**	**0.25**

Gaokao Games: Complete Information 4

3. **College Application**
   - Normal form game
   - All students' final scores are common knowledge. They made decisions based on their final ranks.

3rd: Harvard		**2nd**	
		Harvard	UI
1st	Harvard	2 0 0	2 1 0
	UI	1 2 0	1 0 0

3rd: UI		**2nd**	
		Harvard	UI
1st	Harvard	2 0 0	2 1 0
	UI	1 2 0	1 0 0

- Nash equilibria

Rank	Strategy
1	Harvard
2	UI
3	Harvard/UI

Gaokao Games: Complete Information 5

- **Expected Outcome Distribution**

	A	B	C
Harvard	0.75	0.25	0
UI	0.25	0.5	0.25
None	0	0.25	0.75
Expected Utility	**1.75**	**1**	**0.25**

- Under complete information, the expected outcome distribution is the same with the ideal outcome distribution, well reflecting real academic performance.

Pilot Experiment: Complete Information 1

- **Subjects**
  - Each group has three players. 10 groups and 30 subjects.
  - 8 groups for each treatment (complete, private, and low information).
  - 3 groups played a game of one treatment. 7 groups repeated the game with three different treatments.
  - 21 Chinese (15 experienced), 6 Americans, 1 Taiwanese, and 2 Koreans.
  - 12 undergraduate students, 18 graduate students.

Pilot Experiment: Complete Information 2

1. **Types of Students**
   - Three cards (yellow, blue, and red) represent three types of students. For each group, randomly assign a card to each student.
   - Three types of students differ in their mimic exam scores that reflect their real academic performance.
   - Students do not know the relationship between the color of cards and mimic exam scores until they take two mimic exams.

2. **Mimic Exams**
   - In each mimic exam, show each student a envelope which contains 10 folded numbers, and ask students to randomly pick one.

	Mimic 1	Mimic 2
A	71 – 79	91 - 100
B	51 – 60	81 - 90
C	41 - 50	61 - 70

→ This information is unknown to students.

   - All mimic exam scores are released to all students before the college entrance exam.

Pilot Experiment: Complete Information 3

3. **College Entrance Exam**
   - Randomly pick one number from two mimic exam scores. This number will become the result of college entrance exam.
   - Each student should show her final score to others. Thus, the rank of each student is common knowledge.

4. **College Application**
   - Each student has to apply for a university, either Harvard or UI.
   - Each university only admits one student based on scores of college entrance exam.
   - Harvard: 2 dollars; UI: 1 dollar; rejected by both: 0.
   - Losers will be rewarded a chocolate candy at the end of experiment, but they do not know this during experiment.

Pilot Experiment: Complete Information 4

5. **Post-Game Discussions**
   - Which games are fair and which are not among the three? What make you think so?
   - What was your expectation of other two players' choices (beliefs)? (This question should be asked before college application because people have short memory.)
   - Does the experiment well reflect the reality?
   - Other thoughts?

Pilot Experiment: Complete Information 5

- **Experimental Results**
- **Observed Strategy Distribution**

Rank	Strategy	
	Harvard	UI
1	1 (8)	0 (0)
2	0 (0)	1 (8)
3	0.125 (1)	0.875 (7)

- Nash Equilibria

Rank	Strategy
1	Harvard
2	UI
3	Harvard/UI

- The observed strategy distribution confirms the expected Nash equilibria.
- A quote from a student ranking the third: “UI would 100% reject me, but Harvard would 1000% reject me.”

Pilot Experiment: Complete Information 6

- **Observed Outcome Distribution**

	A	B	C
Harvard	0.75	0.375	0
UI	0.25	0.375	0.5
None	0	0.25	0.5
Expected Utility	**1.75**	**1.125**	**0.5**

  - Two things determine the observed outcome distribution: observed strategy distribution, and luck in picking the exam score.

- **Luck of Picking the Higher Score**

	High	Low
A	0.7	0.3
B	0.3	0.7
C	0.5	0.5

Pilot Experiment: Complete Information 7

- **Adjusted Outcome Distribution**
  - Assume the probability of picking the higher mimic exam score is 0.5 for each student. This assumption is likely to hold with a large sample of subjects.

	A	B	C
Harvard	0.75	0.25	0
UI	0.25	0.5	0.25
None	0	0.25	0.75
Expected Utility	**1.75**	**1**	**0.5**

  - The adjusted outcome distribution exactly corresponds to the expected/ideal outcome distribution. It is not a surprise because all students chose strategies as predicted by the game model.

EITM Framework 1

- **Behavioral Concepts:**
  1. Decision making
  2. Expectations
  3. Strategic interaction
  4. Learning
  5. Bounded rationality/agent error
     "To err is human (Alexander Pope)."

- **Statistical Concepts**
  1. Nominal choice
  2. Measurement error
  3. Distribution

EITM Framework 2

- **Behavioral Analogues**
  1. Utility maximization
  2. Random utility
  3. Bayesian updating
  4. Agent Quantal Response Equilibrium (AQRE)
  - (McKelvey & Palfrey, 1995; McKelvey & Palfrey, 1998)

- **Statistical Analogues**
  1. Discrete choice modeling (multinominal logit model)
  2. Chi-2 test

EITM Framework 3

- **A Cheesy Option: Chi2 Test**

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

where E is expected value, and O is observed value.

- Limit of chi2 test: Expected values may be zero. For example, in the complete information game, the expected probability that C is admitted by Harvard is 0.

Quantal Response Equilibrium 1

- **Agent Quantal Response Equilibrium (AQRE)**
  - Player *i* chooses strategy *j* with probability *p*.

    $$\hat{u}_{ij}(\mathrm{p}) = \bar{u}_{ij}(\mathrm{p}) + \varepsilon_{ij}$$

  - Assumption: Agent errors are IID, and follow extreme value (Weibull) distribution with parameter $\lambda \geq 0$.
  - Logit Quantal Response Function

    $$\pi_{ij} = \frac{e^{\lambda \bar{u}_{ij}}}{\sum_{k=1}^{J_i} e^{\lambda \bar{u}_{ik}}}$$

  - λ indicates the degree of rationality. $\lambda = 0$ means that actions consist of all errors, and $\lambda = \infty$ means no error.

Quantal Response Equilibrium 2

- **AQRE of Gaokao Games: Complete Information**
  - π_1 is the probability that the student ranking the first chooses Harvard; π_2 is the probability that the student ranking the second chooses Harvard; and π_3 is the student ranking the third chooses Harvard.
  - Expected utilities

$$
\begin{aligned}
\bar{u}_1(\mathrm{H}) &= 2 \\
\bar{u}_1(\mathrm{UI}) &= 1 \\
\bar{u}_2(\mathrm{H}) &= 0\times\pi_2\pi_3 + 1\times(1-\pi_2)\pi_3 + 0\times\pi_2(1-\pi_3) + 1\times(1-\pi_2)\times(1-\pi_3) \\
&= 2-2\pi_1 \\
\bar{u}_2(\mathrm{UI}) &= 2\times\pi_2\pi_3 + 0\times(1-\pi_2)\pi_3 + 2\times\pi_2(1-\pi_3) + 0\times(1-\pi_2)(1-\pi_3) \\
&= \pi_1 \\
\bar{u}_3(\mathrm{H}) &= 0 \\
\bar{u}_3(\mathrm{UI}) &= 0
\end{aligned}
$$

Quantal Response Equilibrium 3

- **AQRE of Gaokao Games: Complete Information**

$$\begin{cases} \pi_1 = \dfrac{e^{2\lambda}}{e^{2\lambda} + e^{2\lambda}} = \dfrac{1}{1+e^{-\lambda}} \\ \pi_2 = \dfrac{e^{\lambda(2-2\pi_1)}}{e^{\lambda(2-2\pi_1)} + e^{\lambda\pi_1}} = \dfrac{1}{1+e^{\lambda(3\pi_1-2)}} \\ \pi_3 = \dfrac{e^{0\lambda}}{e^{0\lambda} + e^{0\lambda}} = \dfrac{1}{2} \end{cases}$$

$$\pi_1 = \pi_2 = \pi_3 = 0.5 \quad \text{if} \quad \lambda = 0.$$

$$\pi_1 = 1,\ \pi_2 = 0,\ \pi_3 = 0.5 \quad \text{if} \quad \lambda = \infty.$$

Quantal Response Equilibrium 4

- **Estimating λ with Experimental Data**
  - The bigger the value of **λ**, the more consistent between game model and experimental evidence.
  - Probabilities of all possible strategy profiles

$$\begin{cases} p_1 = pr(\mathrm{H,H,H}) = pr(\mathrm{H,H,UI}) = 0.5\pi_1\pi_2 \\ p_2 = pr(\mathrm{H,UI,H}) = pr(\mathrm{H,UI,UI}) = 0.5\pi_1(1-\pi_2) \\ p_3 = pr(\mathrm{UI,H,H}) = pr(\mathrm{UI,H,UI}) = 0.5(1-\pi_1)\pi_2 \\ p_4 = pr(\mathrm{UI,UI,H}) = pr(\mathrm{UI,UI,UI}) = 0.5(1-\pi_1)(1-\pi_2) \end{cases}$$

  - Maximum Likelihood Estimation

$$\text{maximize } \ln\prod p_1^{\delta_1} p_2^{\delta_2} p_3^{\delta_3} p_4^{\delta_4}$$

$$\text{constraint } \pi_1 = \frac{1}{1+e^{-\lambda}}$$

  - 8 observations are probably not enough to make **λ** converge.

Back to Gaokao Games 1

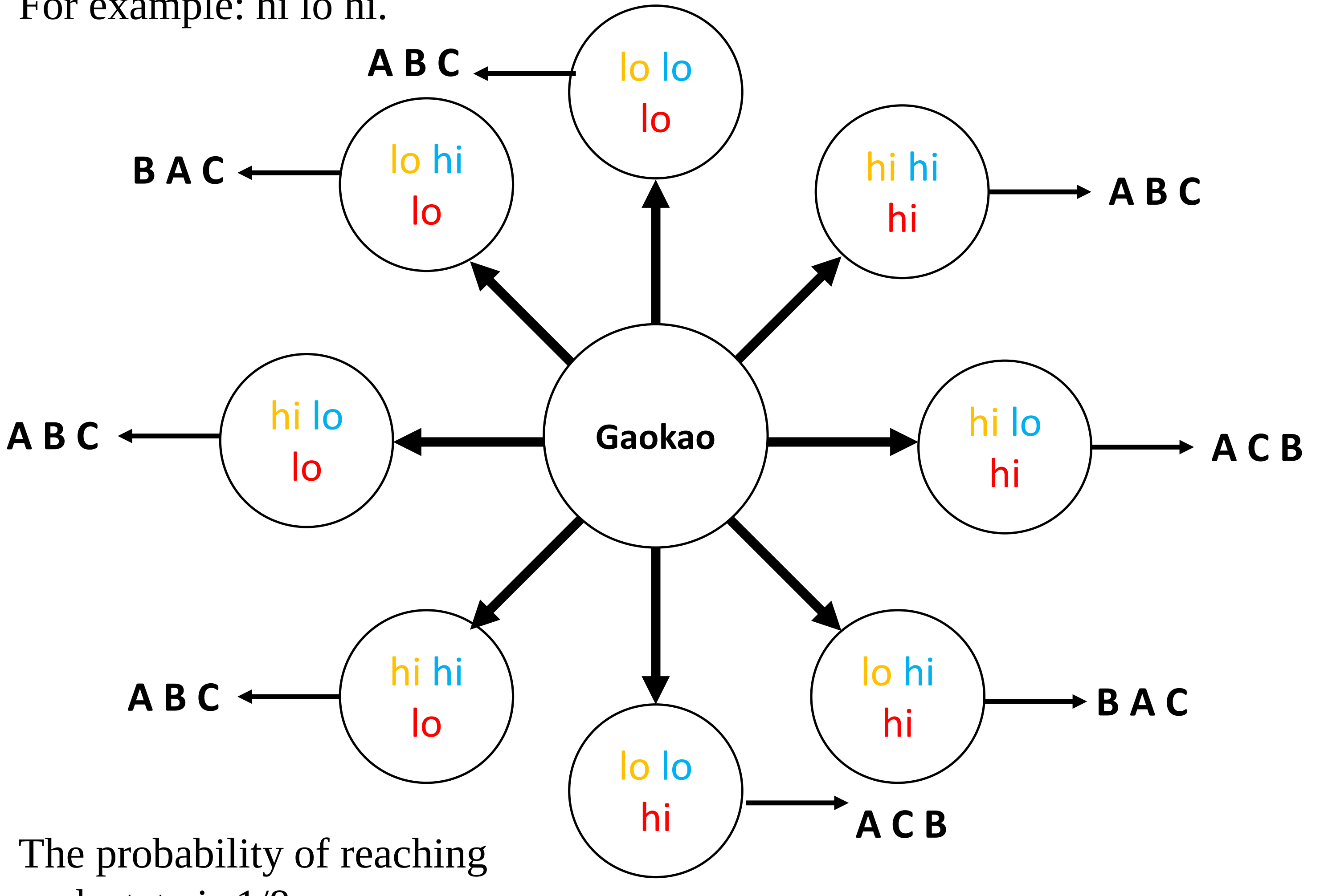
- **The Only Difference in the Three Games: Timing of Application**

1. **Low Information**
   - Information with regard to the distribution of *Gaokao* exam scores.
   - Apply prior to *Gaokao* exam.
   - Don’t know your own and other two players’ scores.
2. **Private Information**
   - Apply in between *Gaokao* exam and result distribution released.
   - Know your own score but not other two players’.
3. **Complete Information**
   - Apply after result distribution is released.
   - Know both your own and other two players’ scores.

Back to Gaokao Games 2

- **Relationship between Three Gaokao Games**

- For example: hi lo hi.



- The probability of reaching each state is 1/8.

Gaokao Games: Low Information 1

- **Bayesian Nash Equilibrium**

	Strategy
A	Harvard
B	UI
C	UI

- **Observed Strategy Distribution**

	Strategy	
	Harvard	**UI**
A	1 (8)	0 (0)
B	0.875 (7)	0.125 (1)
C	0 (0)	1 (8)

- In the experiment, players A and C made decisions as predicted by the game model.
- Player B was risk-seeking. Or, perceived utility might override the induced utility.

Gaokao Games: Low Information 2

- **Expected Outcome Distribution**

	A	B	C
Harvard	1	0	0
UI	0	0.75	0.25
None	0	0.25	0.75
Expected Utility	**2**	**0.75**	**0.25**

- Biased in favor of player A at the cost of player B.
- For C, no difference from the ideal outcome distribution.

- **Adjusted Outcome Distribution**

	A	B	C
Harvard	0.781	0.219	0
UI	0	0.094	0.906
None	0.219	0.688	0.094
Expected Utility	**1.56**	**0.53**	**0.91**

- In the experiment, player B’s risk-seeking behavior harmed both A and herself.
- Player C was the winner who often did not face a competitor.

Gaokao Games: Private Information 1

- **Five Bayesian Nash Equilibria**

	hi	lo
A	Harvard	Harvard
B	UI	UI
C	UI	UI

	hi	lo
A	Harvard	Harvard
B	UI	UI
C	UI	Harvard

	hi	lo
A	Harvard	Harvard
B	Harvard	UI
C	UI	UI

	hi	lo
A	Harvard	UI
B	Harvard	Harvard
C	Harvard	UI

	hi	lo
A	Harvard	UI
B	Harvard	Harvard
C	UI	UI

- A and B’s behaviors regarding risk are complementary. If B believes that A would stick with Harvard, she would not apply for Harvard given the lower score, and vice versa.
- No clear pattern of C.

Gaokao Games: Private Information 2

- **Observed Strategy Distribution**

	hi		lo	
	Harvard	**UI**	**Harvard**	**UI**
A	0.75 (3)	0.25 (1)	0.75 (3)	0.25 (1)
B	0.5 (1)	0.5 (1)	0.333 (2)	0.667 (4)
C	0 (0)	1 (4)	0.25 (1)	0.75 (3)

- Need more observations to have clear patterns.

Gaokao Games: Private Information 3

- **Expected Outcome Distribution**

	A	B	C
Harvard	0.5 - 1	0 – 0.5	0 – 0.125
UI	0 – 0.5	0 – 0.75	0.25 – 0.75
None	0 – 0.25	0.25 – 0.625	0.25 – 0.625
Expected Utility	**1.5 - 2**	**0.75 - 1**	**0.25 – 0.75**

  - Compared to the ideal outcome distribution, the rejection rate is higher for A and B, but lower for C. C also has higher admission rate for both universities.

- **Adjusted Outcome Distribution**

	A	B	C
Harvard	0.828	0.099	0.018
UI	0.109	0.443	0.383
None	0.063	0.458	0.599
Expected Utility	**1.77**	**0.64**	**0.42**

Conclusion

- **From Game Theoretic Models:**
  - Complete information: Fair in terms of outcome distribution.
  - Low information: Biased in favor of A at the expense of B; neutral to C.
  - Private information: Biased in favor of C at the cost of both A and B.

- **From Pilot Experiment:**
  - Complete information: Still fair.
  - Low information: Significantly favoring C, but harming both A and B.
  - Private information: Unclear.