Equilibrium Tuition, Applications, Admissions and Enrollment in the College Market

University of Wisconsin–Madison

Author: Chao Fu (JPE,2014)

Pre by: Dongsheng DENG

复旦大学经济学院

SCHOOL OF ECONOMICS FUDAN UNIVERSITY

Contents

About Chao Fu

Figure: Chao Fu on SSSI 2015, Beijing

Research Fields: Labor Economics, Empirical Microeconomics, Applied Theory

Publications

- *College-Major Choice to College-then-Major Choice.* The Review of Economic Studies (2015).
- *Equilibrium tuition, applications, admissions, and enrollment in the college market.* Journal of Political Economy (2014).
- *Training, search and wage dispersion.* Review of Economic Dynamics (2011).
- *Assumptions Matter: Model Uncertainty and the Deterrent Effect of Capital Punishment.* The American Economic Review (2012).
- *Capital Punishment and Deterrence: Understanding Disparate Results.* Journal of Quantitative Criminology (2013).

Introduction

The level of college enrollment and the composition of college students continue to be issues of widespread scholarly interest as well as the source of much public policy debate.

- Develop and structurally estimate an equilibrium model of the college market.
- Provides insights into the determination of the population of college enrollees and permits quantitative evaluation of the effects of counterfactual experiments.
- Provides a mechanism for assessing the market equilibrium consequences of changes in government policies.

Related Literature

- Manski and Wise (1983) use a non-structural approach to study each stage of the college admissions problem in isolation.
- Arcidiacono (2005) estimates a structural model to address the effects of college admissions and financial aid rules on future earnings.
- Epple, Romano and Sieg (2006): differ in family income and ability, with complete information, no uncertainty and no unobserved heterogeneity.
- Chade, Lewis and Simith (2011): model the decentralized matching of students and two colleges.
- Estimation models with multiple equilibria: Aguirregabiria and Mira (2007) and Bajari, Benkard and Levin (2007) in dynamic games and Bajari, Hong, Krainer and Nekipelov (2010) in static games use a two-step estimation procedure.
- This paper: Moro (2003) two-step estimation strategy.

Depatures from ERS

1. The college market is subject to information frictions and uncertainty: colleges can only observe noisy measures of student ability, and they do not observe student preferences.
2. Student application decisions differ substantially.
3. This paper models the strategic behavior of both public colleges and private colleges.
4. Students have different abilities and preferences for colleges, which are unobservable to researchers.

Building on Work by CLS

- Quantifies the significance of the two key elements of CLS: information frictions and application costs.
- Extend CLS to account for some elements that are important
  - students are heterogeneous in preferences and abilities, both of which are unknown to the colleges.
  - allow for two noisy measures of student ability (signal + test score).
  - model multiple colleges competing via tuition and admission policies.

Advances

This paper makes advances relative to the current literature by simultaneously modeling three aspects of the college market:

1. Application is *costly* to the student.
2. Students differ in their *abilities* and *preferences* for colleges.
3. While trying to attract and select more able students, colleges can only observe *noisy measures* of student ability.

Players: Students

- a continuum of students;
- make application and enrollment decisions;
- come from different family backgrounds (B);
- home state location $l \in B$;
- differ in abilities (measure: $SAT = 1, 2, 3$);
- different preferences for colleges.

Players: Colleges

- J four-year colleges ($j = 1, 2, \ldots, J$);
- 1 two-year community college($j = J + 1$);
- consists of a tuition office and an admissions office;
- fixed capacity $\kappa_j > 0$, $\sum_{j=1}^{J} \kappa_j < 1$;
- student can attend community college without application(exogenous option).

Assumptions

A1. There are 4 groups (g) of 4-yr colleges: (private, elite), (public, elite), (private, non-elite) and (public, non-elite);

A2. From a student's point of view, the location of a college matters only up to whether or not it is within her home state.

A3. All colleges face the same distribution of students (focus on symmetric equilibrium).

With these assumptions, the model focuses on the main features of the college market and factors considered by students:

- The within-group competition is more fierce than that across groups.
- Admissions policies & tuition policies are similar among similar colleges.
- (Student side) tuition cost, whether the college is private or public, elite or non-elite, in or out of one's home state.

Application Cost and Financial Aid

- Application is costly to the student, $C(\cdot)$ is non-decreasing function.
- Financial aid depends on the student's family background(B) and SAT via $f_j(B, SAT)$.
- The exact amounts of financial aid remain uncertain, post-application shocks $\eta \in \mathbb{R}^{J+2}$, distributed i.i.d. $N(0, \Omega_\eta)$.
- The realized financial aid for student i is given by

$$f_{ji} = \max\{f_j(B_i, SAT_i) + \eta_{ji}, 0\} \quad \text{for } j = 0, 1, \ldots, J+1.$$

Student Endowment: Ability

- Student is endowed with certain ability and preferences for colleges.
- Abilities and preferences are potentially correlated.
- Students are of different types (K).
- Unobservable types are correlated with SAT and family background (B): $P(K|SAT, B)$.
- A student type K has two dimensions with $K \equiv (A, z)$.
  - A represents student quality(ability), can be can be low (1), medium (2) or high (3).
  - $z \in \{1, 2\}$ allows for systematic heterogeneity in preferences among students of the same ability.

Student Endowment: Preference

- Each student may have her own idiosyncratic tastes for colleges that are not representative of her type.
- A type-K student i's preferences for colleges are modeled as a random vector $u_i \equiv \{u_{ji}\}_{j=1}^{J+1}$, with

$$u_{ji} = \bar{u}_{g_j K} + \epsilon_{1 g_j i} + \epsilon_{2ji}$$

  g_j represents the group college j belongs to.
- Students differ in their (dis)tastes for studying out of their home states: $\xi_i \sim N(\bar{\xi}_K, \sigma_\xi^2)$.
- Given tuition profile $t \equiv \{\{t_{jl}\}_l\}_j$, the ex-post value of attending college j for student i is

$$U_{ji}(t) = (-t_{jl_i} + f_{0i} + f_{ji}) + u_{ji} - I(l_j \neq l_i)\xi_i, \quad (1)$$

College Payoff

- Colleges care about ability of their enrollees & net tuition revenues.
- For a **private** college j, its payoff W_j is

$$W_j = \int (w_{a_i} + m_{1j}\pi_{ji}) dF_j^*(i) + m_{2j} \frac{\prod_j^2}{N_j} \quad \text{if } j \text{ is private.} \tag{2}$$

  w_a is the value of ability $A = a$, with $w_{a+1} > w_a > 0$, $\pi_{ji} \equiv t_j - f_{ji}$ is the net tuition revenue from student i.

- A **public** college may treat in-state students differently from out-of-state students:

$$W_j = \sum_{\iota=0}^{1} \left(\int (w_{a_i} + m_{1j\iota}\pi_{ji}) dF_{j\iota}^*(i) + m_{2j\iota} \frac{\prod_{j\iota}^2}{N_{j\iota}} \right) \quad \text{if } j \text{ is public.} \tag{3}$$

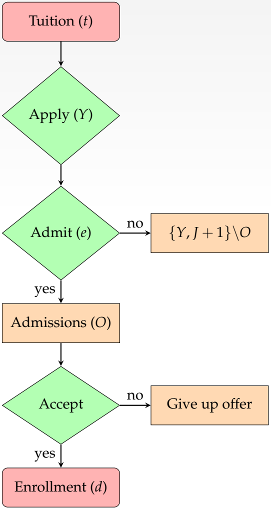
$$\iota \equiv I(l_i = l_j)$$

Timing

Stage 1 : Colleges simultaneously announce tuition levels.

Stage 2 : Students make application decisions; colleges simultaneously choose admissions policies.

Stage 3 : Students learn about admission and financial aid results, and make enrollment decisions.



Information Structure

- Upon student i's application, each college she applies to receives a signal $s \in \{1, 2, 3\}$ drawn from the distribution $P(s|A_i)$. Signals to various colleges are correlated.
- For $A < A'$, $P(s|A')$ first order stochastically dominates $P(s|A)$.
- Randomness is to capture the idiosyncratic interpretations of the student's application materials.
- Public information: $P(s|A)$, the distributions of characteristics, preferences, payoff functions and financial aid functions.
- Private information: type K_i , taste ϵ_i and family background B_i ($l_i \in B_i$), let $X_i \equiv (K_i, B_i, \epsilon_i)$.

Information Sets

	Student	Admissions Office j	Researcher
Application-Admission	SAT_i, X_i	$SAT_i, s_{ji}, (l_i)$	SAT_i, B_i
Enrollment	SAT_i, X_i, η_i	–	SAT_i, B_i

Enrollment Decision

- Given her admission and financial aid results, student i chooses the best among her outside option and admissions on hand.
- O_i Denotes the set of colleges that have admitted student i.
- Optimal ex-post value for student i:

$$v(O_i, X_i, \eta_i | t) \equiv \max\{U_{0i}, \{U_{ji}(t)\}_{j \in O_i}\} \tag{4}$$

- Denote the associated optimal enrollment strategy as $d(O_i, X_i, \eta_i | t)$.

Application Decision

- Given her admissions probability $p_i(A_i, SAT_i|t)$ to each college j, the value of portfolio Y for student i is

$$V(Y, X_i, SAT_i|t) \equiv \sum_{O \subset \{Y, J+1\}} \Pr(O|A_i, SAT_i, t) E[v(O, X_i, \eta_i|t)] - C(|Y|) \tag{5}$$

- The expectation is over financial aid shocks, $|Y|$ is the size of portfolio Y. The probability that the set O of colleges admit student i is

$$\Pr(O|A_i, SAT_i, t) = \prod_{j \in O} p_j(A_i, SAT_i|t) \prod_{j' \in \{Y, J+1\} \setminus O} (1 - p_{j'}(A_i, SAT_i|t))$$

- The student's application problem is

$$Y(X_i, SAT_i|t) = \arg \max_{Y \subset \{1,\ldots,J\}} \{V(Y, X_i, SAT_i|t)\} \tag{6}$$

Admissions Policy

- Given t, admissions office j chooses its policy subject to κ_j.
- The office treats (s, SAT) with the same policy $e_j(s, SAT|t)$.
- From (s, SAT), the college has to infer
  - probability of applicant will accept its admission (α_j);
  - expected ability of this applicant conditional on her acceptance (γ_j).
- Given tuition t, students' strategies $Y(\cdot)$, $d(\cdot)$ and other colleges' admission policies e_{-j}, college j solves

$$\max_{e_j(s,SAT|t)} \left\{ \sum_{(s,SAT)} e_j(s, SAT|t)\alpha_j(s, SAT|\cdot)\mu_j(s, SAT|\cdot)\gamma_j(s, SAT|\cdot) \right\}$$

$$\text{s.t.} \quad \sum_{(s,SAT)} e_j(s, SAT|\cdot)\alpha_j(s, SAT|\cdot)\mu_j(s, SAT|\cdot) \leq \kappa_j$$

$$e_j(s, SAT|t) \in [0, 1]$$

Probability of Admissions

- The probability of admissions for different (A, SAT) groups of students, $p_j(A, SAT|t)$ summarizes the link among various players.
- Students' application decisions are based on p;
- p makes the information about admission policy redundant.
- The relationship between p and e is given by

$$p_j(A, SAT|t) = \sum_s P(s|A)e_j(s, SAT|t) \tag{7}$$

- Each application-admission equilibrium is uniquely summarized in the admission prob $p_j(A, SAT)$.

Application-Admission Equilibrium

Application-Admission Equlibrium, $AE(t)$

Given tuition profile t, a symmetric application-admission equilibrium, denoted as $AE(t)$, is $\left(d(\cdot|t), Y(\cdot|t), e(\cdot|t), p(\cdot|t)\right)$, such that

(a). $d(O, X, \eta|t)$ is an is an optimal enrollment decision for every (O, X, η);

(b). Given $p(\cdot|t)$, $Y(X, SAT|t)$ is an optimal college application portfolio for every (X, SAT), i.e., solves problem (6);

(c). For every j, given $\left(d(\cdot|t), Y(\cdot|t), p_{-j}(\cdot|t)\right)$, $e_j(\cdot|t)$ is an optimal admissions policy, and $e_j(\cdot|t) = e_{j'}(\cdot|t)$ if $g_j = g_{j'}$;

(d). p_j and e_j satisfy (7). (Consistency)

Tuition Policy

- Before the application season begins, college tuition offices simultaneously announce their tuition policies.
- Let $E(W_j|AE(t))$ be college j's expected payoff under $AE(t)$.
- Given t_{-j} and equilibrium profiles $AE(\cdot)$, college j's problem is

$$\begin{aligned} \max_{\tilde{t}_{jl}\geq 0} \quad & \left\{E(W_j|AE(\tilde{t}_j, t_{-j}))\right\} \\ \text{s.t.} \quad & \tilde{t}_{jl} = \tilde{t}_{jl'} \text{ for all } l \text{ and } l' \text{ if } j \text{ is private,} \\ & \tilde{t}_{jl} = \tilde{t}_{jl'} \text{ for all } l, l' \neq l_j \text{ if } j \text{ is public.} \end{aligned} \tag{8}$$

- Each college considers the strategic role of its tuition in the subsequent $AE(\tilde{t}_j, t_{-j})$,
  - low tuition makes the college more attractive to students and more competitive in the market.
  - high tuition as a screening tool and $\Rightarrow$ a better pool of applicants.

Subgame Perfect Nash Equilibrium

Symmetric Subgame Perfect Nash Equilibrium

A symmetric Subgame Perfect Nash equilibrium for the college market is $\left(t^*, d(\cdot|\cdot), Y(\cdot|\cdot), e(\cdot|\cdot), p(\cdot|\cdot)\right)$ such that:

(a). For every t, $\left(d(\cdot|t), Y(\cdot|t), e(\cdot|t), p(\cdot|t)\right)$ constitutes an $AE(t)$.

(b). For every j, given t^*_{-j}, t^*_j is optimal for college j, i.e., solves problem (8), and $t^*_j = t^*_{j'}$, if $g_j = g_{j'}$.

Multiple equilibria

- The estimation is complicated by potential multiple equilibria.
- One way to deal with it: impose some equilibrium selection rule.
- This paper: there is not a single compelling selection rule.
- Building on Moro(2003), this paper use a two-step strategy to estimate the application-admission subgame.
  1. treats p as parameters and estimates them along with structural student-side parameters.
  2. one only needs to solve each college's decision problem instead of the game between colleges.

Step 1: Student-Side Parameters and Equilibrium Admissions Probabilities

The author implement the first step via simulated maximum likelihood estimation (SMLE):

- Estimates of the fundamental student-side parameters ($\widehat{\Theta}_0$),
  - preference parameters $\widehat{\Theta}_{0u}$;
  - application cost parameters $\widehat{\Theta}_{0c}$;
  - financial aid parameters $\widehat{\Theta}_{0f}$;
  - parameters involved in the distribution of types $\widehat{\Theta}_{0K}$.
- Equilibrium admission probabilities $\hat{p}$ should maximize the probability of the observed outcomes of applications, admissions, financial aid and enrollment, conditional on observable student characteristics.

Step 1: Student-Side Parameters and Equilibrium Admissions Probabilities

- Student i is of type K, her contribution to likelihood is composed of
  - $L_{iK}^{Y}(\Theta_{0u}, \Theta_{0C}, \Theta_{0f}, p)$: the contribution of applications Y_i;
  - $L_{iK}^{O}(p)$: the contribution of admissions $O_i|Y_i$;
  - $L_{iK}^{f}(\Theta_{0f})$: the contribution of financial aid $f_i|O_i$;
  - $L_{iK}^{d}(\Theta_{0u}, \Theta_{0f})$: the contribution of enrollment $d_i(O_i, f_i)$.

  such that

$$L_{iK}(\cdot) = L_{iK}^{Y}(\cdot)L_{iK}^{O}(\cdot)L_{iK}^{f}(\cdot)L_{iK}^{d}(\cdot)$$

- To obtain the likelihood contribution of student i, integrate over the unobserved type:

$$L_i(\Theta_0, p) = \sum_K P(K|SAT_i, B_i; \Theta_{0K})L_{iK}(\Theta_{0u}, \Theta_{0C}, \Theta_{0f}, p). \quad (9)$$

- The log likelihood for the entire random sample is

$$\mathcal{L}(\Theta_0, p) = \sum_i \ln(L_i(\Theta_0, p)). \quad (10)$$

Test the Existence of Origin-Based Admissions

Two versions of the student decision model are estimated:

1. $p_j(A, SAT, l)$ depends on $I(l_i = l_j)$;
2. $p_j(A, SAT, l) = p_j(A, SAT, l')$ for all l, l'.

We can test whether or not admissions depend on a student's origin via a likelihood ratio test, the likelihood ratio test fails to reject the hypothesis that admissions are origin-independent.

Specification of the model:

1. student's origin (l) is not in the admissions office information set.
2. only ability measures matter for admissions.
   - consistent with the need-blind admissions practiced by a lot of colleges.
   - it significantly facilitates the estimation.

Step Two: Estimate Admission-Related College-Side Parameters

- Use simulated minimum distance estimation (SMDE) to recover college-side parameters Θ_2: signal distribution $P(s|A)$, capacity κ and values of abilities(w).
- Simulate a population of students and obtain their optimal application and enrollment strategies under $\hat{p}$.
- The resulting equilibrium enrollment in each college group should equal its expected capacity.
- Given $\hat{p}_{-j}$, college j choose admission policy e_j.
- The estimates of the college-side parameters minimize the weighted sum of the discrepancies.
- Let $\widehat{\Theta}_1 = [\widehat{\Theta}_0', \hat{p}']'$, the objective function in Step Two is

$$\min_{\Theta_2} \{q(\widehat{\Theta}_1, \Theta_2)' \widehat{W} q(\widehat{\Theta}_1, \Theta_2)\} \tag{11}$$

Step Three: Tuition Preference

- Under the true tuition preference parameters m, the optimal solution should match the tuition data.
- The objective in Step Three:

$$\min_{m} \left\{ \left(t^* - t(\widehat{\Theta}, m)\right)' \left(t^* - t(\widehat{\Theta}, m)\right) \right\} \tag{12}$$

- where t^* is the data tuition profile, $t(\cdot)$ consists of each college's optimal tuition;
- $\widehat{\Theta} \equiv [\widehat{\Theta}_0, \widehat{\Theta}_2]$ is the vector of fundamental parameter estimates.

Identification

The identification relies on the following assumptions.

IA1: the number of student types is finite; idiosyncratic tastes are separable and independent from type-specific mean preferences; tastes are drawn from an i.i.d. single-mode distribution, with mean normalized to zero, and tastes are independent of (SAT, B, K).

- The modes of these choices informs one of the number of types and the fraction of each type;
- distributions of student type-related characteristics will differ around various modes($\Rightarrow$ one of the correlation between type K and (SAT, y))

IA2: At least one variable in the financial aid functions is excluded from the type distribution function; conditional on (SAT, y); this variable is independent of K.

- students with the same (SAT, y) may differ in other family background variables that affect their expected financial aid($\Rightarrow$ different application behaviors).

NLSY97 Data and Sample Selection

- Respondents from the 1983 and 1984 birth cohorts (administered in years 2003-2005).
- Applied college information (name, location, general financial aid, admission accepted or not, financial aid).
- SAT/ACT score (objective measure of ability).
- Financial-aid-relevant family information (income,assets,race,sibings).
- Focus on first-time college application behavior.
- Exclude early admission + critical info. missing obs (Final: $N = 1646$).

College Groups and Choice Set

- The elite/non-elite division of colleges is based on U.S. News and World Report 2001-2005;
- Top 30 private universities and top 20 liberal arts colleges considered as (pirvate,elite);
- (public, elite) group includes the top 30 public universities;
- Within each of the four groups of 4-yr colleges, a student can send out at most two applications (majority behavior: 83%).

Table 1 Four-Year College Groups

	(pri,elite)	(pub,elite)	(pri,non)	(pub,non)
Num. of colleges (Potential[a])	51	56	1921	595
Num. of colleges (Applied[b])	37	56	312	268
Capacity[c] (%)	1.0	7.7	11.5	21.9

a. Total number of colleges in each group (IPEDS).

b. Number of colleges applied to by some students in the sample.

c. Capacity = Num. of students in the sample enrolled in each group/sample size.

Summary Statistics

Table 2 Student Characteristics

	Non-Applicants	Applicants	2-Yr Attendees	4-Yr Attendees
Female	43.0%	53.1%	47.1%	53.5%
Black	17.6%	13.4%	15.2%	12.3%
Family Income[a]	39,822 (32,428)	68,231 (51,208)	70,605 (51,279)	70,179 (50,995)
$SAT^b = 1$	80.2%	16.6%	58.0%	14.0%
$SAT = 2$	16.7%	59.7%	35.8%	60.3%
$SAT = 3$	3.1%	23.7%	6.2%	25.7%
Observations	892	754	374	693

a. in 2003 dollars, standard deviations are in parentheses.

b. SAT=1 if SAT or ACT equivalent is lower than 800 (Obs: 840).[57]

SAT=2 if SAT or ACT equivalent is between 800 and 1200 (Obs: 599).

SAT=3 if SAT or ACT equivalent is above 1200 (Obs: 207).

Table 3 Number of Applications (%)

	$n = 0$	$n = 1$	$n \geq 2$
All Students	54.2	28.0	17.8
$SAT = 1$	85.1	12.1	2.8
$SAT = 2$	24.9	45.2	29.9
$SAT = 3$	13.0	43.0	44.0

Summary Statistics

Table 4 Application & Admission: All Applicants

(%)	(pri,elite)	(pub,elite)	(pri,non)	(pub,non)
Application Rate	9.7	31.8	44.6	71.5
Admission Rate	53.4	83.0	91.4	94.0
SAT=3 Enrollees	93.8	36.2	27.9	17.8

Num of all applicants: 754

Application rate=num. of group-specific applications/num. of all applications

Admission rate=num. of group-specific admissions/num. of group-specific applications

Table 5 Tuition and Financial Aid

		(pri,elite)	(pub,elite)	(pri,non)	(pub,non)	2-yr College	General
Tuition[a]	(In-State)	27,033	5,000	17,296	3,969	2,744	–
	(out-of-state)		14,435		10,215	–	
Aid Recipients[b]		25%	24.1%	49.5%	27.2%	–	39.9%
Average Aid Offered		12,440	6,962	11,389	5,208	3,095	4,326

a. Tuition and aid are measured in 2003 dollars.

b. Num. of aid offers/num. of admissions in the sample. N/A for 2-yr colleges due to open admissions.

Student Preferences for Colleges

Table 6 Preferences for Colleges

($1, 000)	(pri,elite)	(pub,elite)	(pri,non)	(pub,non)	2-yr
$\overline{u}_g$(A=1,z=1)[a]	−187.7 (188.0)	−183.2 (5.1)	−123.5 (3.8)	−188.6 (4.4)	−38.1 (1.7)
$\overline{u}_g$(A=2,z=1)	−42.2 (66.5)	−37.2 (4.6)	31.0 (1.4)	56.8 (2.1)	36.1 (1.4)
$\overline{u}_g$(A=3,z=1)	−52.8 (21.4)	127.3 (0.4)	8.2 (7.6)	73.2 (3.9)	9.8 (4.5)
$\overline{u}_g$(A=2,z=2)	−74.4 (29.4)	−115.7 (34.9)	96.6 (4.6)	19.4 (3.19)	−13.3 (5.6)
$\overline{u}_g$(A=3,z=2)	139.9 (14.3)	30.4 (14.5)	35.6 (19.5)	−66.2 (16.4)	−12.7 (33.2)
$\sigma^2_{\epsilon_{1g}}$ (college group)	49.9 (8.4)	24.9 (3.0)	42.3 (1.0)	57.4 (1.8)	61.4 (1.2)
$\sigma^2_{\epsilon_2}$ (specific college)			61.5 (1.2)		

[a] The restriction $\overline{u}_g$(A=1,z=2) = $\overline{u}_g$(A=1,z=1) holds at 10% significance level.

- For $A = 1$ (low ability) student, the non-college option is better.
- (Explain) Majority of (low family income, low SAT) students do not apply to or attend any college in the data.
- Middle-A students rank non-elite colleges over elite colleges, while the opposite is true for high-A students.
- z-1 type value public and 2-yr colleges over private colleges.
- By introducing types, the model explains the systematic differences in students' choices.

Home Bias V.S. Application Cost

Table 7 Out-of-State Utility Cost

\$1,000	(A=3,z=2)	(A<3,z=2)	(A=3,z=1)	(A<3,z=1)
Mean ($\overline{\xi}_K$)	22.5 (1.1)	26.1 (0.6)	37.1	40.7
$\overline{\xi}$(A,z=1)−$\overline{\xi}$(A,z=2)		14.6 (0.5)		
Dispersion (σ_ξ)		35.1 (0.5)		

[a] The restriction $\overline{\xi}$(A=1,z)=$\overline{\xi}$(A=2,z) holds at 10% significance level.

- Cost includes both extra monetary costs such as costs for transportation and residence, as well as psychic cost.
- Lower for high-A students (better at adapting new environment).

Table 8 Application Costs

\$1,000	$n = 1$	$n = 2$	$n = 3$	$n \geq 4$
$C(n) - C(n-1)$	1.90 (0.3)	0.90 (0.05)	0.33 (0.02)	0.27 (0.03)

- Cost: collect information; prepare materials; stress; anxiety.
- Marginal cost rapidly decreases (economy of scale).
- Student ability and preferences are far more important.
- $C \rightarrow 0.5C$, non-applicants fraction remains at 51% (baseline: 54%).

Ability Measures

Table 9.1 SAT and Ability: Simulation

%	$P(SAT=1\|A)$	$P(SAT=2\|A)$	$P(SAT=3\|A)$
$A=1$	91.0	8.3	0.7
$A=2$	18.3	65.8	15.9
$A=3$	1.5	52.4	46.1

Table 9.2 Signal Distribution

%	$P(s=1\|A)$	$P(s=2\|A)$	$P(s=3\|A)$
$A=1$	94.1 (0.4)	1.4	4.5 (5.1)
$A=2$	7.7 (0.5)	87.8	4.6 (2.4)
$A=3$	0.04 (0.7)	46.7	53.3 (8.8)

Table 9.3 Family Income and Ability

%	$P(A\|\text{Low Inc})$	$P(A\|\text{Middle Inc})$	$P(A\|\text{High Inc})$
$A=1$	71.8	49.8	20.8
$A=2$	25.1	40.2	49.6
$A=3$	3.1	10.0	26.7

Low Inc: if family income is below 25th percentile (group mean \$10,017)

Middle Inc: if family income is in 25-75th percentile (group mean \$45,611)

High Inc: if family income is above 75th percentile (group mean \$110,068)

- SAT is less useful in distinguishing between medium & high-ability types.
- Family income has substantial influence on forming students' ability as Cameron and Heckman (2001).

Model Fit

Table 10 Model v.s. Data
Num of Applications (%)

Size	Data	Model
0	54.2	54.5
1	28.0	27.8
2 or more	17.8	17.7
χ^2 Stat	0.06	

$\chi^2_{2,0.05}$= 5.99

Table 12 Model v.s. Data
Final Allocation of Students (%)

	Data	Model
(pri,elite)	1.0	1.5
(pub,elite)	7.7	8.0
(pri,non)	11.5	10.9
(pub,non)	21.9	20.2
2-yr college	22.7	22.9
Non-college	35.2	36.5
χ^2 Stat.		6.98

$\chi^2_{5,0.05}$=11.07

Table 11 Model v.s. Data
Application & Admission: Applicants (%)

Application Rate	Data	Model
(pri,elite)	9.7	9.4
(pub,elite)	31.8	29.0
(pri,non)	44.6	44.4
(pub,non)	71.5	67.6
Admission Rate		
(pri,elite)	53.4	58.5
(pub,elite)	83.0	90.1
(pri,non)	91.4	91.5
(pub,non)	94.0	95.9

* All Pass $\chi^2_{1,0.05}$ test.

Model Fit

Table 13 Model v.s. Data: Home Bias

%	Data	Model
Home-Only Applicants[a]	65.6	67.5
Home-State Attendees[b]	76.2	78.0

* Both pass $\chi^2_{1,0.05}$ test.

[a] % students who apply only within home states among all 4-yr applicants.

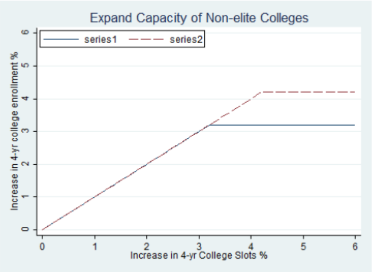
[b] % students who attend home-state 4-yr colleges among all 4-yr attendees.

Table 14 Model v.s. Data: Tuition

\$	(pri,elite)	(pub,elite)		(pri,non)	(pub,non)	
		In-State	Out-of-State		In-State	Out-of-State
Data	27,033	5,000	14,435	17,296	3,969	10,215
Model	27,530	5,090	13,892	16,891	3,451	10,540

Creating More Opportunities

- To what extent can the government expand college access by increasing college capacities?
  1. S1: community college tuition is maintained at its current level ($2,744);
  2. S2: community colleges become free and the lower bound on 4-yr college tuition is set to zero.
- Under each scenario, I conduct a series of expansion experiments and increase the capacities of (pub,non) colleges by growing magnitudes while keeping the capacities of other colleges fixed.



Increasing Supply: Tuition

Table 15.1 Increasing Supply: Tuition

$	(pri,elite)	(pub,elite)		(pri,non)	(pub,non)	
		In-State	Out-of-State		In-State	Out-of-State
Baseline	27,530	5,090	13,892	16,891	3,451	10,540
New 1	29,152	4,177	11,568	15,291	2,744	2,744
New 2	29,952	2,917	7,308	13,631	0	18

- (public,non) cut their tuition for both in/out state students in order to attract enough students.
- (public,elite) and (private,non) lower their tuition.
- (private,elite) increase their tuition.
  - total slots in these colleges are still scarce.
  - increasing its tuition helps to screen out lower-ability students.

Increasing Supply: Admission

Table 15.2 Increasing Supply: Admissions

%	(pri,elite)	(pub,elite)	(pri,non)	(pub,non)
Baseline	58.5	90.1	91.5	95.9
New 1	63.6	90.8	92.1	100.0
New 2	71.8	89.8	91.3	100.0

- In both cases, (public,non) admit all the applicants.
- Under S1, admissions rates also increase in all the other colleges.
- Higher admissions rates and lower tuition reflect their efforts to enroll enough students.
- (private,elite) increase because a better self-selected applicant pool.
- Under S2, (public,elite) and (private,non) slightly lower than baseline.

Increasing Supply: Attendance

Table 15.3 Increasing Supply: Attendance

%	Baseline	New 1	New 2	All Open&Free
4-Yr	40.6	43.2	44.2	55.6
2-Yr	22.9	21.9	22.9	18.0

- Under S1, 4-yr college attendance rate +2.6%, 2-yr college -1%.
- Under S2, 3.6% drawn into 4-yr colleges.
- When all colleges are open and free;
    - 4-yr college attendance rate +15%;
    - 2-yr college attendance rate -5% (most of them choose to stay);
    - Some students (10%) are constrained by tuition and/or available slots.

Increasing Supply: Why Limited Effects

Why expansion has such limited effects on enrollment?

Table 15.4 Increasing Supply: Attendance by Ability

%	Baseline	New 1	New 2	All Open&Free
$A = 1$				
4-Yr	1.0	3.5	4.3	18.9
2-Yr	27.0	26.5	29.2	26.5
$A = 2$				
4-Yr	72.3	75.1	76.7	86.9
2-Yr	24.0	21.9	21.1	12.7
$A = 3$				
4-Yr	93.3	94.1	94.4	97.8
2-Yr	5.8	5.3	5.1	2.2

- Under baseline, only 28% of low-ability attend any college.
- When free and open, 18% more of them be attracted to colleges.
- Almost all students of higher ability attend colleges, mostly 4-yr ones.

Conclusion: The major barrier to college access is student ability and associated preferences, not college capacity or tuition.

Ignoring Signals: Tuition

- In some countries, college admissions are based almost entirely on scores in a nationwide test.
- In this experiment, try to assess the consequences of ignoring signals in the admissions process.
- $e(s, SAT) \Rightarrow e(SAT)$.

Table 16.1 Ignore Signals: Tuition

\$	(pri,elite)	(pub,elite)		(pri,non)	(pub,non)	
		In-State	Out-of-State		In-State	Out-of-State
Baseline	27,530	5,090	13,892	16,891	3,451	10,540
New	30,028	5,131	14,079	14,800	3,083	9,426

- Elite colleges draw on higher tuition to screen students when the information on ability is unavailable.
- Non-elite colleges lower their tuition to compete for high-ability applicants rejected by elite colleges.

Ignoring Signals: Application and Admission

Table 16.2 Ignore Signals: Num of Applications

%	Num $=0$	Num $=1$	Num ≥ 2
Baseline	54.5	27.8	17.7
New	52.7	34.2	13.1

Table 16.3 Ignore Signals: Admission Rates

%	All		$SAT=1$		$SAT=2$		$SAT=3$	
	Base	New	Base	New	Base	New	Base	New
(pri,elite)	58.5	66.7	22.1	N/A	41.3	32.9	76.2	100.0
(pub,elite)	90.1	88.9	16.0	6.5	91.0	100.0	98.0	100.0
(pri,non)	91.5	80.0	77.1	11.2	93.7	100.0	100.0	100.0
(pub,non)	95.9	90.6	83.1	62.3	98.5	100.0	100.0	100.0

*N/A: not applicable because of zero applicant.

- In response to tuition reductions, more students apply to colleges;
- Applicants apply less due to less uncertainty (especially true for high-SAT applicants).

Ignoring Signals: % of High-Ability Students

Table 16.4 Ignore Signals: % of High-Ability Students

%	(pri,top)	(pub,top)	(pri,non)	(pub,non)
Baseline	94.7	80.2	11.0	15.9
New	86.4	79.0	12.7	16.1

- Elite colleges experience a drop in their enrollee ability (less info.).
- The non-elite ones get more high-ability students.

Table 16.5 Ignore Signals: Student Welfare

$\$1,000$	Baseline	New
All	67.8	67.2
$A = 1$	10.4	11.3
$A = 2$	111.0	109.0
$A = 3$	150.4	148.8

- Average student welfare decreases by $600.
- The non-elite ones get more high-ability students.
- low-ability students gain bacause colleges find it harder to distinguish.

Conclusion

- It provides a better understanding of the college market by jointly considering tuition setting, applications, admissions and enrollment.
- Three-step estimation used to cope with multiple equilibria.
- $\exists$ substantial heterogeneity in students' preference for colleges;
- Neither tuition cost nor college capacity is a major obstacle to college access (Expanding college capacities has very limited effects);
- When colleges don't have measure of student ability, elite colleges draw on higher tuition, while non-elite colleges lower their tuition.