College Tuition and Income Inequality

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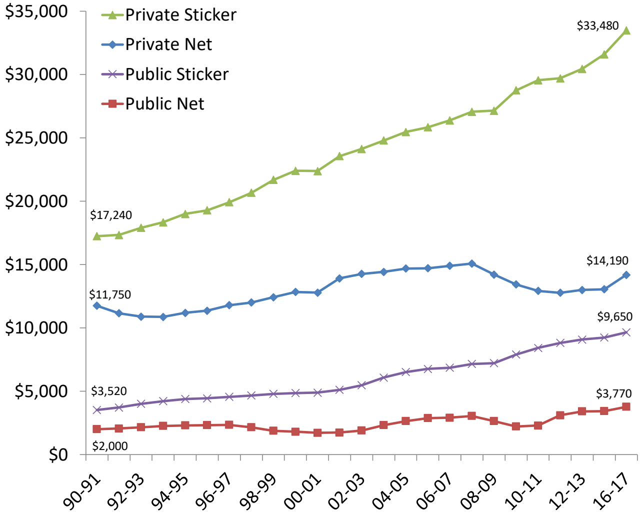
The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

Introduction

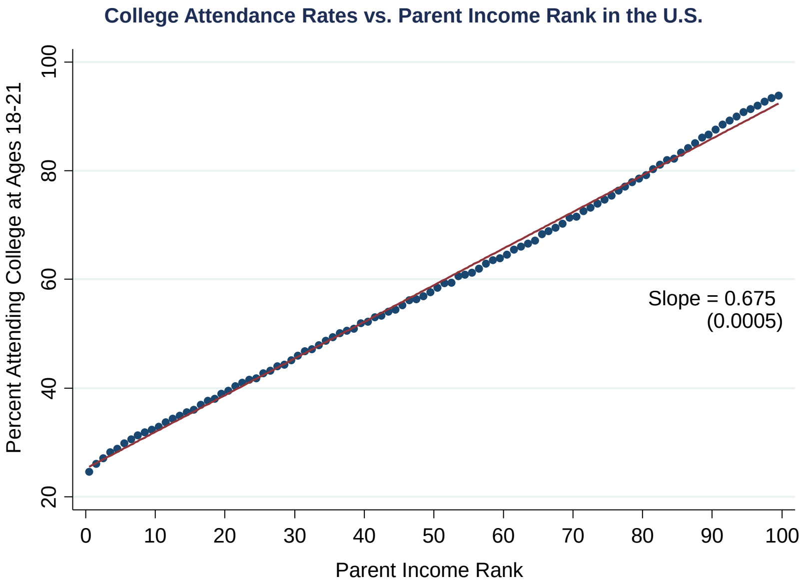
- Price of US college tuition has risen fast in recent decades
- At the same time, income inequality has been rising

  $\rightarrow$ Concern that smart low income students priced out
- Our Hypothesis: Rising income inequality a key factor driving up tuition
- Logic: College disproportionately demanded by high income households, whose income has grown fast
- Model of the college market required to explore the impact of changing pattern of college demand

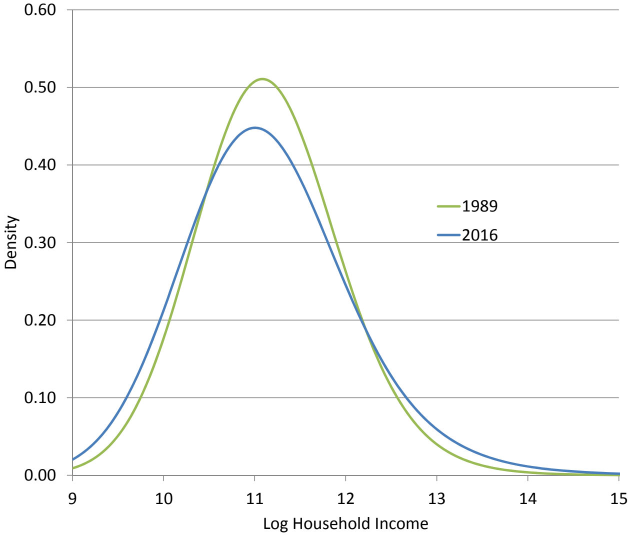
Tuition and Fees (College Board $2016)



College Attendance by Income (Chetty et al. 2014)



Estimated EMG Dist. of Log HH Income (SCF)



Club Good Model

- Households differ by income and student ability, make college choices
- Colleges choose resource spending & who to admit
- College quality increasing in avg. ability of student body
- Student $\rightarrow$ college & college $\rightarrow$ student choices must be consistent
- Lots of these consistency (market clearing conditions) if lots of household types and lots of different college qualities

Existing Literature

- Existing papers assume small number of colleges
  - Epple & Romano (1998), Epple, Romano & Sieg (2006, 2017), Fu (2016), Gordon & Hedlund (2016)
- Limitations:
  - Counterfactual $\Rightarrow$ applied analysis difficult
  - Equilibrium existence problems (Scotchmer, 1997)
  - Price-taking assumption questionable – game theoretic oligopolistic price setting more natural

Our Model

- Standard Elements:
  - Households differ by income and student ability
  - Colleges differ by quality
  - Quality depends on resources & avg. student ability
- Novel Element: Continuous distribution of college quality
  - Entire distribution of college characteristics and prices can be compared to data
  - College distribution can change smoothly and flexibly in response to changing drivers of college demand
  - No existence problems
  - Price taking natural
  - No role for lotteries as in Cole and Prescott (1997) or Caucutt (1999)

Outline

1. Model description
2. Closed-form special case
3. Calibration and model-data comparison
4. Explore impact of 1990–2016 changes in income inequality
5. Decompose rise in college tuition into roles of changes in:
    - average income
    - income inequality
    - college subsidies
    - cost of instructional inputs
    - preferences for college
6. Explore impact of changing college subsidies

Model: Households

- Continuum of measure 1 of households, each containing a parent and a college-age child
- Heterogeneous wrt: (i) income y, (ii) student ability a
- Ability indexed $i \in \{1, ..., I\}$, $a_i < a_{i+1}$, fraction μ_i of type i
- Continuous distribution for income, CDF $F_i(y)$
- Utility from non-durable consumption c and quality q of the college the child attends

$$u(c, q) = \log c + \varphi \log(\kappa + q)$$

Household Problem

- Take as given tuition functions $t(q, a_i)$
- Given idiosyncratic state (y, i), solve

$$\max_{\{c,q\in\mathcal{Q}\}} \{\log c + \varphi \log(\kappa + q)\}$$
$$s.t.$$
$$c + t(q, a_i) = y - I_{\{q>0\}}\omega$$

- ω is foregone earnings
- Solution: $c^i(y)$, $q^i(y)$

Alternative Model of College Demand

- Parents also care about child's consumption
- Child earnings reflect ability and college quality
- Parents can also transfer to and from kids via saving and borrowing (student loans)

$$\max_{\{c_1, c_2, s, q \in \mathcal{Q}\}} \{\log(c_1) + \beta_1 \log(q + \kappa) + \beta_2 \log(c_2)\}$$

$$\begin{aligned} c_1 + t(q, a_i) &= y - I_{\{q>0\}}\omega - s \\ c_2 &= A(q+\kappa)^{\zeta} a_i^{\lambda} + I_{\{s>0\}} R^s s + I_{\{s<0\}} R^b s \end{aligned}$$

- Observationally identical to "consumption" model when:
    1. R^s small and R^b big, so that $s = 0$ for all (y, a_i)
    2. $\beta_1 + \zeta\beta_2 = \varphi$

Model: Colleges

- CRS technology for producing education of a given quality
- Quality (per student) reflects:

  (i) average ability of student body

  (ii) consumption good input (per student) e (faculty etc)

$$q = \left(\sum_{i \in I} \eta^i a_i \right)^{\theta} e^{1-\theta}$$

  where η^i is share of student body that is of type i

- Fixed consumption cost ϕ per student admitted

Public versus Private Schools

- Assume all colleges profit maximize
  - minimize cost of supplying given value of education
- Observe income y and child's ability type i, take as given tuition schedules
- Colleges choose public ($j = 1$) or private status ($j = 2$), receive per student subsidies s_j (all non-tuition income sources)
- Public colleges receive larger subsidies but must keep average tuition below a cap $\bar{T}$ and quality above a threshold $\underline{Q}$

College Problem

1. Choose quality level q
2. Choose public or private model to deliver q
3. Choose mix of students to admit, educational spending, and size

Sub-problem for private college supplying mass 1 spots at $q > 0$

$$\max_{\{\eta^i\},e} \left\{ \sum_{i \in I} \eta^i t(q, a_i) - e - \phi \right\}$$
$$q = \left(\sum_{i \in I} \eta^i a_i \right)^{\theta} e^{1-\theta}$$

Public college problem similar s.t. additional constraints

$$\begin{aligned} \sum_{i \in I} \eta^i t(q, a_i) &\leq \bar{T} \\ q &\geq \underline{Q} \end{aligned}$$

Profit Maximization Given $t(q, a_i)$

1. Fix quality q
2. Compute optimal input mix for unconstrained public college
3. Check whether avg. tuition exceeds $\bar{T}$.
   - If not, only public colleges at quality q
   - Else, compare profit from unconstrained private college to constrained public college
4. Optimal size at each q:

$$\begin{cases} 0 & \text{if} \quad \pi_j(q) < 0 \\ [0, \infty] & \text{if} \quad \pi_j(q) = 0 \\ \infty & \text{if} \quad \pi_j(q) > 0 \end{cases}$$

Equilibrium

$\chi(Q)$: measure of students in colleges with $q \in Q \subset \mathcal{Q}$

Equilibrium is $\{\chi(q),\, t(q,a_i),\, \eta^i(q),\, e(q),\, c^i(y),\, q^i(y)\}$ s.t.

1. Given $t(q,a_i)$, $q^i(y)$ & $c^i(y)$ solve household's problem
2. Given $t(q,a_i)$, $\eta^i(q)$ & $e(q)$ solve college problem
3. Zero profits: $\pi(q) \leq 0\ \forall q$, and

$$\int_Q \pi(q)d\chi(q) = 0 \qquad \forall Q$$

4. Market clearing:

$$\sum_{i=1}^{I} \mu_i \int_0^\infty c^i(y)dF_i(y) + \int_0^\infty e(q)d\chi(q) + (1-\chi(0))(\omega+\phi) = \sum_{i=1}^{I} \mu_i \int_0^\infty ydF_i(y)$$

$$\mu_i \int_Q 1_{\{q^i(y)\in Q\}}dF_i(y) = \int_Q \eta^i(q)d\chi(q) \qquad \forall i \qquad \forall Q$$

Equilibrium Tuition Functions are...

1. Increasing in quality (holding fixed ability):
   $q_2 > q_1 \Rightarrow t(q_2, a_i) > t(q_1, a_i)$

2. Declining in ability (holding fixed quality):
   $t(q, a_{i+1}) < t(q, a_i)$

3. Independent of public / private status

4. Independent of income

5. Linear in ability: $t(q, a_i) = b(q) - d(q)(a_i - a_1)$

Special Case in Closed Form

- Pure club good model: $\theta = 1$
- Two Ability types, (a_h, a_l)

$\Rightarrow q = \eta a_h + (1-\eta) a_l$, $\eta(q) = \frac{q-a_l}{a_h-a_l}$

- $\varphi = 1 \Rightarrow u(c, q) = \log c + \log(\kappa + q)$
- No fixed costs or subsidies: $\phi = \omega = s_j = 0$
- Uniform income distribution:

$$y \sim U\left[\mu_y - \frac{\Delta_y}{2}, \mu_y + \frac{\Delta_y}{2}\right]$$

$$F_h(y) = F_l(y)$$

- Let $\mu_a = \frac{a_h+a_l}{2}$

Questions

1. What are $\chi(q)$, $t^h(q)$, $t^l(q)$?

2. How do these objects depend on Δ_y?

3. How does market for college differ from market for fish?

    - Non-club-good fish model: can sell ability to College A and buy average ability from College B
    - Arbitrage implies fixed price per unit of ability

    - Club good model: selling ability to College A requires buying College A quality education $\Rightarrow$ price per unit of ability varies with college quality

Digression: Modeling College Like Fish

- Households endowed with a_l or a_h units of ability
- Household problem:

$$\max_{c,q} \{\log(c) + \log(\kappa + q)\}$$
$$s.t.$$
$$c + pq = y + pa_i$$

- Market clearing price:

$$p = \frac{\mu_y}{\mu_a + \kappa}$$

- "Tuition" (net price) function:

$$t^i_{fish}(q) = pq - pa_i = (q - a_i)\,\frac{\mu_y}{\mu_a + \kappa}$$

1. Net price functions are linear in q, and
2. Price function does not depend on income inequality Δ_y

The Club Good Model

- College distribution: $\forall Q \subset (a_l, a_h)$

$$\begin{aligned}
\chi(Q) &= \frac{2}{a_h - a_l}\left(\frac{2}{4+\pi}\right)\int_Q \left[(1-\eta(q))^2 + \eta(q)^2\right]^{-2} dq \\
\chi(a_h) &= \chi(a_l) = \frac{2}{4+\pi} = 0.28
\end{aligned}$$

- Tuition functions:

$$t^i(q) = \mu_y \left(\frac{q - a_i}{\kappa + q}\right)\left[1 - \left(\frac{2}{4+\pi}\right)\frac{\Delta_y}{\mu_y} \arctan(1 - 2\eta(q))\right]$$

1. Distribution of quality independent of $(\mu_y, \Delta_y, \kappa)$
2. Price functions **non-linear** in q
3. Price functions **depend on** Δ_y

- Competitive equilibrium is **Pareto efficient**

Sketch of Solution Method

1. Given any college distribution $\chi(q)$, derive income of households attending q quality college: $y^i(q;\chi(.))$
2. Given $y^i(q;\chi(.))$, household's FOC gives an ODE that pins down the college tuition function: $t^i(q;\chi(.))$

$$\frac{dt^i(q;\chi(.))}{dq}\frac{1}{y^i(q;\chi(.))-t^i(q;\chi(.))}=\frac{1}{\kappa+q}$$

3. Given $t^i(q;\chi(.))$, derive a college profit function:

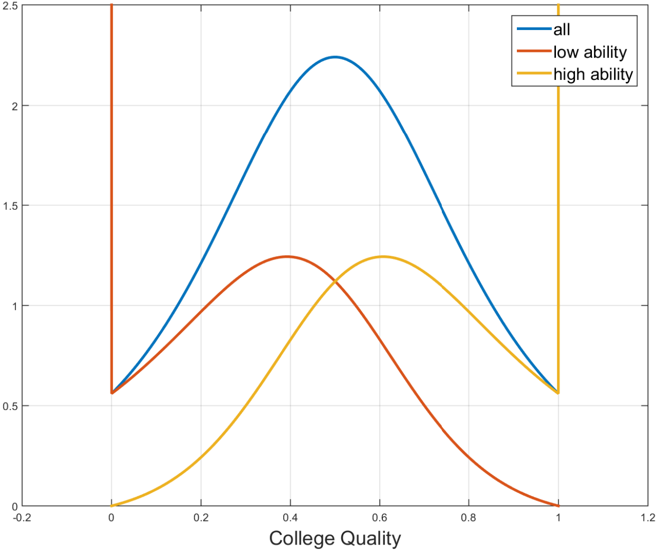
$$\pi(q;\chi(.))=\eta(q)t^h(q;\chi(.))+(1-\eta(q))t^l(q;\chi(.))$$

4. Solve for $\chi(q)$ from the functional equation

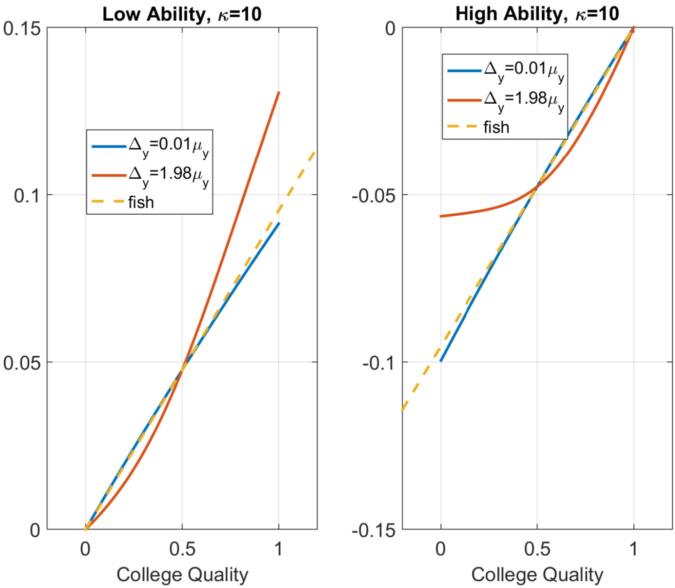
$$\pi(q;\chi(.))=0$$

   - This is a Volterra integral equation of the second kind with degenerate kernels, which has an analytical solution

College Distribution

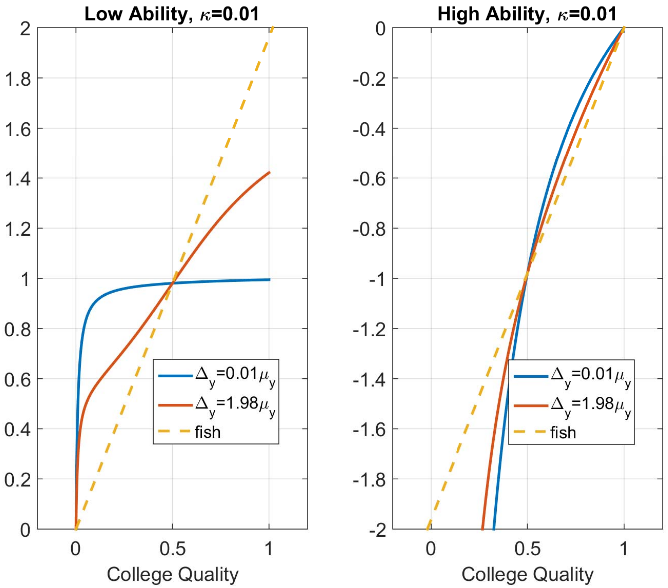


Tuition



Low Ability, κ=10
0.15
0.1
0.05
0
0
0.5
1
College Quality
Δ_y=0.01μ_y
Δ_y=1.98μ_y
fish
High Ability, κ=10
0
-0.05
-0.1
-0.15
0
0.5
1
College Quality
Δ_y=0.01μ_y
Δ_y=1.98μ_y
fish

Tuition


Low Ability, κ=0.01
High Ability, κ=0.01
Δ_y=0.01μ_y
Δ_y=1.98μ_y
fish
College Quality
College Quality
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.5
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2

More Properties of Club Good Equilibrium

1. At any quality level $q \in (0, 1)$ colleges have 2 types of customer:
   - high ability with relatively low income receiving subsidy
   - low ability with higher income paying positive tuition

2. Increasing Δ_y:
   - raises (lowers) $t^l(q)$ for $q \geq (\leq)\ \mu_a$
   - lowers (raises) $t^h(q)$ for $q \geq (\leq)\ \mu_a$
   - raises tuition differential for high q, lowers diff. for low q

Quantitative Example: Calibration

- Income distribution: Pareto Log-Normal:

$$\ln y \sim EMG(\mu_{y|i}, \sigma^2, \alpha)$$

- Estimate (σ^2, α) from SCF household income distribution for households aged 40-59
- Two ability types $a_i \in \{a_l, a_h\}$, equal mass of each
- Ratio $\mu_{y|h}$ to $\mu_{y|l}$ s.t.

$$\frac{E[y|_{i=h}]}{E[y|_{i=l}]} = \frac{\$67,000}{\$45,000}$$

  - (avg. family income conditional on child's AFQT score being above / below median, 1997 NLSY).

Preferences and College Technology

Preferences (φ, κ), Technology: (θ, ω)

1. 4 year graduates, ages 25-34: $37.0\% \Rightarrow \kappa$
2. Average net tuition rel. cons. $\$6,942 \Rightarrow \varphi$
3. Opportunity cost of work $\$20,040 \Rightarrow \omega$
4. Peers vs. goods equally important in quality $\Rightarrow \theta = 0.5$

(targets for 2015-17; all 4 yr colleges)

Preferences and College Technology

5. Fixed cost net of subsidy

$$\phi - s_j = E[t_j] - E[e_j]$$

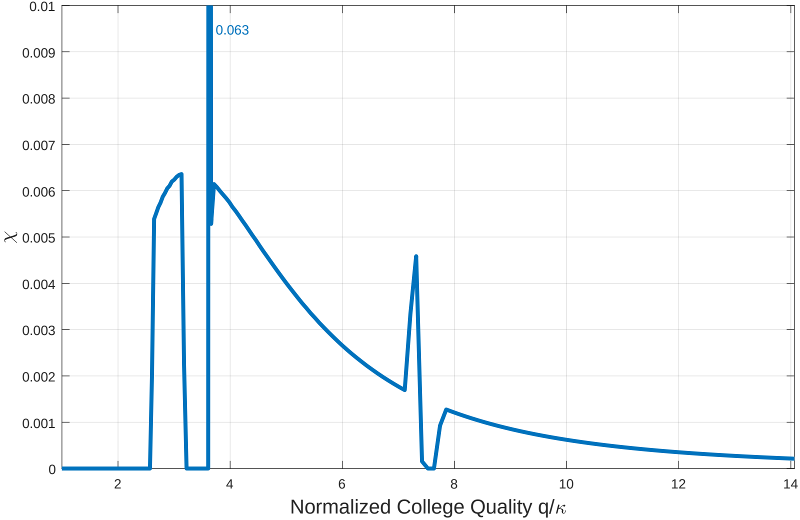
   $e =$ instructional spending + student services

6. Public / private tuition + Public / private graduation $\Rightarrow (\bar{T}, \underline{Q})$

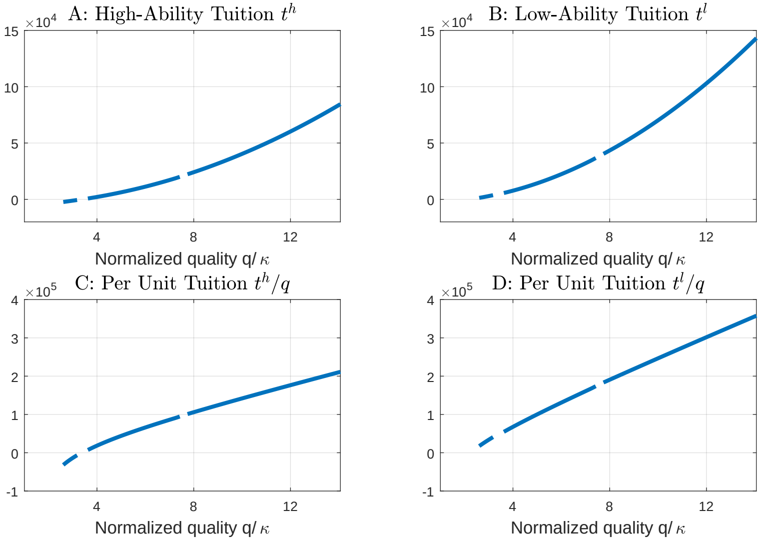
7. Ability gap $a_h - a_l$ drives within-school tuition dispersion

   - Observe avg. sticker price and avg. price net of all subsidies (federal, state and institutional grant aid)
   - Assume everyone gets federal and state aid, only high ability get institutional aid

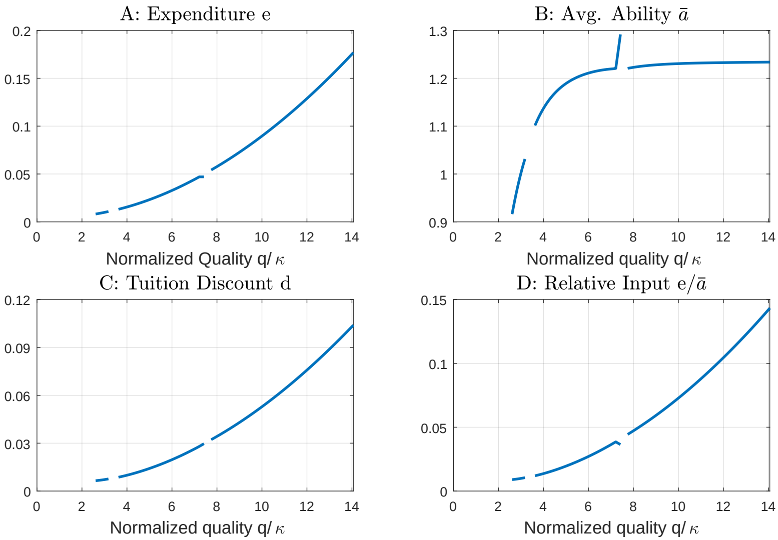
College Quality Distribution



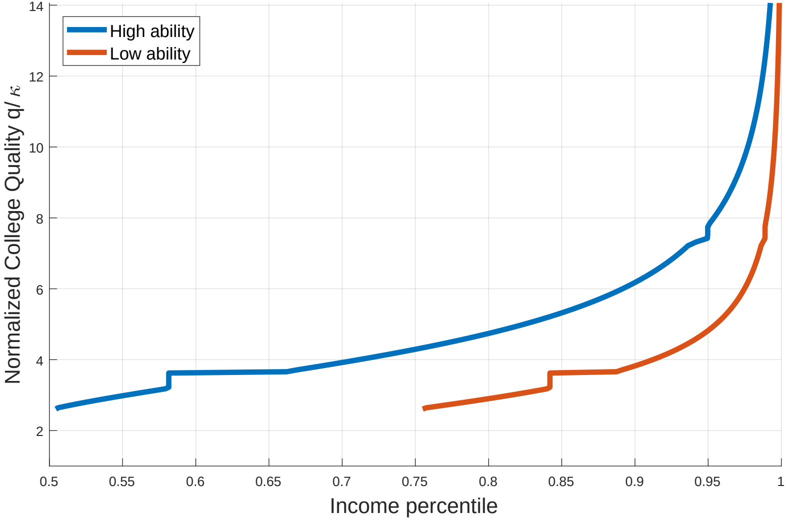
Tuition Schedules



Avg. Ability by Quality



Quality by Income Percentile



First Moments: Model and College Scorecard Data

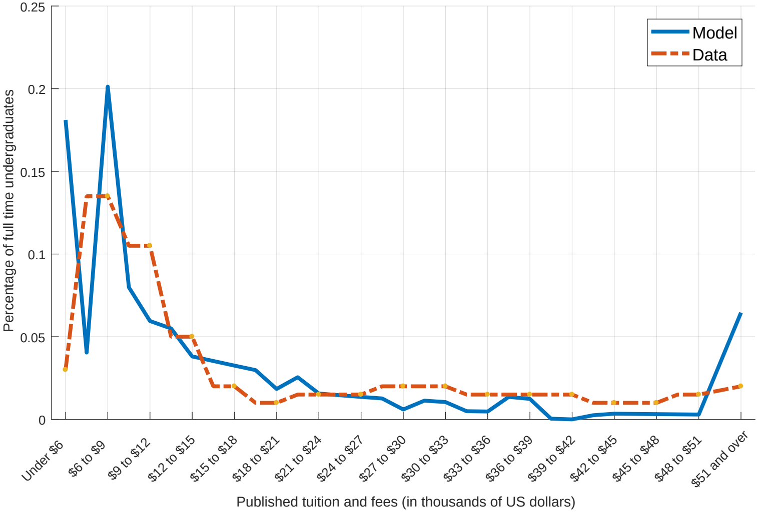
	Model		Data (2016)	
	Public	Private	Public	Private
Graduation %	25.8	11.3	25.8	11.3
Net tuition fees $	3,789	14,226	3,770	14,190
Sticker tuition fees $	12,123	27,248	9,650	33,480
Avg. fam. income / Mean $	1.63	2.90	1.37	1.95
Share high ability %	71.5	56.5	74	79

(Family income data is from Chetty et al., 2017)

Second Moments: Model and Data

	Model	Data (2016)
Standard Deviation/Mean		
Net tuition	0.876	0.989
Sticker tuition	0.947	0.769
Avg. family income	1.572	0.509
Share high ability	0.184	0.258
Correlation		
Net tuition vs. Income	0.774	0.603
Net tuition vs. Share high ability	0.435	0.218
Income vs. Share high ability	0.795	0.585

Tuition Distribution: Model and Data



Understanding Changes in Tuition and Graduation

- Measure changes 1989 to 2016 in $E[y], \sigma^2, \alpha$ (SCF)
- Measure changes 1990 to 2016 in $s_1 - \phi, s_2 - \phi$ (NCES)
- Measure changes in price of expenditure e (faculty salaries)

- Preferences (φ, κ) and caps $(\bar{T}, \underline{Q})$ to replicate net tuition and enrollment, by sector, by year

- Assume no changes in technology parameters $(\theta, \omega, a_h, a_l)$

Year-Specific Parameter Values

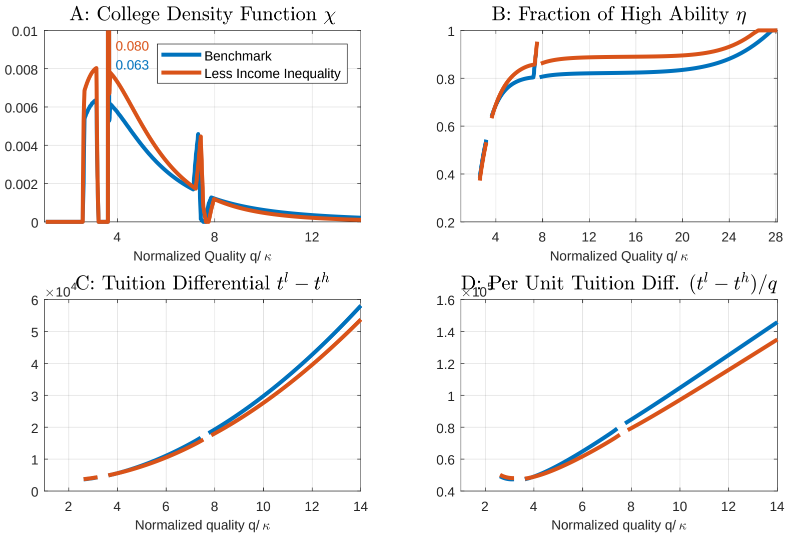
		1990	2016
Income distribution	$E[y]$	0.80	1.00
	σ^2	0.48	0.56
	α	2.40	1.67
Preferences	φ	0.022	0.031
	κ	0.0211	0.0332
Policies	$s_1 - \phi$	0.0119	0.0145
	$s_2 - \phi$	0.0053	0.0142
	$\overline{T}$	0.004	0.038
	$\underline{Q}$	0.149	0.120
Technology	p	0.914	1.000

Impact of Rising Income Inequality

		1989	2016
Income inequality			
	σ^2	0.48	0.56
	α	2.40	1.67

	1989 $\{\sigma^2, \alpha\}$	2016	Growth (%)
Graduation %	45.0	37.0	-17.7
Net tuition, \$	4,054	6,966	71.8
Quality $\frac{q}{\kappa}$	4.45	4.76	6.9
Share high ability %	67.0	66.9	-0.1pp
Expenditure e, \$	12,106	15,015	24.0

Isolating Impact of Rising Income Inequality



Summary: Rising income inequality

1. Rich are richer, willing to pay more for high quality colleges (poor are poorer, but were not going to college anyway)
2. Income of marginal students falls $\Rightarrow$ graduation rate falls
3. Greater demand for quality $\Rightarrow$ more instructional spending
4. But diminishing returns, esp. at high quality colleges where demand increases most $\Rightarrow$ small rise in average college quality
5. Complementarity between expenditure and peer effects $\Rightarrow$ price of ability goes up (bigger discounts for high ability)
6. Less density in the middle of the income distribution $\Rightarrow$ less demand for public colleges

Calibration		All	Public	Private
2016	*baseline (model = 2016 data)*			
	Graduation	37.0	25.8	11.3
	Net tuition	6,966	3,788	14,225
(1)	*1989 inequality* σ^2, α			
	Graduation	45.0	32.3	12.7
	Net tuition	4,054	3,515	5,421
(2)	*1989 mean income* $E[y]$			
	Graduation	28.8	20.1	8.7
	Net tuition	5,912	3,378	11,786
(3)	*1990 preferences* φ, κ			
	Graduation	33.1	20.2	12.9
	Net tuition	4,001	3,095	5,416
(4)	*1990 policy: subsidies* s_1, s_2			
	Graduation	33.3	31.5	1.8
	Net tuition	9,675	5,241	86,080
(5)	*1990 policy: caps* $\overline{T}$, $\underline{Q}$			
	Graduation	37.0	5.2	31.8
	Net tuition	6,954	2,016	7,764
(6)	*1990 instruction cost* p			
	Graduation	38.0	28.5	9.5
	Net tuition	6,787	3,271	17,367
1990	*2016 + (1)-(6) (model = 1990 data)*			
	Graduation	24.2	17.1	7.1
	Net tuition	4,865	2,016	11,781

Role of Subsidies

- Experiment 1: Increase public school subsidy net of fixed cost by 10% ($811)
- Experiment 2: Increase public and private school subsidies by 10% ($811 and $793)

	Baseline	Policy 1	Policy 2
Graduation %	37.0	+0.6pp	+2.0pp
Net tuition	$6,966	-$432	-$1.303
Quality $\frac{q}{\kappa}$	4.76	+2.5%	-1.9%
Share high ability %	66.9	+1.0pp	-0.3pp
Expenditure e	$15,015	+$370	-$501

Aggregate Changes

- Recalibrate all parameters for 1990
- Assume no changes in $(\theta, \omega, a_h, a_l)$

	1990	2016	Growth (%)
Net tuition, \$	4,865	6,966	43.2
Quality $\frac{q}{\kappa_{2016}}$	4.52	4.76	5.3
Share high ability %	76.2	66.9	-9.3pp
Expenditure e, \$	11,460	15,015	31.0

Figure 2a: College Attendance by AFQT and Family Income Quartiles (NLSY79)

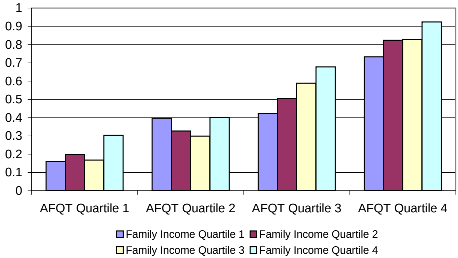
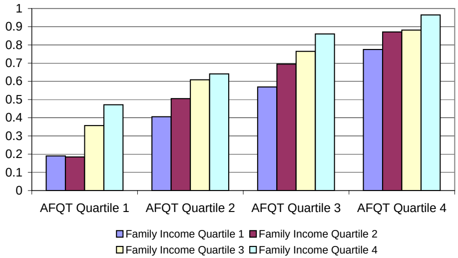


Figure 2b: College Attendance by AFQT and Family Income Quartiles (NLSY97)



Changes in Who Goes to College: Belley and Lochner

- 13pp inc. in college attendance across 2 waves of NLSY
- 45.8% of these extra students from bottom half of AFQT score distribution
- 83.8% of these extra low ability students from top half of family income distribution
- Model closely replicates these patterns:
    - 50% of total growth in enrollment from bottom half of ability and top half of income distribution
- Increasing income inequality $\Rightarrow$ income becoming more important determinant of college attendance

Why Do People Go to College?

- Suppose college has both consumption and investment components:

$$u\left(c, q, y'\right) = \log c + \beta_1 \log\left(\kappa + q\right) + \beta_2 \log\left(y'\right)$$

$$y' = \left(\kappa + q\right)^{\zeta} a^{\lambda}$$

- Assume β_1, β_2, λ constant, ζ increasing
- Change over time in college premium identifies β_1 vs. β_2
  - College spending responds more to college premium the larger is β_2
- College premium increase: 1.61 in 1990 to 1.83 in 2016
- Model replicates this with $\beta_1 = 0.0077$, $\beta_2 = 0.0715$

Conclusions

- Widening income inequality driving enrollment down, tuition up:

    1. rich demand higher quality colleges $\Rightarrow$ college spending goes up
    2. marginal high ability become poorer, but are offered larger discounts $\Rightarrow$ little change in average student ability
    3. decreasing returns to extra spending, especially at the top $\Rightarrow$ modest quality gains

- Increasing taste for (return to) college and average income growth also important factors pushing up average tuition
- Rising subsidies pushing tuition growth down
    - Increasing subsidies lowers average tuition more than dollar-for-dollar

Work in Progress

- Introduce borrowing and lending
  - borrowing / lending rate spread to match average income / ability of college attendees
- Income based college subsidies (Pell Grant program)
- Preference heterogeneity in the taste for college
- Large number of ability types
- Sensitivity with respect to strength of peer effects