College Tuition and Income Inequality

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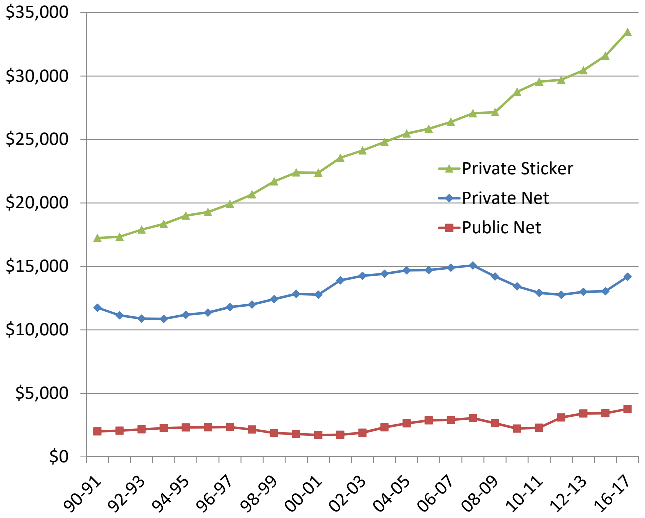
Introduction

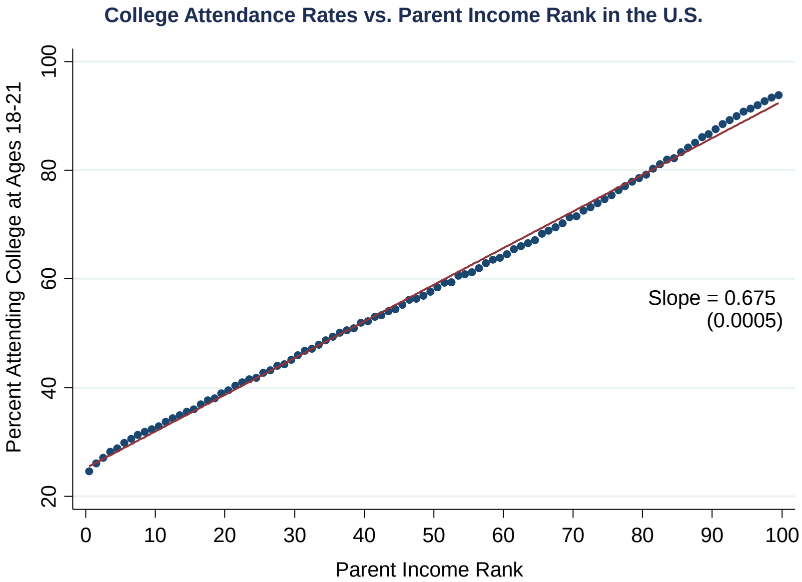
- Price of US college tuition has risen fast in recent decades
- At the same time, income inequality has been rising

  $\rightarrow$ 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

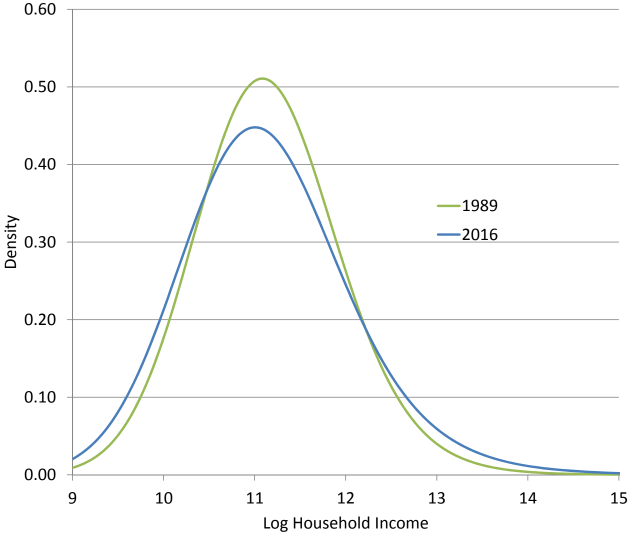
Tuition and Fees (College Board $2016)



College Attendance by Income (Chetty et al. 2014)



Estimated EMG Dist. of Log HH Income (SCF)



College is a Club Good

- Quality (desirability) of a given college depends on attributes of students who attend (e.g. academic ability)
- Student $\rightarrow$ college & college $\rightarrow$ student choices must be consistent
- Rich college and household heterogeneity $\Rightarrow$ lots of consistency (market-clearing) conditions
- Existing literature assumes 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

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
  - 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

Model: Households

- Continuum of measure 2 of households, each containing a parent and a college-age child
- Heterogeneous wrt: (i) income y, (ii) student ability a
- Two ability levels, indexed $i \in \{l.h\}$, $a_l < a_h$, measure 1 of each level
- 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 $t^i(q)$
- Given idiosyncratic state (y,i), solve

$$\max_{\{c,q\in\mathcal{Q}\}} u(c,q)$$
$$s.t.$$
$$c + t^i(q) = y - I_{\{q>0\}}\omega$$

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

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)

$$q = (\eta a_h + (1-\eta) a_l)^{\theta} e^{1-\theta}$$

  where η is share of student body that is high ability

- 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 input mix and size

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

$$\max_{\eta,e} \left\{ t^h(q)\eta + t^l(q)\left(1-\eta\right) - e + s_2 - \phi \right\}$$
$$s.t.$$
$$q = \left(\eta a_h + \left(1-\eta\right) a_l\right)^{\theta} e^{1-\theta}$$

Optimal input mix:

$$\frac{t^l(q) - t^h(q)}{1} = \frac{\theta(a_h - a_l)\frac{q}{\eta(q)a_h + (1-\eta(q))a_l}}{(1-\theta)\frac{q}{e(q)}}$$

Public college problem similar s.t. additional constraints:

Profit Maximization Given $t^i(q)$

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, where $\eta_1(q)$ s.t.

$$t^h(q)\eta_1(q) + t^l(q)\left(1 - \eta_1(q)\right) = \bar{T}$$

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

1. Given $t^i(q)$, $q^i(y)$ & $c^i(y)$ solve household's problem
2. Given $t^i(q)$, $\eta(q)$ & $e(q)$ 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:

$$\int c^i(y) dF^i(y) + \int e(q) d\chi(q) + (2 - \chi(0))(\phi - s + \omega) = \int y dF^i(y)$$

$$\begin{aligned} \int 1_{\{q^h(y) \in Q\}} dF^h(y) &= \int_Q \eta(q) d\chi(q) \qquad \forall Q \\ \int 1_{\{q^l(y) \in Q\}} dF^l(y) &= \int_Q (1 - \eta(q)) d\chi(q) \qquad \forall Q \end{aligned}$$

Properties of Equilibrium Tuition Functions

- At each quality level, $t^h(q) < t^l(q)$
  - Otherwise colleges would strictly prefer high ability students
- Tuition is increasing in quality: $q_1 > q_2 \Rightarrow t^i(q_1) > t^i(q_2)$
  - Otherwise no students would choose lower quality college
- Tuition is independent of public / private status
  - Households care only about quality
- Tuition is independent of income
  - Colleges have no market power and ability is only attribute valued in production

Special Case in Closed Form

- Pure club good model: $\theta = 1 \Rightarrow q = \eta a_h + (1-\eta)a_l$,

  $\eta(q) = \frac{q-a_l}{a_h-a_l}$

- $\varphi = 1 \Rightarrow u(c,q) = \log c + \log(\kappa + q)$

- 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 Princeton and buy average ability from Rutgers
    - Arbitrage implies fixed price per unit of ability

    - Club good model: selling ability to Princeton entails buying Princeton 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: $\forall Q \subset (a_l, a_h)$

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

$$\chi(a_h) = \chi(a_l) = \frac{2}{4+\pi} = 0.28$$

- Tuition functions:

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

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:

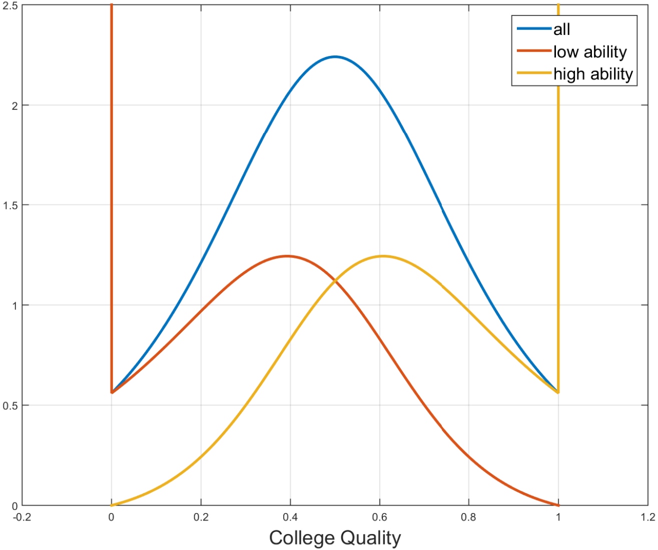
$$\pi(q;\chi(.))=\eta(q)t^h(q;\chi(.))+(1-\eta(q))t^l(q;\chi(.))$$

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

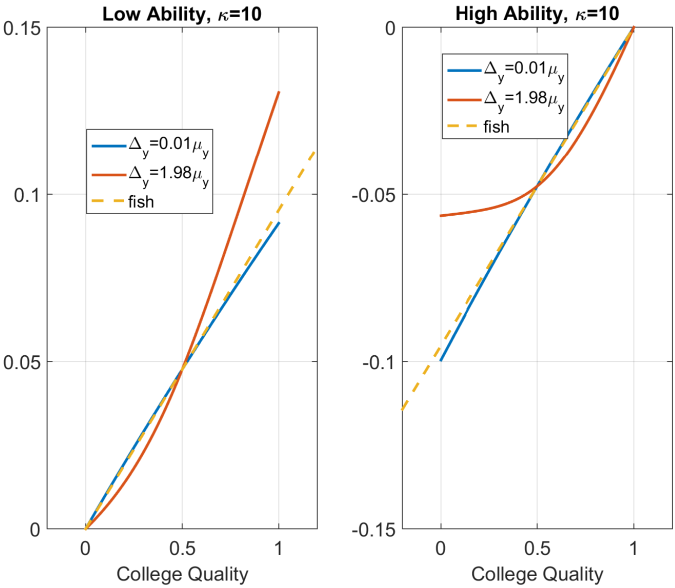
$$\pi(q;\chi(.))=0$$

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

College Distribution

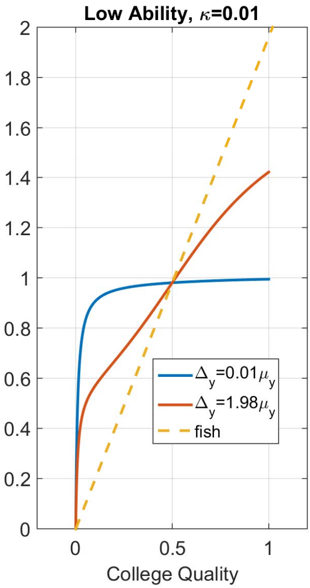


Tuition



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

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:

$$\ln y \sim EMG(\mu^i, \sigma^2, \alpha)$$

- Estimate (σ^2, α) from SCF household income distribution for households aged 40-59
- Ratio μ^h to μ^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, F)

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 (federal & state grant aid + direct support to colleges)

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

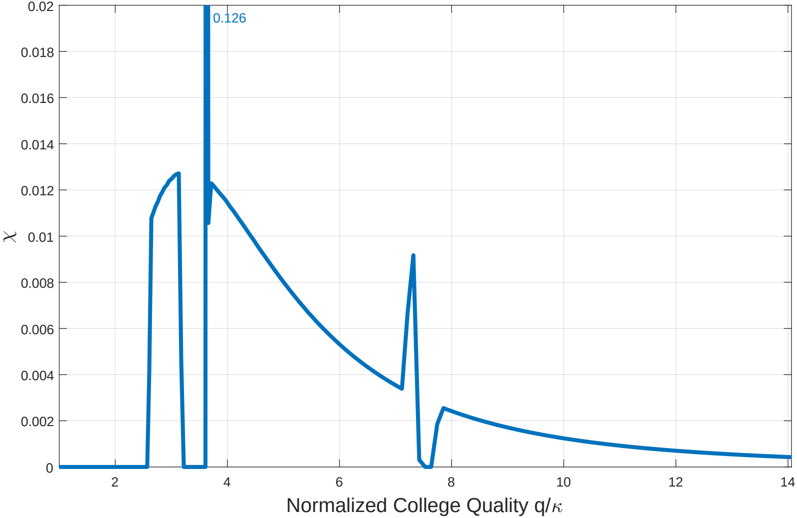
$e =$ instructional spending + student services

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

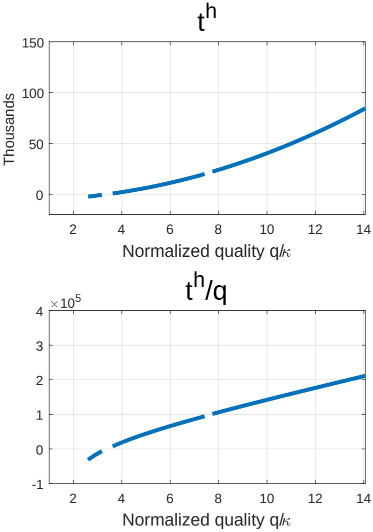
7. Ability gap $a_h - a_l$ drives within-school tuition dispersion

   - 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

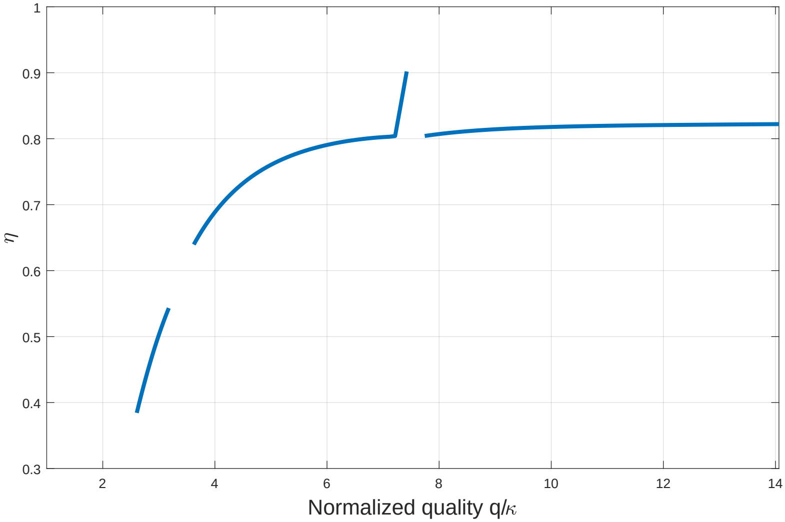
College Quality Distribution



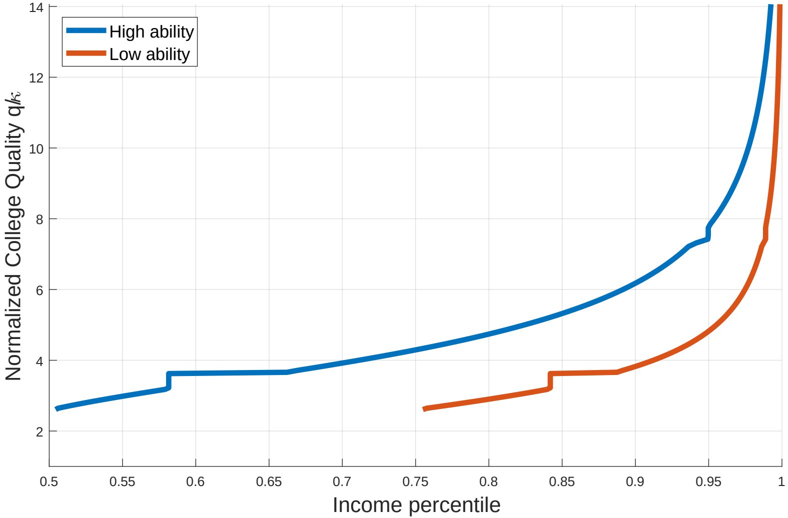
Tuition Schedules



Avg. Ability by Quality



Quality by Income Percentile



First Moments: Model and College Scorecard Data

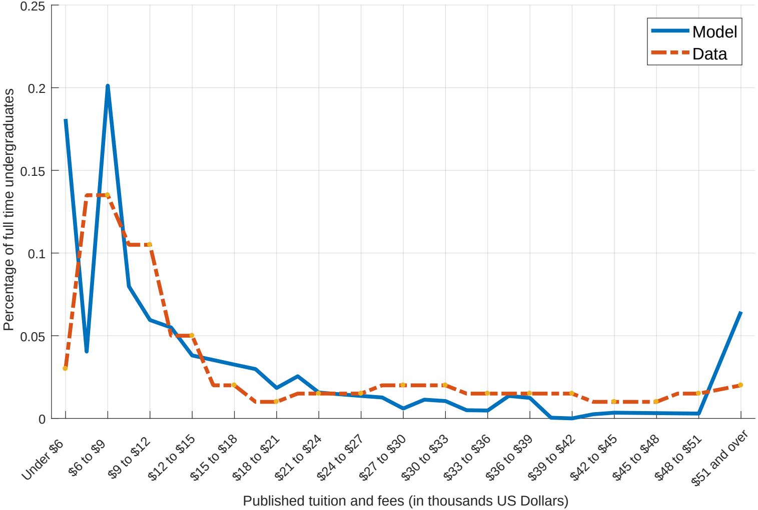
	Model		Data (2016)	
	Public	Private	Public	Private
Graduation	25.8	11.3	25.8	11.3
Net tuition fees $	3,789	14,226	3,770	14,190
Sticker tuition fees $	12,123	27,248	9,650	33,480
Avg. fam. income / Mean $	1.63	2.90	1.37	1.95
Fraction of high ability	0.71	0.57	0.74	0.79

(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
Fraction of high ability	0.184	0.258
Correlation		
Net tuition vs. Income	0.774	0.603
Net tuition vs. Frac. high ability	0.435	0.218
Income vs. Frac. 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

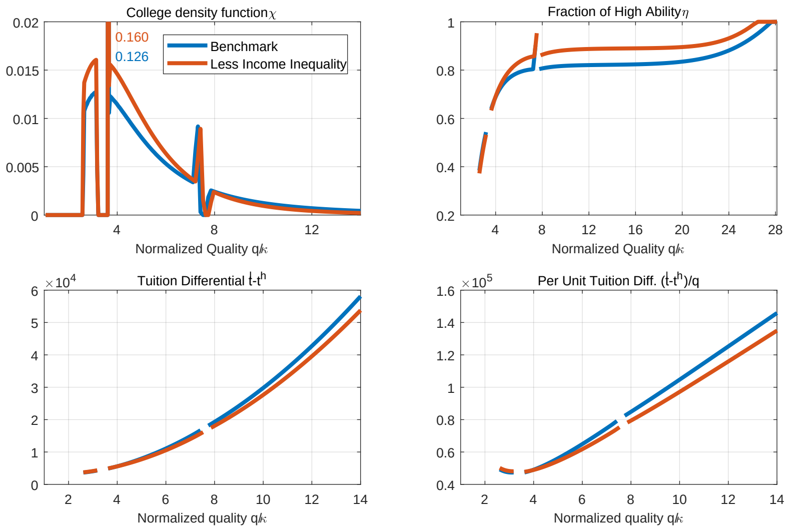
		2016	1990
Income distribution	$E[y]$	1.00	0.80
	σ^2	0.56	0.48
	α	1.67	2.40
Preferences	φ	0.031	0.022
	κ	0.0332	0.0211
Policies	$s_1 - \phi$	0.0145	0.0119
	$s_2 - \phi$	0.0142	0.0053
	$\overline{T}$	0.038	0.004
	$\underline{Q}$	0.120	0.149
Technology	p	1.000	0.914

Impact of Rising Income Inequality

	1989 inequality*	2016	Growth (%)
Graduation	0.450	0.370	-17.7
Net tuition, $\$$	4,054	6,966	71.8
Quality $\frac{q}{\kappa}$	4.45	4.76	6.9
Share high ability η	0.670	0.669	-0.2
Expenditure e, $\$$	12,106	15,015	24.0

*1989 income inequality parameters, average income fixed
all other parameters as in 2016

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

Aggregate Changes

	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 η	0.762	0.669	-12.2
Expenditure e, $\$$	11,460	15,015	31.0

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

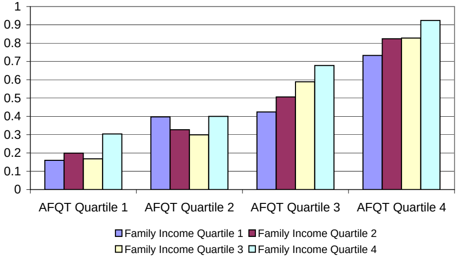
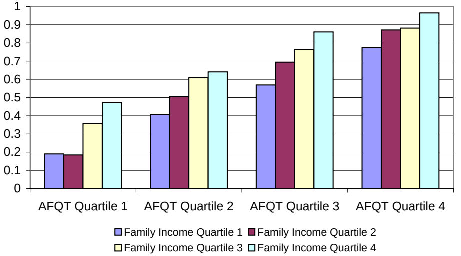


Figure 2b: College Attendance by AFQT and Family Income Quartiles (NLSY97)



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 drawn from top half of the family income distribution
- Our model closely replicates these patterns:
    - 50% of the total growth in model enrollment from (i) bottom half of ability, and (ii) top half of income distribution
- Increasing income inequality $\Rightarrow$ income becoming more important determinant of college attendance
- Plus looser quality and tuition caps on public sector $\Rightarrow$ more willing to admit low ability students

Why Do People Go to College?

- Suppose college has both consumption and investment components:

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

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

- All parameterizations satisfying $\beta_1 + \beta_2 \times \zeta = \varphi$ observationally equivalent wrt. moments considered so far
- 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
  - Reducing public subsidies pushes up average tuition more than dollar-for-dollar