

College Tuition and Income Inequality

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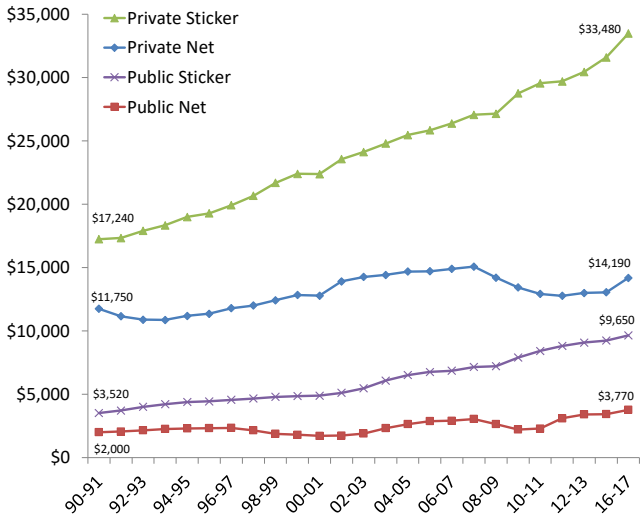
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Introduction

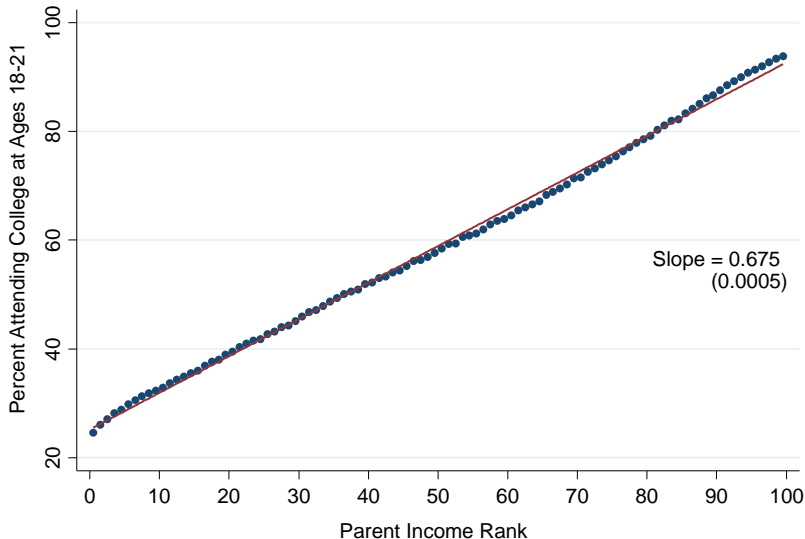
- Price of US college tuition has risen fast in recent decades
- At the same time, income inequality has been rising
→ Concern that smart low income students priced out
- **Our Hypothesis**: Rising income inequality a key factor driving up tuition
- **Logic**: College disproportionately demanded by high 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)

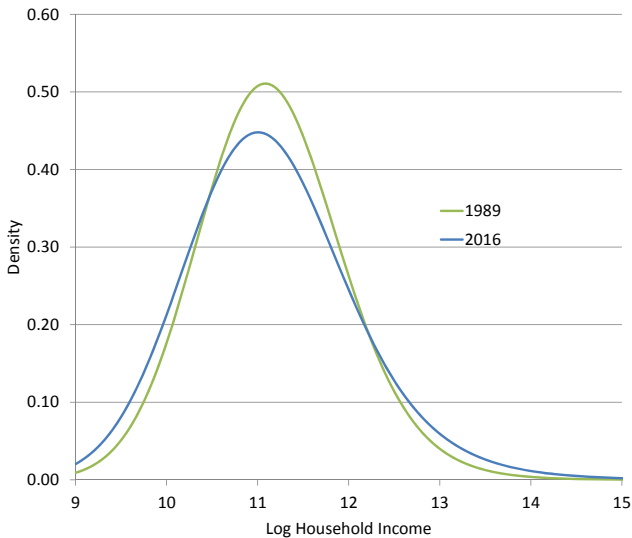


College Attendance by Income (Chetty et al. 2014)

College Attendance Rates vs. Parent Income Rank in the U.S.



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)
- (1) Student \rightarrow college & (2) 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

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 $i \in \{1, \dots, I\}$, $a_i < a_{i+1}$, fraction μ_i of type i
- Continuous income distribution (cond. on ability), 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

$$\begin{aligned} & \max_{\{c, q \in \mathcal{Q}\}} u(c, q) \\ & \text{s.t.} \\ & c + t(q, a_i) = y - I_{\{q > 0\}} \omega \end{aligned}$$

- 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)

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

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 input mix 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

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.

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

4. Optimal size at each q :

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

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

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

4. Market clearing:

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

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

Equilibrium Tuition Functions are...

1. Declining in ability (holding fixed quality):

$$t(q, a_i) < t(q, a_{i+1})$$

2. Increasing in quality (holding fixed ability):

$$q_1 > q_2 \Rightarrow t(q_1, a_i) > t(q_2, a_i)$$

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: $\theta = 1$
- $\varphi = 1 \Rightarrow u(c, q) = \log c + \log(\kappa + q)$
- 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 \Rightarrow Arbitrage implies fixed price per unit of ability
 - **Club good model:** selling ability to College A entails buying education from the same college \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:

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

- Market clearing per-unit price:

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

- “Tuition” (net price) function:

$$t_{fish}^i(q) = pq - pa_i = (q - a_i) \frac{\mu_y}{\mu_a + \kappa}$$

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:

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

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: $y^i(q; \chi(\cdot))$
2. Given $y^i(q; \chi(\cdot))$, household's FOC gives an ODE that pins down the college tuition function: $t^i(q; \chi(\cdot))$

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

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

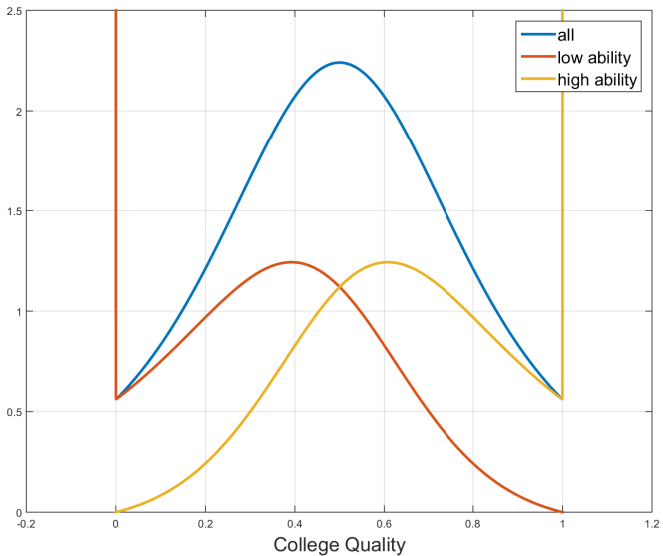
$$\pi(q; \chi(\cdot)) = \eta(q)t^h(q; \chi(\cdot)) + (1 - \eta(q))t^l(q; \chi(\cdot))$$

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

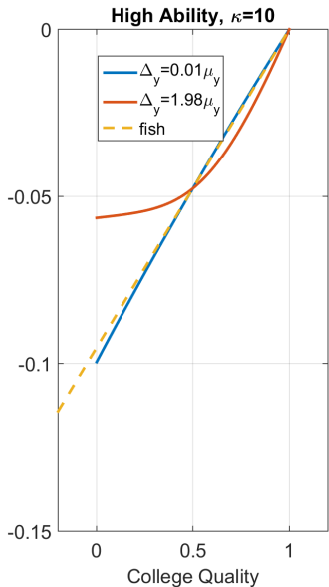
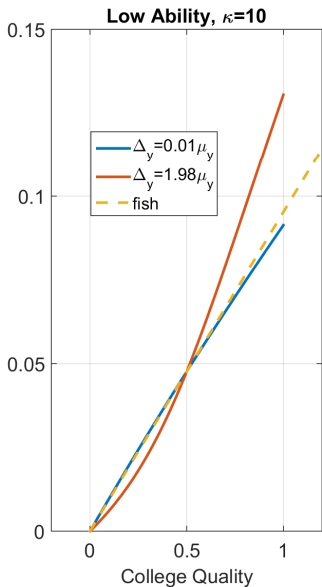
$$\pi(q; \chi(\cdot)) = 0$$

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

College Distribution



Tuition



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 (κ, φ) , Technology: (ω, θ)

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)

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

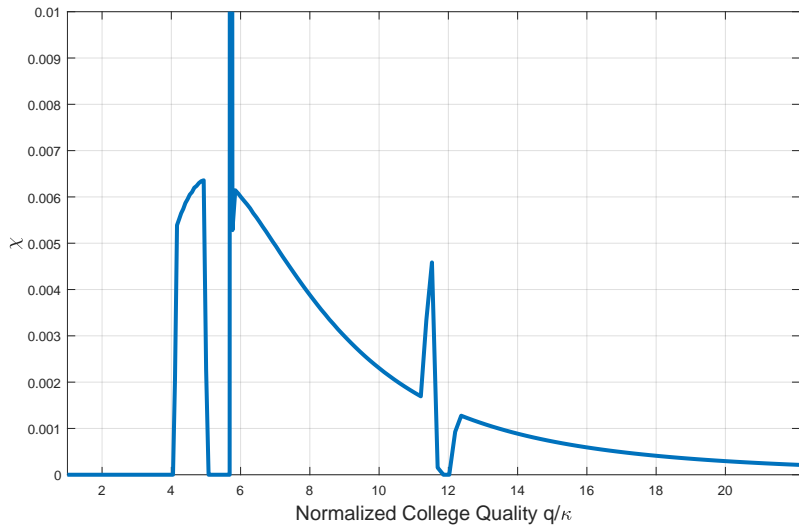
e = instructional spending + student services

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

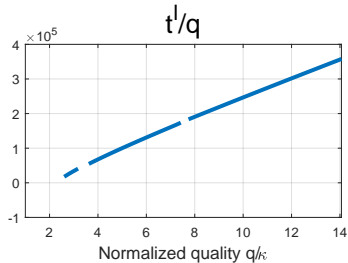
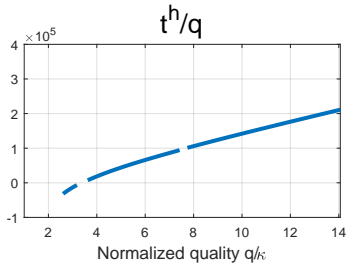
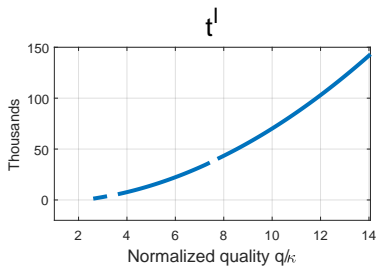
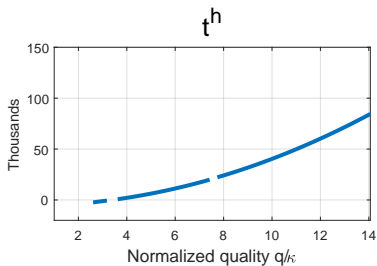
7. Ability gap $a_h - a_l$ drives within-school tuition dispersion

- 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

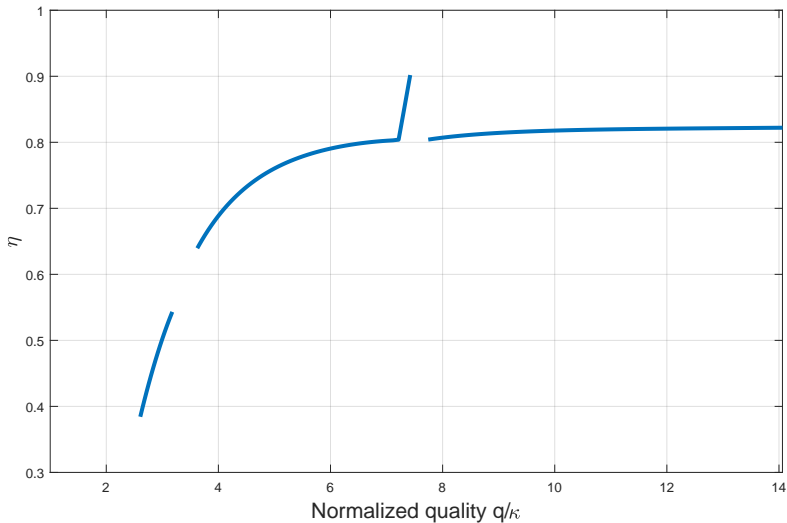
College Quality Distribution



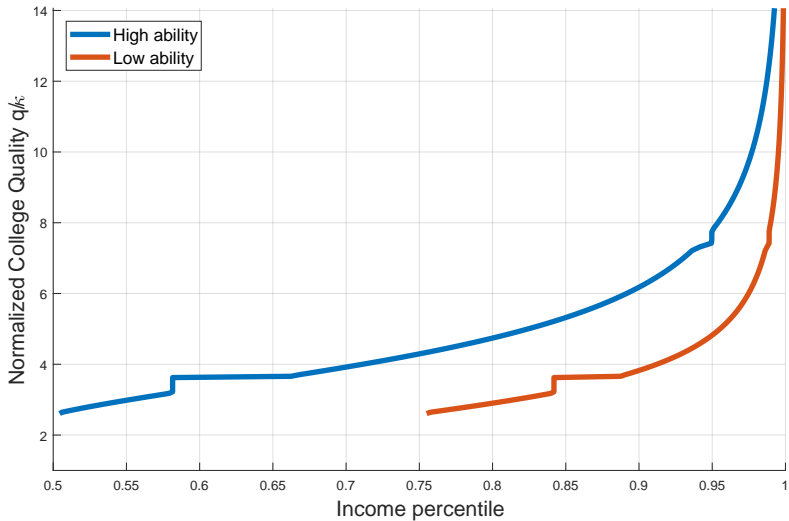
Tuition Schedules



Avg. Ability by Quality



Quality by Income Percentile



First Moments: Model and College Scorecard Data

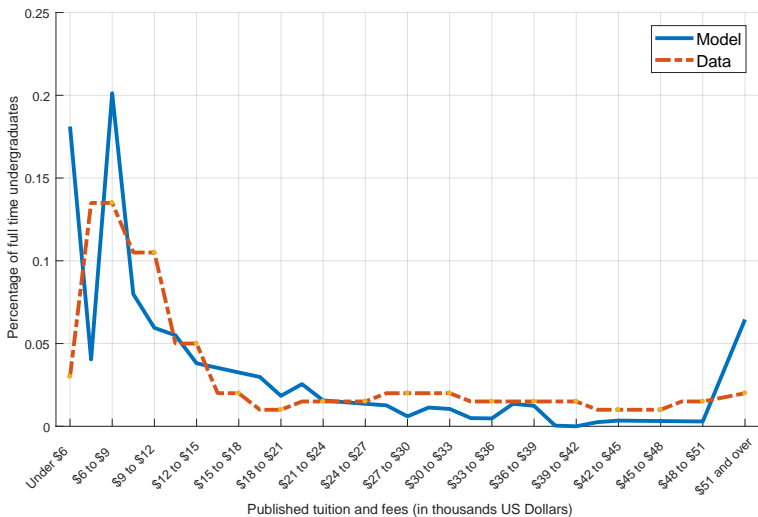
	Model		Data (2016)	
	Public	Private	Public	Private
Graduation %	25.8	11.3	25.8	11.3
Net tuition fees \$	3,789	14,226	3,770	14,190
Sticker tuition fees \$	12,123	27,248	9,650	33,480
Avg. fam. income / Mean \$	1.63	2.90	1.37	1.95
Share high ability %	71.5	56.5	74	79

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

Second Moments: Model and Data

	Model	Data (2016)
<i>Standard Deviation/Mean</i>		
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
<i>Correlation</i>		
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

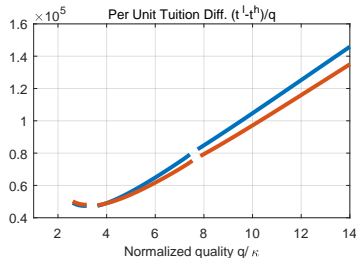
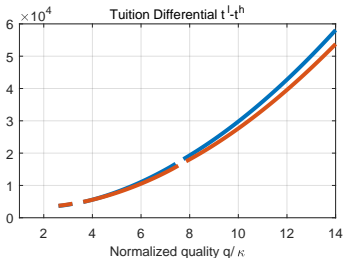
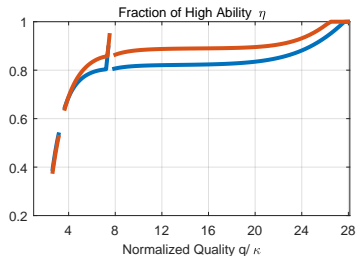
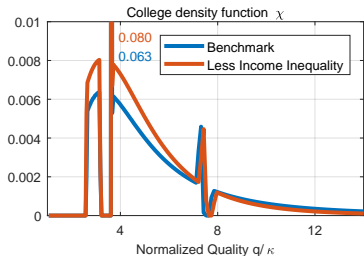
		2016	1990
Income distribution	$E[y]$	1.00	0.80
	σ^2	0.56	0.48
	α	1.67	2.40
Preferences	φ	0.031	0.022
	κ	0.0332	0.0211
Policies	$s_1 - \phi$	0.0145	0.0119
	$s_2 - \phi$	0.0142	0.0053
	\bar{T}	0.038	0.004
	\underline{Q}	0.120	0.149
Technology	p	1.000	0.914

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	<i>baseline (model = 2016 data)</i>		
	Enrollment	25.8	11.3
	Net tuition	3,788	14,225
(1)	<i>1989 inequality σ^2, α</i>		
	Enrollment	32.3	12.7
	Net tuition	3,515	5,421
(2)	<i>1989 mean income $E[y]$</i>		
	Enrollment	20.1	8.7
	Net tuition	3,378	11,786
(3)	<i>1990 preferences φ, κ</i>		
	Enrollment	20.2	12.9
	Net tuition	3,095	5,416
(4)	<i>1990 policy: subsidies s_1, s_2</i>		
	Enrollment	31.5	1.8
	Net tuition	5,241	86,080
(5)	<i>1990 policy: caps \bar{T}, \underline{Q}</i>		
	Enrollment	5.2	31.8
	Net tuition	2,016	7,764
(6)	<i>1990 instruction cost p</i>		
	Enrollment	28.5	9.5
	Net tuition	3,271	17,367
1990	<i>2016 + (1)-(6) (model = 1990 data)</i>		
	Enrollment	17.1	7.1
	Net tuition	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)

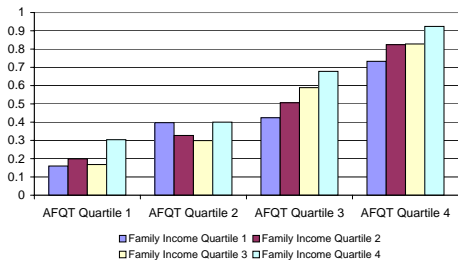
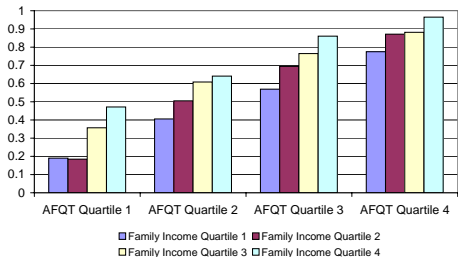


Figure 2b: College Attendance by AFQT and Family Income Quartiles (NLSY97)



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:

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

$$y' = (\kappa + q)^\zeta a^\lambda$$

- All parameterizations satisfying $\beta_1 + \beta_2 \times \zeta = \varphi$ observationally equivalent wrt. moments considered so far
- Assume $\beta_1, \beta_2, \lambda$ 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