Accounting for Tuition Increases
Across U.S. Colleges

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What is causing net tuition to rise?
Motivation

Many theories exist.

Supply side:
- Baumol’s cost disease — costs increase, productivity does not.
- Cuts in government support of schools.
- Bowen rule — “arms race of spending” (Ehrenberg, 2002).

Demand side:
- Bennett hypothesis — colleges capture student aid rents.
- College premium / graduation rate increases.
- Parental income changes.

Our goal: test these theories quantitatively.
We combine

- a mostly standard lifecycle model with
- Epple, Romano, Sarpca, and Sieg (2013)’s model of colleges.

We feed in estimates or statutory law for exogenous processes:

- college costs,
- college non-tuition revenue (including government aid),
- borrowing limits, interest rates, and grants,
- and college earnings premium, graduation rates, parental transfers.
Between 1987 and 2010, net tuition increased 92%.

We find the theories jointly give a 108% net tuition increase.

Separately, holding else equal at 1987, change in net tuition due to
- Bennett (FSLP etc.) is +42%
- Baumol is +7%
- Non-policy-driven demand changes is +76%
- Public funding of schools is −6%
- Private non-tuition revenue is −23%

(These do not sum to 108% because of interactions.)

The effect of demand-side changes is fairly uniform across schools.

College-side changes more heterogeneous.
Work most closely related to

- Epple, Romano, and Sieg (2006),
- Epple, Romano, Sarpca, and Sieg (2013),
- Jones and Yang (2016),
- Gordon and Hedlund (2015), and

Also connected to a vast empirical literature.
We decompose the college budget sheet into

\[ T + E^g + E^p = pl + pC \]

The categories:

1. \( T \) is net tuition, direct from student, Pell grants, et al.
2. \( E^g \) is appropriations / grants / contracts (excludes Pell)
3. \( E^p \) is endowment revenue, gifts, “auxiliary and other”
4. \( pl + pC \): all expenditures, quality-enhancing and not.

Currently, we don’t associate \( I, C \), etc. with budget items.
Budgets over time

Baumol says cost increases pass through to $T$. 
Bowen say colleges compete in spending using $T$ to finance $I$. 
Some argue cuts in $E^g$ have increased $T$. If so, only for public?
Bennett argues $T$ increases to capture gov. aid (and use on $I$).
If Bennett is right, $T$ also increases due to college premium, etc.
A simple model

Potential students have ability $x$, parental income $y$.

$t(x, y) \equiv$ maximum willingness to pay, known by college.
$\alpha(x, y) \equiv$ enrollment of type $(x, y)$, less than density $f(x, y)$.

College’s problem:

$$\max_{\alpha(x,y) \in [0,f(x,y)]} q(X, l)$$

s.t. $plN + p(c_0 + c_1 N + c_2 N^2) = EN + \int \int t(x, y)\alpha(x, y)dxdy$

$$N = \int \int \alpha(x, y)dxdy,$$
$$X = \int \int x\alpha(x, y)dxdy / N$$

Solution: admit if

$$t(x, y) \geq EMC(x, y) \equiv pl + p(c_1 + 2c_2 N) - E - p\frac{q_x}{ql}(x - X)$$

Evidence for $q$ maximization
A simple model

Break this into a two stage problem:

1. Choose $N$
2. Choose $\alpha(x, y)$ subject to $\int \int \alpha dx dy = N$.

Let $X(N)$ and $T(N)$ be the implied average ability and average net tuition from the $2^{nd}$ stage problem.

Then $1^{st}$ stage problem can be written

$$\max_{N} q \left( X(N), -\frac{c_0}{N} - c_2 N + \frac{1}{p} E + \frac{1}{p} T(N) \right)$$
A simple model

The solution,

$$\frac{q}{q_l} X'(N) + \frac{1}{p} T'(N) = c_0 N^{-2} - c_2,$$

gives some sharp predictions.

If $E \uparrow$, then no change in $N$, $T$, $X$; increase in $I$.

- fixed effects regressions support this prediction

Similarly, if $c_1 \uparrow$, then no change in $N$, $T$, $X$; decrease in $I$.

If demand increases $T(N)$ but not $T'(N)$ or $X'(N)$,

- there is no effect on optimal enrollment, $T$ and $I$ increase.
A simple model

With no heterogeneity in $x$, the 1st stage is

$$\max_{N} -p \left( \frac{c_0}{N} + c_1 + c_2 N \right) + E + T(N).$$

One can show $T'(N) < 0$ and

1. lump sum cost increases ($c_0 \uparrow$) $\Rightarrow$ $T \downarrow$, $N \uparrow$
2. “more than marginal” cost increases ($c_2 \uparrow$) $\Rightarrow$ $T \uparrow$, $N \downarrow$
3. $p$ increase effect depends on sign of avg total cost derivative
4. if $t(x, y)$ increases uniformly, then $\bar{N}$, $T \uparrow$.

Simple intuition does not work: $T = EMC$, not $T = MC$.

Note $t(x, y)$ is given: Same results with perfect competition!
The full model

Now let’s look at a richer model to quantify the forces.

There are $K$ college types—**exogenous heterogeneity in red**:

- maximize
  $$ q(X, I, N, Y) = \left( X^{\frac{\epsilon-1}{\epsilon}} + \alpha_I I^{\frac{\epsilon-1}{\epsilon}} + \alpha_Y Y^{\frac{\epsilon-1}{\epsilon}} + \alpha_N N^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}} $$

- endowed with
  - $E^g(N) = \bar{E}^g N$ government appropriations per student,
  - $E^p(N) = \bar{E}^p N$ private funding per student,
  - quadratic “custodial cost” function $C(N) = c_0 + c_2 N^2$

- choose $I$ with relative price $p$

- post vacancies $v$ in submarkets $m$ characterized by
  - $T$, net tuition
  - $s_Y$, student type (ability $x$ and parental income $y$)

- number $g(k)$ of each college type

- each vacancy costs $\kappa$ and matches at rate $\rho(\theta(m))$
Tuition pricing

In active submarkets, tuition satisfies

\[ T(m) = \frac{\kappa}{\rho(\theta(m))} + \left( pl + pC'(N) - \bar{E}^g - \bar{E}^p \right) \]

Search premium

\[ - p \frac{q_x}{q_l} (x - X) \]

Ability discount

\[ - p \frac{q_Y}{q_l} (y - Y) \]

Parental income penalty

The theories reflected here:

- \( p \) increase  
  - Baumol
- \( \bar{E}^g \) increase  
  - Public Support
- \( \bar{E}^p \) increase  
  - Private Revenues
- \( I \) increase  
  - Bowen
- \( \theta \) decrease \( \rightarrow \) \( \kappa/\rho(\theta) \) increase OR \( N \) increase  
  - Demand

“Wealth effects” can be large: \( \bar{E}^g \) increase can have no effect on \( T \)
Worker/retiree problem

Worker/retiree life-cycle problem is standard except

- student loans are a state variable
- student loan default allowed
- if default, garnished and principal increases
Student problem

College student budget constraint:

\[ c + T \leq e_Y + \xi EFC(s_Y) + b_s + b_u + \zeta(T + \phi, EFC(s_Y)) \]

- Endowment: \( e_Y \)
- Parental transfers: \( \xi EFC(s_Y) \)
- FSLP: \( b_s + b_u \)
- Grants: \( \zeta(T + \phi, EFC(s_Y)) \)

Graduates get college premium \( \lambda^k(s_Y) = \bar{\lambda}^k(\mu_\lambda + (1 - \mu_\lambda) \frac{x}{X_k}) \).

Face a constant dropout risk \( \delta^k(s_Y) = \min\{1, \max\{0, 1 - (1 - \bar{\delta}^k)(\mu_\delta + (1 - \mu_\delta) \frac{x}{X_k})\}\}\)

- 5 years w/o dropping-out → graduate
- if drop out, get prorated fraction of \( \lambda^k \)
Submarket $m \equiv (T, s_Y, k)$ has tightness $\theta^k(T, s_Y)$.

A youth chooses $k$, $T$, and search intensity $i$ to solve

$$
\max_{k,T,i} \left[ Y^k(T, s_Y) - \psi(i - 1)^2 + \frac{\epsilon^k}{\sigma} \right] \\
\text{Fundamental value} \quad \text{Search intensity cost} \quad \text{Preference shock}
$$

s.t. $i \eta(\theta^k(T, s_Y)) = 1$

Matching rate

“No college,” $k = 0$, identical but without search intensity.

Reduces to

$$
\max_{k,T,i \geq 1} \left[ Y^k(T, s_Y) - \psi(1/\eta(\theta^k(T, s_Y)) - 1)^2 + \frac{\epsilon^k}{\sigma} \right]
$$

(If $\eta = 1$, i.e., match with probability 1, no disutility from search.)
Equilibrium

Equilibrium is

- Individuals optimize
- Colleges optimize (taking $\theta$ as given)
- The tightnesses $\theta$ are consistent.

The model is not yet closed in terms of consumption goods, assets.

For now, government budget does not balance because of FSLP.
Seven college types (research/non, public/private, selective/non)

Within each $k$ type, $g(k)$ identical schools (from data).

<table>
<thead>
<tr>
<th>Type</th>
<th>Rel. premium</th>
<th>Comp. rate</th>
<th>P. inc.</th>
<th>Rel. X</th>
<th># schools</th>
</tr>
</thead>
<tbody>
<tr>
<td>GTN</td>
<td>0.83</td>
<td>0.47</td>
<td>53</td>
<td>0.26</td>
<td>242</td>
</tr>
<tr>
<td>GRN</td>
<td>0.95</td>
<td>0.58</td>
<td>65</td>
<td>0.48</td>
<td>129</td>
</tr>
<tr>
<td>PTN</td>
<td>0.89</td>
<td>0.58</td>
<td>71</td>
<td>0.34</td>
<td>639</td>
</tr>
<tr>
<td>PRN</td>
<td>1.08</td>
<td>0.65</td>
<td>81</td>
<td>0.51</td>
<td>50</td>
</tr>
<tr>
<td>GRS</td>
<td>1.19</td>
<td>0.73</td>
<td>77</td>
<td>0.90</td>
<td>20</td>
</tr>
<tr>
<td>PTS</td>
<td>1.29</td>
<td>0.89</td>
<td>110</td>
<td>0.94</td>
<td>36</td>
</tr>
<tr>
<td>PRS</td>
<td>1.63</td>
<td>0.87</td>
<td>91</td>
<td>0.96</td>
<td>42</td>
</tr>
</tbody>
</table>
Preferences

Individual flow utility is CRRA 2, time discount factor $\beta = .96$

$$q(X, I, N, Y) = (X^{\frac{\epsilon - 1}{\epsilon}} + \alpha_I I^{\frac{\epsilon - 1}{\epsilon}} + \alpha_Y Y^{-\frac{\epsilon - 1}{\epsilon}} + \alpha_N N^{\frac{\epsilon - 1}{\epsilon}})^{\frac{\epsilon}{\epsilon - 1}}.$$ We allow $\alpha_N$ to differ by public / private schooling.

Endowments

Parental transfers $\xi EFC(s_Y)$ has $\xi = .7$ (NLSY97 estimate)
Earnings in college $e_Y$ is $7,100$ (NLSY97 estimate)
$x \sim U[0, 1]$, $y|x \sim$ bounded $N(a + bx, \sigma^2)$; $a, b, \sigma$ estimated

Technology/Environment

CES, CRS matching function so $\eta(\theta) = \min\{f(\theta), 1\}$.

$$\lambda^k(x) = \overline{\lambda}^k(\mu_\lambda + (1 - \mu_\lambda)(x/X^k))$$ bounded: $\mu_\lambda \approx .1$
$$\delta^k(x) = 1 - (1 - \overline{\delta}^k)(\mu_\delta + (1 - \mu_\delta)(x/X^k))$$ bounded: $\mu_\delta \approx .6$
For the custodial cost, $C^k(N) = c_0^k + c_2^k N^2$, we exploit the solution from the simple model.

Specifically, we choose $c_2^k$ as a function of $c_0^k$ to deliver $\overline{N}^k$ as the optimal choice.

Last, we make fixed costs proportional to expenditures per FTE $\overline{S}^k$:

$$c_0^k = c \frac{1}{\overline{S}^k} \overline{N}^k.$$  

We are left with just one free parameter, $c \in [0, 1]$. 

Calibration of free parameters

Remaining free parameters: \( \kappa, c, \alpha_I, \alpha_Y, \alpha^g_N, \alpha^p_N, \sigma, \psi \).

Choose to minimize distance between model and target moments:

1. Net tuition at each school type
2. Sticker tuition* at each school type
3. FTE shares at each school type
4. Ability at each school type
5. Correlation(ability, enroll)
6. Enrollment rate

*Sticker tuition \equiv\ net tuition at \( p^{th} \) pctile getting \( p^{th} \) from data.
Calibration of free parameters

Note: numeraire is thousands of 2010 dollars.

<table>
<thead>
<tr>
<th>Parameter description</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search friction size</td>
<td>$\kappa$</td>
<td>0.008</td>
</tr>
<tr>
<td>Cost parameter</td>
<td>$c$</td>
<td>0.001</td>
</tr>
<tr>
<td>Quality’s weight on investment</td>
<td>$\alpha_I$</td>
<td>31.805</td>
</tr>
<tr>
<td>Quality’s weight on enrollment, public</td>
<td>$\alpha_{N}^g$</td>
<td>0.133</td>
</tr>
<tr>
<td>Quality’s weight on enrollment, private</td>
<td>$\alpha_{N}^p$</td>
<td>0.088</td>
</tr>
<tr>
<td>Quality’s weight on inverse p. income,</td>
<td>$\alpha_Y$</td>
<td>0.012</td>
</tr>
<tr>
<td>Preference shock size</td>
<td>$\sigma$</td>
<td>8.062</td>
</tr>
<tr>
<td>Search effort level</td>
<td>$\psi$</td>
<td>1000</td>
</tr>
</tbody>
</table>

Search disutility is very high: only go to submarkets where get in without search intensity.

1 s.d. preference shock is $\approx 8\%$ lifetime consumption.

We need to work on interpretation of other parameters.
Model fit

G/P gov./private, R/T research/teaching, S/N selective/not
Sorting in initial (1987) steady state.

Look at marginal distribution of ability at GTN, GRN, PTN: “tails”
Validation and experiments

Two types of results:

1. Validation: allow all factors to change simultaneously
2. Counterfactuals: decompose relative importance of factors, only allow some to change.

Exogenous changes:

- Borrowing limits, int. rates, Pell grants, loan eligibility
- College premium, graduation rates, parental transfers
- $p, E^g, E^p$
Dot is 2010, opposite end 1987. Perfect predictions lie on the 45°.
Dot is 2010, opposite end 1987. Perfect predictions lie on the $45^\circ$. 
Validation: predicted/actual changes

Dot is 2010, opposite end 1987. Perfect predictions lie on the 45°.
Dot is 2010, opposite end 1987. Perfect predictions lie on the 45°.
Experiments: quantifying the theories

#1: Demand and Bennett have increased tuition everywhere.
Experiments: quantifying the theories

#2: The impact seems fairly stable across school types.
Experiments: quantifying the theories

Net Tuition

<table>
<thead>
<tr>
<th>% Δ</th>
<th>PTS</th>
<th>PTN</th>
<th>PRS</th>
<th>PRN</th>
<th>GTN</th>
<th>GRS</th>
<th>GRN</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>87</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>43</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>77</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
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<td>%</td>
</tr>
<tr>
<td>170</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
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<tr>
<td>46</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>178</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

Pct. change

GRN
GRS
GTN
PRN
PRS
PTN
PTS

#3: $E^p$ generally restrained $T$. 

<table>
<thead>
<tr>
<th>Model</th>
<th>$L^\infty$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baumol ($p$)</td>
<td>0.00</td>
</tr>
<tr>
<td>Demand ($\lambda, \delta$)</td>
<td>0.00</td>
</tr>
<tr>
<td>Bennett</td>
<td>0.00</td>
</tr>
<tr>
<td>Pub. rev. ($E^p$)</td>
<td>0.00</td>
</tr>
<tr>
<td>Priv. rev. ($E^p$)</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Experiments: quantifying the theories

#4: $E^g$ also generally restrained $T$, but not at GTN.
Experiments: quantifying the theories

#5: Baumol has comparatively small effects.
#1: Demand and Bennett increase $T$, but also $N$. Welfare?
#2: Baumol again plays a small role.
Experiments: quantifying the theories

Enrollment

<table>
<thead>
<tr>
<th>Enrollment %</th>
<th>Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>33%</td>
<td>33%</td>
</tr>
<tr>
<td>48%</td>
<td>48%</td>
</tr>
<tr>
<td>32%</td>
<td>32%</td>
</tr>
<tr>
<td>32%</td>
<td>32%</td>
</tr>
<tr>
<td>57%</td>
<td>57%</td>
</tr>
<tr>
<td>27%</td>
<td>27%</td>
</tr>
<tr>
<td>63%</td>
<td>63%</td>
</tr>
</tbody>
</table>

#3: Changes in non-tuition revenue can matter, but complicated.
Experiments: quantifying the theories

#1: Bennett increases $T$ and $N$, but also access for low income.
Experiments: quantifying the theories

#2: Demand increases enrollment of rich who can afford higher $T$. 

![Bar chart showing parental income and percent change](chart.png)

- **PTS**: $\% \Delta = -3$
- **PTN**: $\% \Delta = 3$
- **PRS**: $\% \Delta = -6$
- **PRN**: $\% \Delta = 2$
- **GTN**: $\% \Delta = 2$
- **GRS**: $\% \Delta = -6$
- **GRN**: $\% \Delta = -3$

### Key:
- Baumol ($p$) $L^\infty$ 0.00
- Demand ($\lambda, \delta$) $L^\infty$ 0.00
- Bennett $L^\infty$ 0.00
- Pub. rev. ($E^g$) $L^\infty$ 0.00
- Priv. rev. ($E^p$) $L^\infty$ 0.00
Experiments: quantifying the theories

#1: With few exceptions, the forces tend to drive up expenditures.
Experiments: quantifying the theories

#2: The main reason colleges do this (in the model) is a love of spending. The Bowen rule matters.
Conclusion

Extended the Epple et al. framework in a few ways.

The calibrated model fit cross-sectional variation well.

Also matched untargeted variation across time in $T$, $I$, $N$.

Demand (policy and non-policy driven) main drivers of $T$.
⇒ But policy also increased $N$ and lowered $Y$.

Baumol had a small impact.

Non-tuition revenue changes have restrained $T$ increases.
Appendix
Non-exhaustive Literature

**Cost disease:** Baumol (1967), Archibald and Feldman (2008)


Colleges as quality maximizers

Log expenditures per person, \( \log(I+C) \)

Ability (SAT measured) conditional on college attendance
Colleges as quality maximizers

As an implication of quality maximization, colleges offer tuition discounts to high ability students.

<table>
<thead>
<tr>
<th>Discount (% off)</th>
<th>Ability</th>
<th>Parental income in 1996 (real)</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7.472**</td>
<td>-0.0972***</td>
<td>34.15***</td>
</tr>
</tbody>
</table>

Observations 1609

$R^2$ 0.047

* $p < .1$, ** $p < .05$, *** $p < .01$

This type of behavior is evident in the data
Empirical effects of non-tuition revenue

In the data, we can try to look at how changes in non-tuition revenue impact tuition.

<table>
<thead>
<tr>
<th></th>
<th>(1) (4)</th>
<th>(2) (4)</th>
<th>(3) (4)</th>
<th>(4) (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
</tr>
<tr>
<td>Eg</td>
<td>-0.26***</td>
<td>-0.04*</td>
<td>-0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Ep</td>
<td>0.09***</td>
<td>0.00</td>
<td>-0.00</td>
<td>-0.00</td>
</tr>
<tr>
<td>Observations</td>
<td>1158</td>
<td>1158</td>
<td>27792</td>
<td>27792</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.149</td>
<td>0.727</td>
<td>0.750</td>
<td>0.463</td>
</tr>
</tbody>
</table>

* $p < .10$, ** $p < .05$, *** $p < .01$

1. A significant cross-sectional correlation in 1987,
2. which disappears after state × school type × flagship effects.
3. Expanding to 1987-2010 still has insignificance
4. Fixed effects regressions says the same thing.

In the simple model, this coefficient is exactly 0.
Empirical effects of non-tuition revenue

The converse—which has to hold because of the budget—is a 1:1 effect on expenditures

<table>
<thead>
<tr>
<th></th>
<th>(1) XPND</th>
<th>(2) XPND</th>
<th>(3) XPND</th>
<th>(4) XPND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eg</td>
<td>0.74***</td>
<td>0.96***</td>
<td>0.99***</td>
<td>1.02***</td>
</tr>
<tr>
<td>Ep</td>
<td>1.09***</td>
<td>1.00***</td>
<td>1.00***</td>
<td>1.00***</td>
</tr>
<tr>
<td>Observations</td>
<td>1158</td>
<td>1158</td>
<td>27792</td>
<td>27792</td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.980</td>
<td>0.994</td>
<td>0.994</td>
<td>0.974</td>
</tr>
</tbody>
</table>

* $p < .10$, ** $p < .05$, *** $p < .01$

In a quality-maximizing college model, this coefficient is exactly 1.
Empirical effects of non-tuition revenue

<table>
<thead>
<tr>
<th></th>
<th>(1) log(N)</th>
<th>(2) log(N)</th>
<th>(3) log(N)</th>
<th>(4) log(N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(Eg)</td>
<td>0.40***</td>
<td>-0.05</td>
<td>-0.05***</td>
<td>-0.06***</td>
</tr>
<tr>
<td>log(Ep)</td>
<td>-0.14***</td>
<td>-0.15***</td>
<td>-0.19***</td>
<td>-0.12***</td>
</tr>
<tr>
<td>Observations</td>
<td>1105</td>
<td>1105</td>
<td>26721</td>
<td>26721</td>
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<tr>
<td>Adjusted $R^2$</td>
<td>0.366</td>
<td>0.711</td>
<td>0.718</td>
<td>0.463</td>
</tr>
</tbody>
</table>

* $p < .10$, ** $p < .05$, *** $p < .01$

Effect of $E_g$ on enrollment seems to be small, negative if anything

$E_p$ seems to decrease enrollment $N$

In a quality-maximizing college model, this coefficient is
- zero if non-tuition revenue is per-student
- negative if non-tuition revenue is partly “lump sum”
Full student problem

\[ \tilde{Y}_j(l, s_Y; T) = \max_{c \geq 0, l' \geq l} u(c) \]

\[ + \beta \left[ p \tilde{Y}_{j+1}(l', s_Y; T) + (1 - p) \mathbb{E}V_{j+1}(0, l', t_{max}, z'(\lambda^k(s_Y)), 0) \right] \]

subject to

\[ c + T \leq e_Y + \xi EFC + b_s + b_u + \zeta (T + \phi, EFC) \]

\[ (l_s, l_u, l'_s, l'_u) = f(l, l', T, EFC), \]

\[ (b_s, b_u) = (l'_s - l_s, l'_u(1 + i)^{-1} - l_u) \]

\[ \bar{l} \geq l'_s + l'_u(1 + i)^{-1} \]

\[ b_u \leq \min \{ \bar{b}_u, T, EFC \} \]

\[ b_s + b_u \leq \min \{ \bar{b}_j, T, EFC \} \]

with \( EFC \equiv EFC(s_Y), p \equiv (1 - \delta^k(s_Y))1[j < J_Y] \).
Regression relationships

To identify \( \varepsilon^g \) and \( \varepsilon^p \), we run regressions in data and model like

\[
\log(T) = \beta_0 + \beta_1 \log(E^g) + \beta_2 \log(E^p) + u_T
\]

<table>
<thead>
<tr>
<th>Regressor</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \log(E^p) )</td>
<td>0.318</td>
<td>0.321</td>
</tr>
<tr>
<td>( \log(E^g) )</td>
<td>-0.221</td>
<td>-0.224</td>
</tr>
</tbody>
</table>

Regressions are weighted by FTE counts and include a constant.
Borrowing limit changes

Total borrowing limits (2010 dollars) over time

Year
Thousands of 2010 dollars
Subsidized borrowing
Unsubsidized borrowing

Total borrowing limits (2010 dollars) over time

Year
Thousands of 2010 dollars
Subsidized borrowing
Unsubsidized borrowing
College premium changes

Log college-high school premium

Fitted values

Year
Log college-high school premium

0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7

Back
Completion rates over time

Note: data only begins in 2002
From 1987 to 2010, real GDP per capita 44%.

We increase parental incomes holding fixed the EFC formula.

This increases parental transfers $\xi EFC(s_Y)$. 
Budget constraint changes
Quantifying factors

Net Tuition

PTS: %Δ = -44
PTN: %Δ = -47
PRS: %Δ = -30
PRN: %Δ = -43
GTN: %Δ = -63
GRS: %Δ = -31
GRN: %Δ = -64

Pct. change

Baumol (p)  $L^\infty$  0.00
Demand (λ, δ)  $L^\infty$  0.00
Bennett  $L^\infty$  0.00
Pub. rev. ($E^g$)  $L^\infty$  0.00
Priv. rev. ($E^p$)  $L^\infty$  0.00
Quantifying factors

- Enrollment % = -25
- Enrollment % = -32
- Enrollment % = -24
- Enrollment % = -24
- Enrollment % = -36
- Enrollment % = -21
- Enrollment % = -39

Pct. change
-50 -40 -30 -20 -10 0 10 20

GRN
GRS
GTN
PRN
PRS
PTN
PTS

Enrollment

Baumol (p) $L^\infty 0.00$
Demand ($\lambda, \delta$) $L^\infty 0.00$
Bennett $L^\infty 0.00$
Pub. rev. ($E^g$) $L^\infty 0.00$
Priv. rev. ($E^p$) $L^\infty 0.00$
Quantifying factors

Parental Income

- PTS: %Δ = 3
- PTN: %Δ = -3
- PRS: %Δ = 7
- PRN: %Δ = -2
- GTN: %Δ = -2
- GRS: %Δ = 6
- GRN: %Δ = 3

Pct. change

Baumol (p) \( L^\infty \) 0.00
Demand (λ, δ) \( L^\infty \) 0.00
Bennett \( L^\infty \) 0.00
Pub. rev. (\( E^g \)) \( L^\infty \) 0.00
Priv. rev. (\( E^p \)) \( L^\infty \) 0.00
Quantifying factors

Expenditures

- PTS: %Δ = -37
- PTN: %Δ = -19
-PRS: %Δ = -37
- PRN: %Δ = -24
- GTN: %Δ = -24
- GRS: %Δ = -35
- GRN: %Δ = -26

Pct. change

<table>
<thead>
<tr>
<th>Expenditures</th>
<th>%Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTS</td>
<td>-37</td>
</tr>
<tr>
<td>PTN</td>
<td>-19</td>
</tr>
<tr>
<td>PRS</td>
<td>-37</td>
</tr>
<tr>
<td>PRN</td>
<td>-24</td>
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<tr>
<td>GTN</td>
<td>-24</td>
</tr>
<tr>
<td>GRS</td>
<td>-35</td>
</tr>
<tr>
<td>GRN</td>
<td>-26</td>
</tr>
</tbody>
</table>

Legend:
- Baumol (p)    $L^\infty$ 0.00
- Demand ($\lambda, \delta$) $L^\infty$ 0.00
- Bennett      $L^\infty$ 0.00
- Pub. rev. ($E^g$) $L^\infty$ 0.00
- Priv. rev. ($E^p$) $L^\infty$ 0.00
# Quantifying factors

Start with 1987 and add one force at a time (not cumulatively)

<table>
<thead>
<tr>
<th></th>
<th>GRN</th>
<th>GRS</th>
<th>GTN</th>
<th>PRN</th>
<th>PRS</th>
<th>PTN</th>
<th>PTS</th>
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<td>FSLP</td>
<td>2.5</td>
<td>12.2</td>
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<td>7.1</td>
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<tr>
<td>Gov. support ($E^g$)</td>
<td>1.3</td>
<td>8.9</td>
<td>3.9</td>
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<tr>
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<td>0.7</td>
<td>8.2</td>
<td>4.3</td>
<td>12.7</td>
<td>23.9</td>
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<td>19.4</td>
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<td>2010 (everything)</td>
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<td>7.1</td>
<td>17.0</td>
<td>18.1</td>
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<td>28.5</td>
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Quantifying factors

Start with 2010 and remove one force at a time (not cumulatively)

<table>
<thead>
<tr>
<th>Net tuition $T$ by school type</th>
<th>GRN</th>
<th>GRS</th>
<th>GTN</th>
<th>PRN</th>
<th>PRS</th>
<th>PTN</th>
<th>PTS</th>
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<tbody>
<tr>
<td>2010</td>
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<td>7.1</td>
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<td>Baumol ($p$)</td>
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<td>Demand ($\lambda, \delta$)</td>
<td>1.7</td>
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<tr>
<td>FSLP</td>
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<td>5.6</td>
<td>12.7</td>
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## College types

**Table:** College types, 1987

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<tr>
<th></th>
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<th>$E^g$</th>
<th>$E^p$</th>
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<td>PRN</td>
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### Table: College types, 2010

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