Accounting for Tuition Increases across U.S. Colleges*

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Abstract

This paper uses detailed institution-level data and an equilibrium model to assess different theories for the steep, persistent rise in college tuition. The framework embeds quality-maximizing, imperfectly competitive colleges into an incomplete markets, life-cycle environment with student loan borrowing and default. We measure the contribution of supply-side factors—namely, Baumol's cost disease and changes in the availability of non-tuition revenue sources—as well as demand-side forces, such as evolutions in the college earnings premium and changes to the Federal Student Loan Program. Together, these forces explain the entire increase in net tuition since 1987 with increases in demand playing the largest role.

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1 Introduction

Over the past few decades, the stubborn upward march of college tuition across all major segments of higher education has led to growing concerns about access, affordability, and mounting student loan debt. Among selective, frequently wealthy private research institutions, net tuition—that is, sticker price minus institutional aid coming in the form of need-based and merit-based scholarships—increased by 50% between 1987 and 2010 in real terms (from $15,500 to $23,700 in constant 2010 dollars) and by an astonishing 140% (from $2,700 to $6,400) for non-selective public teaching colleges that tend to be more resource constrained.[1] Several explanations have emerged to explain these and other higher education trends pertaining to enrollment, graduation, and post-graduation outcomes, but little consensus has emerged regarding their quantitative salience. While some explanations highlight the importance of broad macroeconomic forces, such as rising labor market skill premia that increase the value of a college degree, others focus on college-specific factors such as cuts in state support or the unintended consequences of federal student aid.

This paper quantitatively evaluates several prominent theories of tuition inflation using detailed micro-data and a rich equilibrium macroeconomic model that incorporates several key features of the higher education landscape. To organize thinking, we separate the theories which involve factors that directly affect college supply from those that revolve around forces that shift demand. On the supply side, Baumol's cost disease emphasizes the commonality between higher education and other service sectors, where the stipulated combination of stagnant productivity growth and rising labor costs creates persistent inflationary pressures. Another common supply-side explanation focuses on the role of declining state support for public institutions. We analyze this theory both independently and within the broader context of changes to other sources of non-tuition revenue. On the demand side, we examine the frequently-mentioned Bennett hypothesis, which attributes higher tuition to the same federal student aid programs that are meant to help with college affordability. Specifically, we assess the contribution of pre-Great Recession reforms to the Federal Student Loan Program (such as the addition of unsubsidized loans in 1993) in addition to the evolution of loan limits, interest rates, and Pell Grants. Lastly, we also quantify the role of rising labor market skill premia and higher parental income through their impact on college demand.

With the presence of extensive public subsidies, complicated financial aid rules, market power, and widespread price discrimination, higher education functions quite differently from most other markets. Furthermore, non-profit institutions—which are the focus of this paper—face different objectives and incentives than profit-maximizing firms. To capture these features, we assume that colleges maximize quality, which is a function of per-student investment and average student ability, just as in the static models of Epple, Romano, and Sieg (2006) and Epple, Romano, Sarpca, and Sieg (2013). By operating with market power, colleges engage in price discrimination to balance student recruitment against the need to raise revenue for quality-enhancing investment. Students,

[1] This time period omits the most recent wave of significant policy changes implemented since the Great Recession.

in turn, weigh cost and quality when choosing from among the set of colleges to which they receive an offer of admission. In equilibrium, the endogenous sorting of students across colleges affects both dimensions of the college quality distribution, which creates a computationally challenging fixed point problem. Our quantitative framework does well at capturing this sorting.

We find that the aforementioned theories in conjunction can explain the *entire* 107% increase in average college net tuition since 1987. However, across institutions, the contribution of any one factor varies based on the differing circumstances faced by each college type. Overall, our estimates indicate that demand-side changes have driven most of the rise in tuition, with student loan policy changes alone accounting for a 42% increase. On the supply side, we find only modest support for Baumol's cost disease. Lastly, changes in *total* non-tuition revenue have actually held down tuition by 7% for public institutions and 23% for private institutions.

1.1 Related Literature

A growing literature employs general equilibrium models to analyze higher education while taking the behavior of colleges and tuition as given. For example, Abbott, Gallipoli, Meghir, and Violante (2016) develop an equilibrium model to analyze financial aid policies intended to promote college attendance. Their framework features a rich intergenerational setting, intervivos transfers, and college attendance financed partly by grants and loans. In other work, Athreya and Eberly (2016) study the impact of a rising college wage premium on college attainment in the presence of heterogeneous drop-out risk and post-graduation earnings risk. Hendricks and Leukhina (2016) and Chatterjee and Ionescu (2012) also investigate the importance of drop-out risk for college attainment. Garriga and Keightley (2010), Lochner and Monge-Naranjo (2011), Belley and Lochner (2007), and Keane and Wolpin (2001) also develop equilibrium models to answer various important questions that lie at the intersection of macroeconomics and higher education.

This paper endogenizes tuition and the response of colleges to evolving market conditions and policies. In this vein, recent work by Jones and Yang (2016) closely mirrors the objectives here. They explore the role of skill-biased technical change in explaining the rise in college costs from 1961 to 2009. However, their study differs from this paper in several ways. First, this paper takes a unified look at both supply-side and demand-side factors that influence tuition, whereas they focus on the role of cost disease. Second, the object of interest in Jones and Yang (2016) is college costs, which increased by 35% in real terms between 1987 and 2010, whereas this paper addresses the much larger 92% increase in net tuition. Also, whereas they use a competitive, representative college framework, this paper employs a model with heterogeneous, imperfectly competitive colleges, peer effects, and student loan borrowing with default. Fillmore (2016) and Fu (2014) develop rich frameworks with heterogeneous colleges, but in both cases, students have static, reduced-form utility functions. Furthermore, peer effects are exogenous in Fillmore (2016), and Fu (2014) does not allow price discrimination based on ability and income.

Methodologically, the most closely related papers are Epple et al. (2006), Epple et al. (2013), and our earlier paper, Gordon and Hedlund (2016). The former two papers develop a static model of heterogeneous, quality-maximizing colleges that operate in an environment of imperfect competition and engage in price discrimination. Gordon and Hedlund (2016) embed this framework in a broader macroeconomic model but consider only the case of a single, monopolistic college. Such a case greatly simplifies computation but implies exaggerated market power with colleges facing no competitive pressure besides that provided by the outside option of skipping college entirely. This paper takes the important step of adding heterogeneous colleges, which allows for rich competition and sorting.

This paper also relates to a large empirical literature that estimates the effects of macroeconomic factors and policy interventions on tuition and enrollment. The origins of cost disease emerge from seminal works by Baumol and Bowen (1966) and Baumol (1967). They lay out a clear mechanism: productivity increases in the economy at large drive up wages everywhere, which service sectors that lack productivity growth pass along by increasing their relative prices. Recently, Archibald and Feldman (2008) use cross-sectional industry data to forcefully advance the idea that cost and price increases in higher education closely mirror trends for other service industries that utilize highly educated labor. In short, they "reject the hypothesis that higher education costs follow an idiosyncratic path."

The empirical literature has conflicting findings on the impact of state higher education appropriation on college tuition. For example, Heller (1999) suggests a negative relationship between state support and tuition, asserting that "the higher the support provided by the state, the lower generally is the tuition paid by all students." Recent empirical work by Chakrabarty, Mabutas, and Zafar (2012), Koshal and Koshal (2000), and Titus, Simone, and Gupta (2010) support this hypothesis, but notably, Titus et al. (2010) show that this relationship only holds up in the short run. Lastly, in a large study commissioned by Congress in the 1998 re-authorization of the Higher Education Act of 1965, Cunningham, Wellman, Clinedinst, Merisotis, and Carroll (2001a) conclude that "decreasing revenue from government appropriations was the most important factor associated with tuition increases at public 4-year institutions."

Shifting to demand-side factors, the empirical literature is split on the impact of financial aid on tuition. For example, McPherson and Shapiro (1991), Singell and Stone (2007), Rizzo and Ehrenberg (2004), Turner (2012), Turner (2013), Long (2004a), and Long (2004b) find at least some evidence in support of the Bennett hypothesis, though they disagree on the magnitude of the pass-through of aid into higher tuition and whether public or private institutions are more responsive. Most recently, Lucca, Nadauld, and Shen (2015) find a 65% pass-through effect for changes in federal subsidized loans and positive but smaller pass-through effects for changes in Pell Grants and unsubsidized loans. Similarly, Cellini and Goldin (2014) show that tuition is 78% higher at for-profit colleges that participate in federal student aid compared to those that do not. By contrast, in their commissioned report for the 1998 re-authorization of the Higher Education

Act, Cunningham et al. (2001a); Cunningham, Wellman, Clinedinst, Merisotis, and Carroll (2001b) conclude that "the models found no associations between most of the aid variables and changes in tuition in either the public or private not-for-profit sectors." Long (2006) and Frederick, Schmidt, and Davis (2012) echo these sentiments.

We also analyze how labor market trends over the past few decades have impacted tuition. Empirically, Autor, Katz, and Kearney (2008) report that the college earnings premium increased from 58% in the mid-1980s to 93% in 2005, which Autor et al. (2008), Katz and Murphy (1992), Goldin and Katz (2007), and Card and Lemieux (2001) ascribe to skill-biased technological change and a fall in the relative supply of college graduates. In recent work, Andrews, Li, and Lovenheim (2012) and Hoekstra (2009) study the *distribution* of college earnings premia and find substantial heterogeneity attributable to variation in college quality.

2 The Model

The model consists of heterogeneous, finitely-lived households, heterogeneous colleges, and the government.

2.1 Colleges

There is a finite number K of college *types* with each $k \in K$ representing a positive measure $g(k)$ of identical colleges. Each college maximizes quality, which depends positively on average academic ability of the student body, investment per student, and total enrollment while depending negatively on average parental income, as in Epple et al. (2006). School types differ exogenously along several dimensions, and additional heterogeneity arises in equilibrium from endogenous sorting.

The first source of heterogeneity enters the college budget constraint, with colleges of type k receiving non-tuition public (private) support $E^{g,k}(N^k)$ $(E^{p,k}(N^k))$ and facing operating costs $C^k(N^k)$, where N^k is enrollment. Next, colleges differ in terms of their student retention probabilities and post-graduation labor market outcomes. Specifically, students attending college type k face an annual dropout risk of $\delta^k(s_Y)$ and earnings premia of $\lambda^k(s_Y)$, both of which also depend on the student's type s_Y. We take the student's type as consisting of an "ability" measure x (which includes any innate ability and embodied human capital as of age 18) and parental income y.

To keep the model tractable, we follow Gordon and Hedlund (2016) by introducing additional assumptions that make the college problem each period independent of past decisions. Doing so allows us to analyze rich peer effects, sorting, and imperfect competition in equilibrium without the additional complications of strategic investment and dynamic market power. To be concrete, we first assume that colleges are subject to an annual balanced budget constraint. Instead of actively managing an investment portfolio, colleges simply receive an exogenous flow of non-tuition revenue (which includes endowment earnings, direct government support, etc.) which supplements funds from endogenous tuition. Secondly, we assume that, after making admissions, tuition, and spending decisions for each incoming cohort, colleges immediately sell the associated stream of future cash flows to a deep pocketed intermediary in exchange for the expected, undiscounted sum of these cash flows.[2] In terms of practical effect, the college commits to keeping tuition and spending fixed for each cohort, and there is no cross-cohort subsidization. The expected stream of payments for an incoming student with annual dropout probability δ paying net tuition T (defined as sticker price $\overline{T}$ minus institutional aid) is T, $(1-\delta)T, \ldots, (1-\delta)^{J_Y-1}T$. Defining $\omega = \sum_{j=1}^{J_Y}(1-\delta)^{j-1}$, the net present value of these payments is $T\omega$.

What is the objective function of a non-profit college? Following Epple et al. (2006, 2013), we assume they maximize *quality*, a function of average ability X and quality-enhancing spending per student I. While the results of Epple et al. (2006, 2013) and our benchmark results show this assumption will give nice quantitative predictions, the appendix provides several additional pieces of evidence in favor of this assumption. Additionally, for better quantitative properties, we allow quality also to depend on the student body size N—which will let us better match the large and comparatively cheap tuition at public schools—and, inversely, on average parental income Y—which, through correlations between income and race, allows for a diversity or affirmative action motive.

We introduce tuition discounting and matching of students with colleges via competitive search. In this setup, students and admissions vacancies at each college type are matched frictionally in submarkets $m \equiv (k, T, s_Y)$ indexed by the college type k, net tuition T and student type $s_Y = (x, y)$. We use the notation $k(m)$, $T(m)$, $x(m)$, $y(m)$ to select the various components of m. Vacancies cost κ and are filled with probability $\rho(\theta(m))$, with students and colleges taking the tightness $\theta(m)$—that is, the ratio of vacancies to search-intensity-adjusted applications—as given.

A college of type k's problem is

$$\begin{aligned}
&\max_{v(m)\geq 0} q(X, Y, I, N) \\
\text{s.t. } pIN + pC(N) + \kappa \int v(m)dm &= \int T(m)\omega(m)v(m)\rho(\theta(m))dm + E^g(N) + E^p(N) \\
X &= \int x(m)\omega(m)v(m)\rho(\theta(m))dm/N \\
Y &= \int y(m)\omega(m)v(m)\rho(\theta(m))dm/N \\
N &= \int \omega(m)v(m)\rho(\theta(m))dm
\end{aligned} \tag{1}$$

with vacancies only in the college's own type $((k(m)-k)v(m) = 0)$. The interior solution states

[2] Having an undiscounted sum is not essential to the theory, but simplifies some of the formulas.

that, in active submarkets, tuition satisfies

$$T(m) = \underbrace{\frac{\kappa}{\omega(m)\rho(\theta(m))}}_{\text{Search premium}} + \overbrace{\underbrace{pI + pC'(N) - E^{g\prime}(N) - E^{p\prime}(N)}_{\text{Marginal resource cost}} - \underbrace{p\frac{q_N}{q_I}N}_{\text{Size discount}} - \underbrace{p\frac{q_X}{q_I}(x-X)}_{\text{Ability discount}} - \underbrace{p\frac{q_Y}{q_I}(y-Y)}_{\text{Low income discount}}}^{EMC(s_Y)}. \tag{2}$$

If, for a given $\theta(m) > 0$, a submarket has $T(m)$ strictly greater than the right hand side, the college would post an infinite number of vacancies implying $\theta(m)$ should be infinite, which cannot happen in equilibrium. Conversely, if for a given $\theta(m) > 0$ a submarket has $T(m)$ strictly less than the right hand side, the college would post no vacancies, implying $\theta(m)$ should be zero and hence not an active submarket.

Absent search frictions ($\kappa = 0$), students pay individual-specific net tuition equal to their effective marginal cost $EMC(s_y)$, which is a term first coined by Epple et al. (2006). Intuitively, each student tightens the college's budget constraint by $pI + pC'(N) - E^{g\prime}(N) - E^{p\prime}(N)$, but they also contribute to college quality based on their characteristics s_Y, as shown by the last three terms of (2). The role of search ($\kappa > 0$) is then to introduce a markup representing college market power.

2.2 Households

Households go through three phases of life: youth, working age, and retirement.

2.2.1 Youth

Each period, a fixed measure of heterogeneous youths with characteristics $s_Y = (x, y)$ enter the economy at age $j = 1$ corresponding to high school graduation. Their main decision is whether to immediately join the workforce ($k = 0$) or attend a college $k \in \{1, \ldots, K\}$. While enrolled, students receive additive utility $v(q^k)$ that depends positively on college quality q^k. In addition, higher educational attainment (and especially graduation) delivers future labor market benefits. Youth who skip college and directly enter the labor market receive earnings $\mu_j e^z$ where μ_j is an age-specific deterministic profile and z follows a random walk with $z_0 = 0$ and innovations $\sigma\varepsilon$.[3] For youth who attend college, graduation confers a log earnings premium $\lambda^k(s_Y)$ that is specific to college k and individuals with characteristics s_Y. To graduate, a student must not dropout for J_Y periods where the annual dropout probability is $\delta^k(s_Y)$. Students who dropout after attending for j years receive a prorated premium of $\lambda^k(s_Y)j/(J_Y + 1)$, which will imply a 17% sheepskin effect in our calibration.

When making the decision to attend college k, a youth of type s_Y must also choose a desired net tuition level T, implicitly choosing a submarket $m = (k, T, s_Y)$. Naturally, students prefer to pay lower tuition, but acceptance probabilities $\eta(\theta(m))$ increase in T. (For instance, in equilibrium

[3] A random walk versus an AR(1) is not theoretically important but saves a state variable.

the probability of being accepted in a submarket with $T < EMC^k(s_Y)$ must be zero.) Rather than explicitly model the choice of students to apply to several colleges within type k, we assume that, conditional on choosing submarket m, students exert search intensity $s \geq 1$ to ensure they get admitted to a college within that type, i.e. $s\eta(\theta(m)) = 1$.[4] Thus, students trade off the cost of net tuition T against the search disutility $\psi(s-1)^2$.

Besides net tuition T, students face non-tuition expenses ϕ. These total costs $T + \phi$ can be covered using a combination of personal and family resources, student loans, and government grants. Eligibility for need-based grants $\zeta(T + \phi, EFC(s_Y))$ depends on $EFC(s_Y)$, which is the expected family contribution formula. After subtracting these grants, the net cost of attendance $NCOA(T, s_Y) = T + \phi - \zeta(T + \phi, EFC(s_Y))$ acts as a ceiling on the amount students can borrow through the Federal Student Loan Program (FSLP).

The FSLP contains two main borrowing instruments. Subsidized loans are the most financially attractive because they do not accrue interest while the student is enrolled in college. For this program, eligibility depends on financial need, defined as $NCOA(T, s_Y) - EFC(s_Y)$. Also, beginning in 1993, the government has allowed students to borrow the remainder of their education costs up to $NCOA$ using unsubsidized loans that *do* accrue interest during college.

In addition to the constraint that borrowing cannot exceed $NCOA$, students face annual and aggregate limits for subsidized and combined borrowing (i.e., subsidized plus unsubsidized). Let $\bar{b}_j$ denote the annual combined borrowing limit for a age j youth and $\bar{l}$ the aggregate combined limit. Then subsidized borrowing b_s and unsubsidized borrowing b_u must satisfy

$$b_s + b_u \leq \min\{\bar{b}_j, NCOA(T, s_Y)\}. \tag{3}$$

Additionally, the choice of subsidized and unsubsidized loans, denoted as l'_s and l'_u, respectively, must be less than $\bar{l}$. Analogously, define $\bar{b}^s_j$ as the statutory annual subsidized limit and $\bar{l}^s_j$ as the statutory aggregate subsidized limit. Annual subsidized borrowing b_s must be less than $\bar{b}^s_j$, and total subsidized borrowing l'_s must be less than $\bar{l}^s_j$.

Apart from loans, students have two other means of paying for college. First, they have earnings e_Y, which we treat as an endowment. Second, they receive a parental transfer $\xi EFC(s_Y)$, where $\xi \in [0, 1]$ is a parameter. The budget constraint for a type-s_Y college student is

$$c + NCOA(T, s_Y) \leq e_Y + \xi EFC(s_Y) + b_s + b_u. \tag{4}$$

Our calibration of ξ will capture data on parental transfers, irrespective of whether they are financed by PLUS Loans, second mortgages, or credit card borrowing.

[4] We make this assumption for two reasons. First, it simplifies the discrete choice problem with preference shocks over college types. Second, because the empirical counterpart of each type k is a whole set of similar colleges, it is reasonable to think that qualified students (i.e. those for whom $T > EMC$) who happen for idiosyncratic reasons to not receive an offer of admission to one college of type k will likely get admitted to some other type-k college.

2.2.2 Workers and Retirees

Workers and retirees receive non-asset income based on their level of education, age, retirement status, and a stochastic component that follows a random walk with innovations $\varepsilon \sim N(0, \sigma_z^2)$. This income is then taxed at a proportional rate τ. Consumption provides period utility $u(c)$, and the future is discounted at rate β. Workers with student loans owe constant payments of $p(l,t) = l\frac{i(1+i)^{t-1}}{(1+i)^t - 1}$ that amortize the remaining balance l at interest rate i over the t years left on the loan. Under current law, default has two costs. First, collection charges of up to 25% of the outstanding principal may be added to payments. We model this via a penalty η added to the loan when the household first defaults. Second, wages and tax refunds may be garnished. We model this as a wage garnishment γ that remains until the household rehabilitates the loan (by resuming on time payments) or pays it off. Households in the model cannot engage in borrowing outside of the student loan program, but they can save using discount bonds having a price $1/(1+r)$.

2.3 Value Functions

Workers with loans in good standing choose whether to default or make a payment,

$$V_j(a, l, t, z, f = 0) = \max\{V_{j+1}^R(a, l, t, z), V_{j+1}^D(a, l(1+\eta), z)\}. \tag{5}$$

where V^R is the value of repayment and V^D is the value of default. The decision to default results in a proportional balance penalty η added to the loan.

Workers in a state of delinquency choose whether or not to rehabilitate their student loan,

$$V_j(a, l, z, f = 1) = \max\{V_{j+1}^R(a, l, t_{\max}, z), V_{j+1}^D(a, l, z)\} \tag{6}$$

where rehabilitation resets the loan repayment clock to t_{max}.

The value function for workers who make a loan payment is

$$\begin{gathered} V_j^R(a, l, t, z) = \max_{a' \geq 0} u(c) + \beta \mathbb{E}_{\varepsilon'} V_{j+1}(a', l', t', z + \varepsilon', 0) \\ \text{s.t. } c + a'/(1+r) + p(l,t) \leq (1-\tau)\mu_j e^z + a \\ l' = (l - p(l,t))(1+i) \\ t' = \max\{t-1, 0\} \end{gathered} \tag{7}$$

The value of choosing to remain in default is

$$\begin{gathered} V_j^D(a, l, z) = \max_{a' \geq 0} u(c) + \beta \mathbb{E}_{\varepsilon'} V_{j+1}(a', l', z + \varepsilon', 1) \\ \text{s.t. } c + a'/(1+r) \leq (1-\gamma)(1-\tau)\mu_j e^z + a \\ l' = \max\{0, (l - \gamma(1-\tau)\mu_j e^z)(1+i)\} \end{gathered} \tag{8}$$

where γ is the lost fraction of earnings from wage garnishment.

Upon matriculation, each college student has an associated drop-out probability δ, net tuition T, expected family contribution EFC, and log-college earnings premium λ as state variables with a value function

$$\begin{aligned}
\widetilde{Y}_j(l;\lambda,\delta,T,EFC) = \max_{c\geq 0, l'\geq l} u(c) + \beta\Big[&(1-\delta)\mathbf{1}_{[j<J_Y]}\widetilde{Y}_{j+1}\left(l';\lambda,\delta,T,EFC\right) \\
&+ (1-\delta)\mathbf{1}_{[j=J_Y]}\mathbb{E}_{\varepsilon'}V_{j+1}\left(0,l',t_{max},\lambda+\sigma_z(j+1)^{1/2}\varepsilon',0\right) \\
&+ \delta\mathbb{E}_{\varepsilon'}V_{j+1}\left(0,l',t_{max},\lambda\frac{j}{J_Y+1}+\sigma_z(j+1)^{1/2}\varepsilon',0\right)\Big] \\
\text{s.t. } c+T \leq e_Y + \xi EFC + b_s + b_u + \zeta(T+\phi, EFC)& \\
NCOA = T+\phi-\zeta(T+\phi,EFC)& \\
b_s = l'_s - l_s, \quad b_u = \frac{l'_u}{1+i} - l_u& \\
b_u \leq \min\{\bar{b}^u_j, NCOA\}, \quad b_s + b_u \leq \min\{\bar{b}_j, NCOA\}& \\
l'_s + \frac{l'_u}{1+i} \leq \bar{l}&
\end{aligned} \tag{9}$$

where the decomposition of total loan balances into subsidized/unsubsidized components is

$$\begin{aligned}
(l'_s,l'_u) &= \begin{cases} (l',0) & \text{if } l' \leq \widetilde{l}^s_j(NCOA,EFC) \\ (\widetilde{l}^s_j(NCOA,EFC), l'-\widetilde{l}^s_j(NCOA,EFC)) & \text{otherwise} \end{cases} \\
(l_s,l_u) &= \begin{cases} (l,0) & \text{if } l \leq \widetilde{l}^s_{j-1}(NCOA,EFC) \\ (\widetilde{l}^s_{j-1}(NCOA,EFC), l-\widetilde{l}^s_{j-1}(NCOA,EFC)) & \text{otherwise.} \end{cases}
\end{aligned} \tag{10}$$

Note that the college earnings premium gradually increases with each year of enrollment, and there is a discrete jump upon graduation to reflect the sheep-skin effect.

The value of attending college k (before preference shocks) is given by

$$Y^k(T,s_Y) = \widetilde{Y}_1(0;\lambda^k(s_Y),\delta^k(s_Y),T,EFC(s_Y)) + \sum_{j=1}^{J_Y}\beta^{j-1}(1-\delta_k(s_Y))^{j-1}v(q^k). \tag{11}$$

The value of not attending college is defined as

$$\hat{Y}^0(s_Y) = \mathbb{E}_{\varepsilon'}V_1(0,0,0,\varepsilon',0), \tag{12}$$

which depends on s_Y only superficially.

Conditional on applying to college k, the youth's choice of T and search intensity s solves

$$\begin{aligned} \hat{Y}^k(s_Y) \equiv \max_{s\geq 1,T} \min\{s\eta(\theta(m)),1\}(Y^k(T,s_Y) - \hat{Y}^0(s_Y)) + \hat{Y}^0(s_Y) - \psi(s-1)^2 \\ \text{s.t. } s\eta(\theta(m)) = 1 \\ m = (k,T,s_Y) \end{aligned} \tag{13}$$

where $k=0$ is the decision to skip college and $M^k(s_Y) = \{(T^k, s_Y)\}$. Simplifying, this is

$$\begin{aligned} \hat{Y}^k(s_Y) = \max_{T} Y^k(T,s_Y) - \psi(1/\eta(\theta(m)) - 1)^2 \\ \text{s.t. } m = (k,T,s_Y) \end{aligned} \tag{14}$$

Lastly, to account for unobserved preferences, we add idiosyncratic taste shocks when the student is choosing k:

$$\max_{k\in\{0,\ldots,K\}} \hat{Y}^k(s_Y) + \frac{1}{\sigma}\varepsilon^k. \tag{15}$$

These preference shocks introduce non-pecuniary benefits of attending specific colleges, which results in smoother, more mixed sorting behavior of student types across colleges.

Assuming the taste shocks are distributed according to a Type 1 extreme value distribution, the probability of choosing college k is

$$A^k(s_Y) := \frac{\exp(\sigma(\hat{Y}^k(s_Y) - \hat{Y}^0(s_Y))))}{\sum_{\tilde{k}=0}^{K} \exp(\sigma(\hat{Y}^{\tilde{k}}(s_Y) - \hat{Y}^0(s_Y)))}. \tag{16}$$

Because we assume that applicants must jointly choose submarkets and search effort to guarantee attendance, this probability is also the attendance rate for type s_Y.

2.4 Government

The government levies proportional taxes on labor earnings to fund transfers and loans (both subsidized and unsubsidized) to students in college. Other sources of revenue for the government include interest payments on unsubsidized loans for students in college as well as loan payments and garnishment from workers with outstanding student loans.

2.5 Equilibrium

A steady state equilibrium consists of market tightnesses θ, college vacancy postings v^k, value functions Y^k, $\hat{Y}^k$, and V, application rates A^k, and tax rates such that

1. colleges optimally choose v^k taking market tightnesses as given;

2. students and workers optimize taking market tightnesses and tax rates as given;

3. application rates A^k and market tightnesses θ^k are consistent with the student value functions $Y^k, \hat{Y}_k$ and vacancy creation v^k; and

4. the government balances its budget.

While we compute steady state equilibria to ensure the FSLP budget balances given its pay-as-you-go structure, all the other equilibrium conditions are for a given cohort. Consequently, a better way to think of the equilibrium may be as a cohort-specific equilibrium where the government can fund the FSLP at zero interest.

3 Data, Calibration, and Estimation

We now turn to the calibration and estimation of the model.

3.1 College Data and Types

Colleges are large, multifaceted organizations, and this complexity manifests itself in their balance sheets. In line with the model, we distill college budgets into net tuition revenue T, non-tuition revenue E, operating costs pC, recruiting costs $K \equiv \kappa \int v dm$, and quality-enhancing investment pI. The budget constraint we work with for accounting purposes is

$$pI + pC + K = T + E^g + E^p. \tag{17}$$

Table 1 provides the mapping between model and data using institution-level IPEDS data from the Delta Cost Project (DCP). As the distinction between quality enhancing expenditures and other expenditures is not obvious in the data, we do not try to separately identify the expenditure components in the data.

We break schools into seven types based on three criteria: Whether they are public (G) or private (P), teaching (T) or research-intensive (R) as defined by the Carnegie Classification; and selective (S) or non-selective (N). The selectivity metric is based on whether the mean SAT score is above 1250 (in a 1600 point system) or not. For some schools, we must impute this measure, and the details are in the appendix. At times, we will use the abbreviations to designate school types with, e.g., PRS denoting private, research-intensive, selective schools. There are not eight types because GTS schools do not exist according to our classification. Summary statistics by school type and year—including the budgetary items discussed above—are given in table 9 in the appendix, but most of the values can be inferred from figures 1 and 2 and table 7.

Balance Sheet Item	Model Equivalent
Total Expenditures	$pI + pC + K$
E&G Spending	Component of $pI + pC + K$
Auxiliary and "Other" Spending	Component of $pI + pC + K$
Total Revenue	$T + E^g+$ Component of E^p
Net Tuition	T
Directly from Student	Out of Pocket for T
From Government	Students Pay Towards T
Pell	Students Pay Towards T
Local, State, and Other Federal	Students Pay Towards T
Approp., Contracts, Excluding Pell	E^g
Auxiliary and "Other" Revenue	Subcomponent of E^p
Endowment Revenue, Gifts	Subcomponent of E^p
Gross Operating Margin (Rev. − Exp.)	Remainder of E^p

Notes: E^p = "Component of E^p" + "Remainder of E^p." We only distinguish between pI, pC and K in the model as the empirical distinction is not clearcut.

Table 1: The College Balance Sheet

3.2 Mapping of Model to Data Units

One unit of the consumption good is treated as $1,000 in 2010 dollars. We take ability to be uniformly distributed between 0 and 1 and measure it using the AFQT for students.[5] We assume that enrollment N corresponds to a school's full-time equivalent (FTE) share in the data multiplied by the enrollment rate. The number of schools within each type $g(k)$ is given by the number of schools in the data. (There is virtually no school entry or exit in the data over this time period, so we assume it is time-invariant.) The number of schools plays a material role in limiting market power at school types having large $g(k)$—all coming through changes in market tightness which measure aggregate postings of a school type. In particular, PTN, GTN, and PRN have between 120 and 640 schools while the selective schools range from 20 to 42. Table 2 summarizes how we map the data and model populations.

Data	Model
Youth population	1
Number of schools within each type	$g(k)$
A school's FTE share $\times$ the enrollment rate	N

Table 2: Mapping between the data and model

3.3 College Quality

We assume q is given by a CES quality function

$$q(X, Y, I, N) = \left(\alpha_X X^{\frac{\epsilon-1}{\epsilon}} + \alpha_Y Y^{-\frac{\epsilon-1}{\epsilon}} + \alpha_I I^{\frac{\epsilon-1}{\epsilon}} + \alpha_N N^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}. \tag{18}$$

Note that Y is a "bad" because its exponent is $-(\epsilon-1)/\epsilon < 0$.

Note that, while the model has extremely tight predictions about net tuition for each student, it is silent regarding the pre-institutional aid "sticker price" tuition. To overcome this shortcoming and allow sticker prices in the data to help discipline the quality function parameters, we construct an artificial sticker price in the model. To do so, we use the percentage of students receiving institutional grants in the data to construct a cutoff $\mathcal{T}$ such that $P(T \le \mathcal{T})$ is the fraction receiving institutional grants. We then take $\mathbb{E}(T|T > \mathcal{T})$ as the "sticker price."

With the sticker price defined as $\mathbb{E}(T|T > \mathcal{T})$, we can then use the disparity in sticker price and net tuition to discipline α_X/α_I and ϵ (which play a crucial role in determining the ability discounts). Likewise, α_Y/α_I and ϵ are disciplined by the average parental income across schools. Larger α_N/α_I depresses tuition uniformly and expands enrollments, and so the level of net tuition and enrollments

[5] For colleges, we will sometimes refer to a relative ability measure. This measure assumes SAT scores of college attendees are normally distributed. The relative ability $\tilde{X}$ is then the the inverse of the cdf (i.e. $\tilde{X} = F^{-1}(SAT)$). When we compare this with the model, we compute the mean value of x conditional on students who enroll.

helps identify them, and we allow α_N to differ by whether the school is public or private. Jointly $\alpha_X, \alpha_Y, \alpha_N, \alpha_I$ cannot be separately identified because scaling them all by a constant represents the same preferences. Hence, we normalize α_X to be 1. Consequently, the quality function has five free parameters, which we will identify using 42 cross-sectional moments (an observation for each of the school types for net tuition, sticker price tuition, expenditures, enrollments, ability, and parental income).

3.4 Non-Tuition Revenue and Operating Costs

We use linear specifications $E^g(N) = \overline{E}^{g,k}N$ and $E^p(N) = \overline{E}^{p,k}N$ for non-tuition revenue and, following Epple et al. (2006), we posit operating costs of the form

$$C(N) = c_0^k + c_1^k N + c_2^k N^2. \tag{19}$$

Rather than calibrate $3K$ parameters, we simplify the process by using information from a "nearby" problem. Specifically, we first assume that $c_1^k = 0$ for all k. Next, we consider the solution to the college problem under the assumption that there is no student heterogeneity. Under these assumptions, one can show the optimal choice of colleges must satisfy

$$\frac{q_N}{q_I} + \frac{1}{p}\frac{d(E(N)/N)}{dN} = \frac{d(C(N)/N)}{dN} \tag{20}$$

where q_N/q_I is $(\alpha_N/\alpha_I)(N/I)^{-1/\epsilon}$.

For calibrating the c_0^k, c_1^k, c_2^k parameters, we assume that enrollments in the data correspond to the efficient scale given by the solution to this problem, i.e. $\overline{N}^k = N$. Given I and $\overline{N}^k$, the cost parameters c_2^k and c_0^k are related by

$$c_2^k(\overline{N}^k)^2 = c_0^k + \frac{\alpha_N}{\alpha_I}\left(\frac{\overline{N}^k}{I}\right)^{-1/\epsilon}(\overline{N}^k)^2. \tag{21}$$

We do not take a stand on which components of college spending per FTE $\overline{S}^k$ in the data are operating costs and which represent quality-enhancing investment. Instead, we simply proxy for I by assuming it is two-thirds of average expenditures per FTE in the data, i.e., $\overline{I}^k = \frac{2}{3}\frac{1}{p}\overline{S}^k$. After this process, only K cost parameters remain: c_0^k for each k.

To discipline each fixed cost c_0^k, we assume it is a proportion $\mathfrak{c} \in [0, 1]$ of total expenditures,

$$c_0^k = \mathfrak{c}\frac{1}{p}\overline{S}^k\overline{N}^k. \tag{22}$$

Thus, we are left with just one free parameter, $\mathfrak{c}$, to be calibrated.

3.5 Matching Technology

We assume a CES matching function for vacancies v and intensity-adjusted applicants $\widetilde{u} = su$ is

$$m(\widetilde{u}, v) = \widetilde{u} \min\left\{\frac{A(v/\widetilde{u})}{(1 + (v/\widetilde{u})^{\gamma})^{1/\gamma}}, 1\right\} \tag{23}$$

The resulting matching rate for intensity-adjusted applicants is $\eta(\theta) = \frac{m(\widetilde{u},v)}{\widetilde{u}} = \min\left\{\frac{A\theta}{(1+\theta^{\gamma})^{1/\gamma}}, 1\right\}$, where $\theta = v/\widetilde{u}$ is the market tightness. Analogously, the matching rate for vacancies is $\rho(\theta) = \eta(\theta)/\theta$. We set $\gamma = 1$ and then choose A such that students and colleges match with a 95% probability when $\theta = 1$, which gives $A = 2 \cdot 0.95$.

3.6 Dropout Risk and Earnings Premia

Graduation rates and labor market premia depend both on school type and individual student ability. To best match the data while maintaining tractability of estimation, we assume a constant weight μ_δ for the contribution of college type. Specifically,

$$(1 - \delta^k(x)) = \min\left\{\max\left\{\left(1 - \overline{\delta}^k\right)\left(\mu_\delta + (1 - \mu_\delta)\frac{x}{X^k}\right), 0\right\}, 1\right\} \tag{24}$$

where $\overline{\delta}^k$ is from the data (specifically, the institution level data), x is individual ability, and X^k is average ability at school k.

To determine μ_δ, we first compute average ability and graduation rates by college type, as defined by sticker tuition quintile. Next, we regress graduation on a quintile dummy multiplied by the average graduation rate times the ratio of individual ability to average ability. The results are presented in Table 19 in the appendix. Except for the lowest quintile, the relationship between ability and graduation is statistically significant and stable at around 40%. Consequently, we take $\mu_\delta = 0.6$.

We follow a similar procedure for the college earnings premium by assuming that

$$\lambda^k(x) = \overline{\lambda}^k\left(\mu_\lambda + (1 - \mu_\lambda)\frac{x}{X^k}\right) \tag{25}$$

and replacing the graduation dummy on the left side of the regressions with the log college premium. The results, which also appear in Table 19, are relatively stable across the quintiles and lead us to set $\mu_\lambda = 0.1$. Note that a k-invariant μ_λ in no way implies similar college premia across colleges. In fact, using the NLSY97 data, we find the log college premium for the lowest quintile is 0.363 while the highest quintile is 0.643. We use the institution level data to recover $\bar{\lambda}^k$ for our seven school types, and the differences are even larger with $\bar{\lambda}^k$ for PRS schools (which comprise only 3.6% of schools) 0.67 log points larger than at GTN schools (which comprise 20.8%).

3.7 Parental Transfers

We use NLSY97 data to calibrate the fraction ξ of parental transfers that appear directly in the student budget constraint, i.e. $\xi EFC(s_Y)$. The first step involves computing parental income and applying the simplified formula from Epple et al. (2013) to get an EFC measure (the same as in the model). Next, we use data on family aid for college that is not expected to be paid back and find the annual level of support. Lastly, we regress this transfer measure on interaction terms between EFC and whether a student dropped out or graduated. We do this for two samples, the full sample and a subsample where EFC is less than net tuition, expecting transfers are not unconditional but contingent on having sufficiently large college costs. The results, which are given in Table 3, lead us to set $\xi = 0.7$, loosely the midpoint of 0.419 and 0.901.

	(1) Family grant	(2) Family grant
Dropped out × EFC (real)	0.0939***	0.419***
	(6.70)	(4.46)
Graduated × EFC (real)	0.185***	0.901***
	(27.31)	(30.16)
Observations	2063	771
R^2	0.277	0.547

t statistics in parentheses

(1) is the full sample; (2) includes only those with EFC < net tuition.

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

Table 3: Transfers as a function of EFC

3.8 Household Preferences

In the benchmark, we assume $v(\cdot) = 0$ so that college quality does not change utility. The flow utility is standard with a constant relative risk aversion of two. We take the time discount factor β to be 0.96. Search intensity disutility ψ is jointly estimated, as is the preference shock size σ.

3.9 Jointly Estimated Parameters

Table 4 summarizes the calibration of most non-college-specific parameters. The remaining parameters are jointly estimated to fit a large number of moments ranging from net and sticker tuition, enrollment shares, expenditures, enrollment rates, and ability at each school type along with the correlation between parental income and enrollment. Table 5 provides a summary. Of note, the calibrated value for $\mathfrak{c}$ turns out to be quite small, implying fixed costs are relatively unimportant with the quadratic term being most important. In fact, the custodial costs turn out to be largest at

Description	Value	Source/Reason
Discount factor	0.96	Standard
Risk aversion	2	Standard
Savings interest rate	0.02	Standard
Borrowing premium	0.107	12.7% rate on borrowing
Earnings in college	$7,128	NLSY97
Loan balance penalty	0.05	Ionescu (2011)
Loan duration	10	Statutory
Age-earnings profile	Cubic	STY (2004)*
College premium	GH (2016)**	Autor et al. (2008)
Non-tuition costs	GH (2016)**	IPEDS
Grant aid	GH (2016)**	IPEDS
Student loan rate	GH (2016)**	Statutory
Annual loan limits	GH (2016)**	Statutory
Aggregate loan limits	GH (2016)**	Statutory

*Storesletten, Telmer, and Yaron (2004).
**Web appendix A of Gordon and Hedlund (2016).

Table 4: Independently determined model

Description	Parameter	Value
Preference shock size	σ	8.062
Vacancy posting cost	κ	0.008
Search effort level	ψ	1000.000
Cost parameter	$\mathfrak{c}$	0.001
Quality's elasticity	ϵ	0.525
Quality's weight on investment	α_I	31.805
Quality's weight on enrollment N, public schools	α_N^g	0.133
Quality's weight on enrollment N, private schools	α_N^p	0.088
Quality's weight on inverse parental income Y^{-1}	α_Y	0.012

Table 5: Jointly estimated parameters

private schools, consistent with the quadratic term capturing capacity constraints that are tighter at small schools. The search intensity parameter ψ is very large, which implies students only go to submarkets where they get in with zero search intensity.[6] The vacancy posting cost κ ends up small (as a share of total revenue, total posting costs are on the order of 0.01%) implying there is not much market power. The preference shock σ ends up being large with a standard deviation shock being worth around 12% of lifetime consumption.[7] The quality elasticity parameter ϵ implies more complementarity than Cobb-Douglas.

Because of the large number of targeted moments, it is most convenient to represent the model fit graphically, as shown in figure 1. Each blue dot represents a college type, with the vertical position giving the data moment and the horizontal position showing the model moment. A perfect fit would be represented by all the blue dots falling along the 45-degree line. Figure 1 also labels the worst fitting school type. For instance, the worst fit for net tuition comes from GRS (where, as discussed earlier, G stands for public, R stands for research, and S stands for selective). Similarly, the worst fit for FTE share comes from PTN (which stands for private (P), teaching (T), nonselective (N) schools). Overall, the model does a good job of matching the targeted moments, except for parental income which received a lower weight in the GMM estimation.

4 Results

This section assesses whether the theories from section 1 can jointly explain the large rise in net tuition between 1987 and 2010 while also demonstrating consistency with other empirical trends.[8] Following this joint analysis, we undertake a quantitative decomposition to measure the consequences of each theory individually both for aggregates and across institution types.

4.1 Testing the Theories

The main analysis involves a comparison of equilibrium calibrated to 1987 with the new equilibrium after changing select model parameters to their 2010 values.

Factors Affecting College Supply Baumol's cost disease and changes in non-tuition revenue (chiefly from endowments and direct state support) impact the provision of higher education from the supply side of the market. To measure the impact of Baumol's cost disease, we exogenously increase the relative price p of college inputs (used both for operating costs and quality-enhancing investment) to match the CPI-adjusted rise in the Higher Education Price Index from 1987 to 2010.

[6] We bound the parameter space for ψ at 1000 as once ψ is sufficiently large, larger values have no effect.

[7] The $Y^k(s_Y)$ values are on the order of -1.5 given our normalizations. The standard deviation of the preference shocks is $\pi 6^{-1/2}(1/\sigma)$ or around 0.16. Hence a 1 standard deviation shock is, in consumption equivalent variation terms, around $-1.5/(-1.5 + .16)$ or 12% of lifetime consumption.

[8] We omit the years after this period during which another wave of large policy changes was implemented, e.g. growing prevalence of income-based student loan repayment.

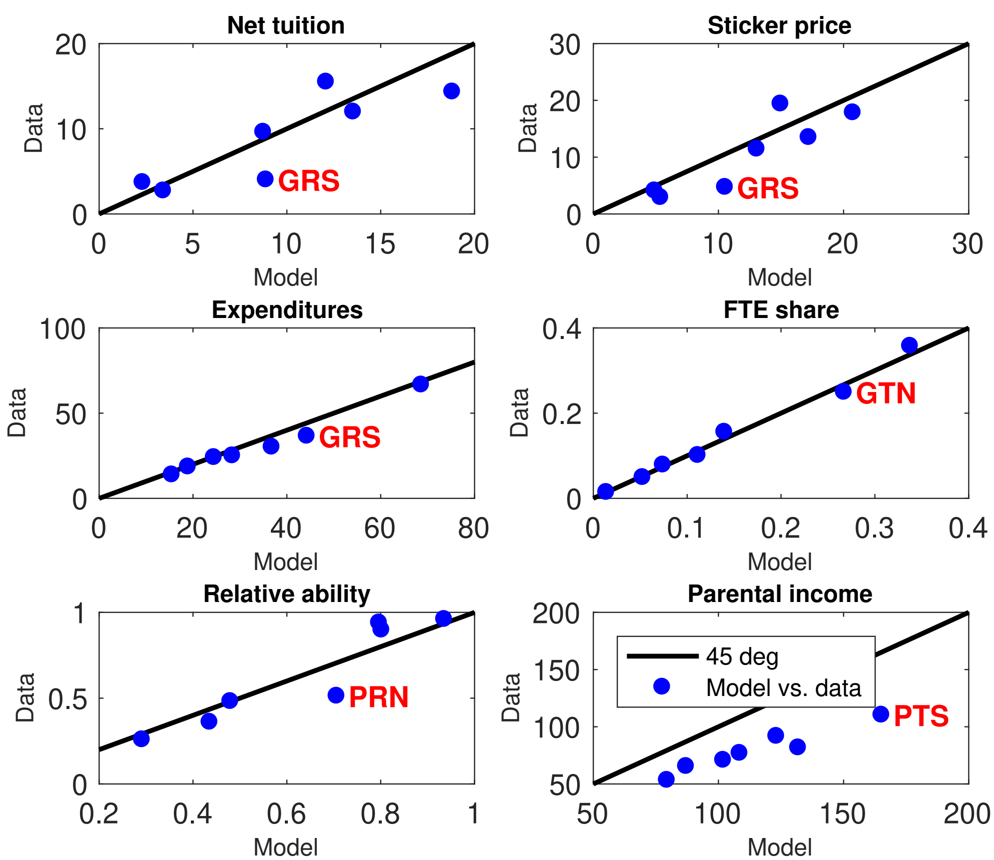

Figure 1: Goodness of fit in calibration

This rose from around 1.08 to 1.30 as can be seen in figure 7 in the appendix. To capture changes in the non-tuition revenue received by each type of college, we adjust $\overline{E}^{g,k}$ and $\overline{E}^{p,k}$ in the model to be consistent with their evolution in the IPEDS data.

Factors Affecting College Demand On the demand side, we incorporate a rise in the return to college enrollment (both because of higher post-graduation labor market returns and lower ex-ante dropout risk), an increase in average parental income due to economic growth, and changes to financial aid, both in the form of loans and grants. Regarding the returns to college, we increase the post-graduation labor market premium λ to match the trends in Autor et al. (2008), and we adjust the exogenous dropout probabilities to reflect the rise in college completion rates over the past two decades.[9] To capture the effects of economic growth on parental income, we adjust $EFC(s_Y)$ to reflect the 44% rise in real GDP per capita from 1987 to 2010. Lastly, to test the Bennett hypothesis—which postulates that colleges seek to capture increases in external financial aid by raising tuition—we carefully model the evolution of the Federal Student Loan Program and the Pell Grant program. Specifically, we incorporate shifts in borrowing limits, interest rates, Pell Grant amounts, and the introduction of supplemental unsubsidized loans in 1993. Lastly, because our focus is on tuition and not other expenses associated with college attendance, we increase the parameter ϕ for non-tuition expenses to reflect the estimates reported by the National Center for Education Statistics (NCES).

4.2 Jointly Accounting for the Trends in Higher Education

Figure 2 provides a visual representation of the model's performance in matching higher education changes between 1987 and 2010. The base of each segment represents the model (horizontal axis) and data (vertical axis) values for 1987, and the "cannonball" circle represents the 2010 values. Thus, a perfect match is represented by a trajectory that lies completely along the 45 degree line. Trajectories parallel to but not coinciding with the 45 degree line indicate that the model successfully matches the change from 1987 to 2010 while missing the initial level. Each college type is represented by a different color, where, as before, G/P stands for government/private, T/R stands for teaching/research, and N/S stands for non-selective/selective. As the model is calibrated using only cross-sectional data, success in matching trends serves as model validation.

Along most dimensions, the model captures quite well the evolution of higher education between 1987 and 2010. For example, both the model and data report that the largest *absolute* rise in net tuition comes from private colleges, and an even larger increase occurs for sticker price tuition. Thus, while private schools are now more expensive on average, they have also made institutional aid more generous to attract the most desirable students. When the comparisons between 1987 and

[9] The college graduate labor market premium data in Autor et al. (2008) stops in 2005, so we extrapolate to 2010 following the procedure in Gordon and Hedlund (2016). We move the college completion rates from their 2002 value (the earliest year for which we have data on this series from IPEDS/DCP) to their 2010 value.

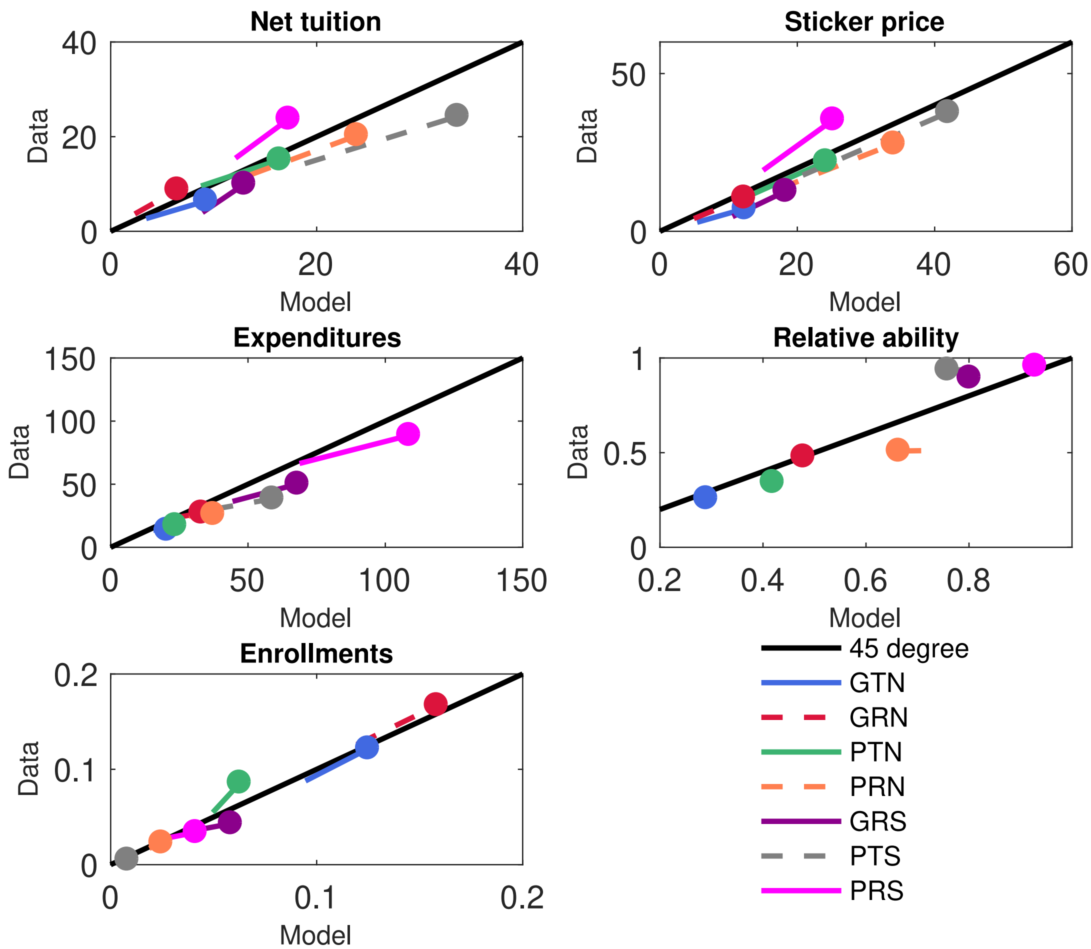

Figure 2: Data vs. model, 1987-2010

2010 are made on a percentage change basis, however, *public* colleges exhibit the most rapid net tuition inflation both in the model and data (though the model underestimates tuition inflation for selective public research institutions). On the spending side, a clear dichotomy emerges by degree of admissions selectivity. Expenditures per student at selective colleges, whether public or private, goes up by 30% or more in the data, whereas it only rises by 15% for public research non-selective schools and remains stagnant or even declines for all other types. The model captures this dichotomy but overestimates the total rise in expenditures.

Regarding enrollment, the model replicates the 13 percentage point rise in the data—from 35% to 48%—along with the fact that two-thirds of the increase accrues to public colleges. Delving into the cross section, figure 3 shows heat maps for equilibrium enrollment in the model for both 1987 and 2010. The distributions of student abilities within each college type remain mostly stable, though some interesting patterns emerge regarding the sorting of students by family resources. Specifically, non-selective institutions increase admissions of higher income students, while selective colleges become more financially accessible because of greater tuition discounting.

While we cannot compare the enrollment patterns explicitly in 1987 and 2010 for want of data, we can use the NLSY97 to look at enrollment patterns around 2000. These are displayed in figure 4 broken down into public verse private and high (i.e., above median) sticker versus low (below median) sticker colleges. Evidently the sorting patterns in the model and data line up very closely. The highest ability and highest income students enroll at high sticker private schools (like PRS). Students widely differing in ability attend public schools, with still some tendency towards higher income (like GRN, GTN, and GRS). The lower price private schools cater mostly to affluent students (like PTS and PTN). Overall, the sorting of students across schools looks very reasonable both in 1987 and 2010 when compared to attendance in the late 1990s and early 2000s.

4.3 What are the Most Important Tuition Drivers?

With the knowledge that the combined effect of all supply-side and demand-side forces is to cause the model to replicate many of the trends in higher education from 1987 to 2010, we turn now to quantifying the relative contribution of each factor in isolation. Table 6 gives the results of this decomposition exercise for enrollment-weighted net tuition. The first column under the net tuition heading shows average equilibrium tuition in the model under several different scenarios, beginning with a value of 5.8 (in thousands of 2010 dollars) from the calibration for 1987. All other values are untargeted.

When only Baumol's cost disease is introduced, tuition rises from 5.8 to 6.2—an increase of \$400. The "Contribution" column scales this change in equilibrium tuition by the total *actual* change of 5.4 ($= 11.2 - 5.8$) observed in the data. Thus, Baumol's cost disease explains approximately $0.4/5.4 = 7\%$ of the total rise in net tuition from 1987 to 2010. Next up is the contribution of higher parental income and the increased expected return to college. Together, these factors inflate net tuition by over \$4,000, which accounts for 76% of the total observed empirical change. Turning to the remaining demand-side factor—the Bennett hypothesis—we find that shifts in financial aid (mostly in the direction of greater generosity) account for 42% of the rise in tuition over this period. The next two rows shows the impact of movements in the non-tuition revenue received by colleges. Given that both sources of endowment revenue have remained flat or gone up since 1987, they have acted to restrain tuition growth, even if only modestly. Put another way, while it is true that state support for public institutions has declined as a *percentage* of college revenue, what matters for equilibrium tuition is the *absolute* level of state support per student. With all forces present, the last line confirms that the model matches (in fact, slightly overestimates by 8%) the overall rise in net tuition across all institutions.

Figure 5 shows that underneath the aggregate decomposition lies substantial heterogeneity by college type.[10] In this figure, each color represents the change induced by one factor in isolation,

[10]Because interaction terms may be important, figure 9 in the appendix repeats the decomposition by starting with

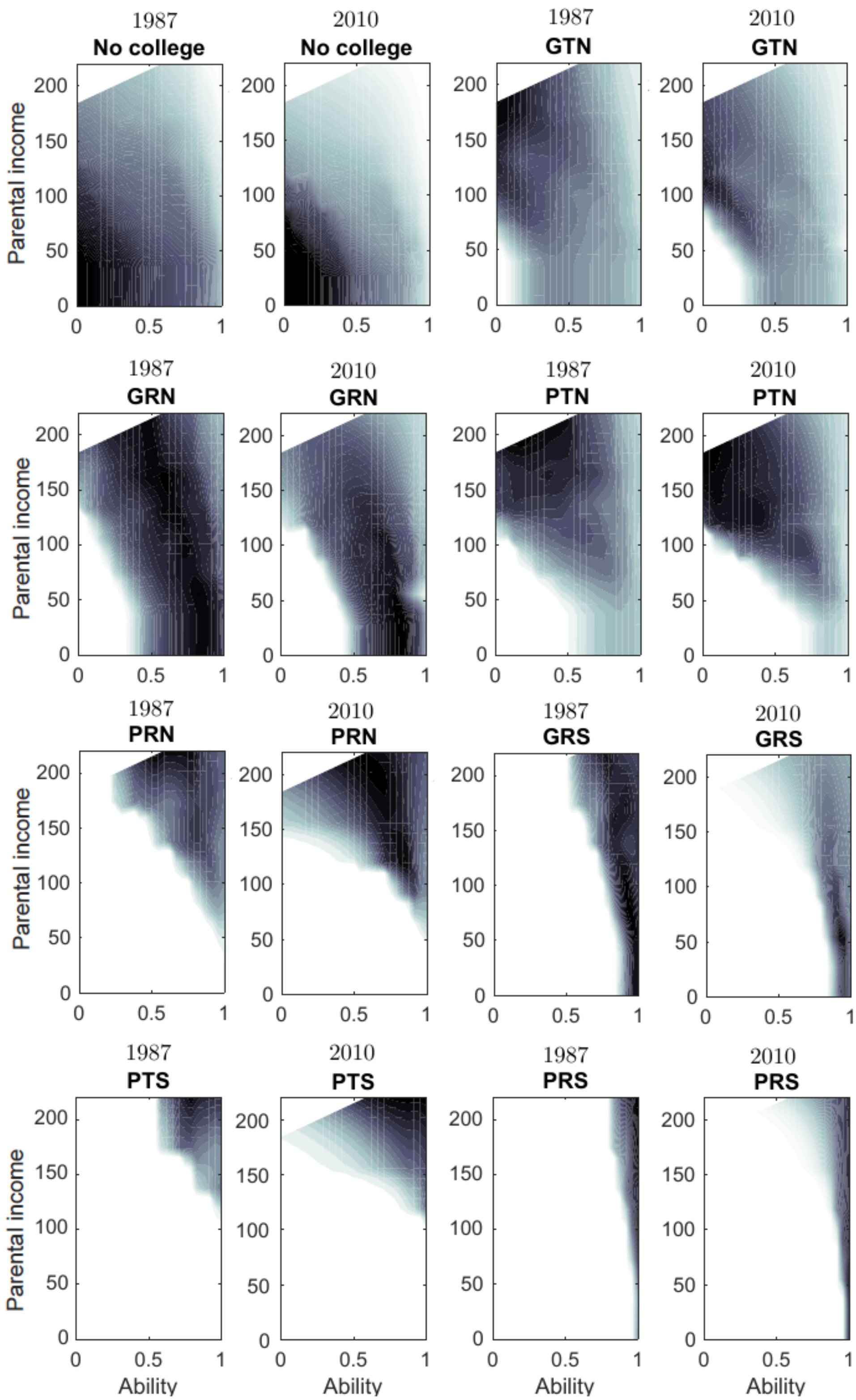

Figure 3: Sorting in 1987 and 2010

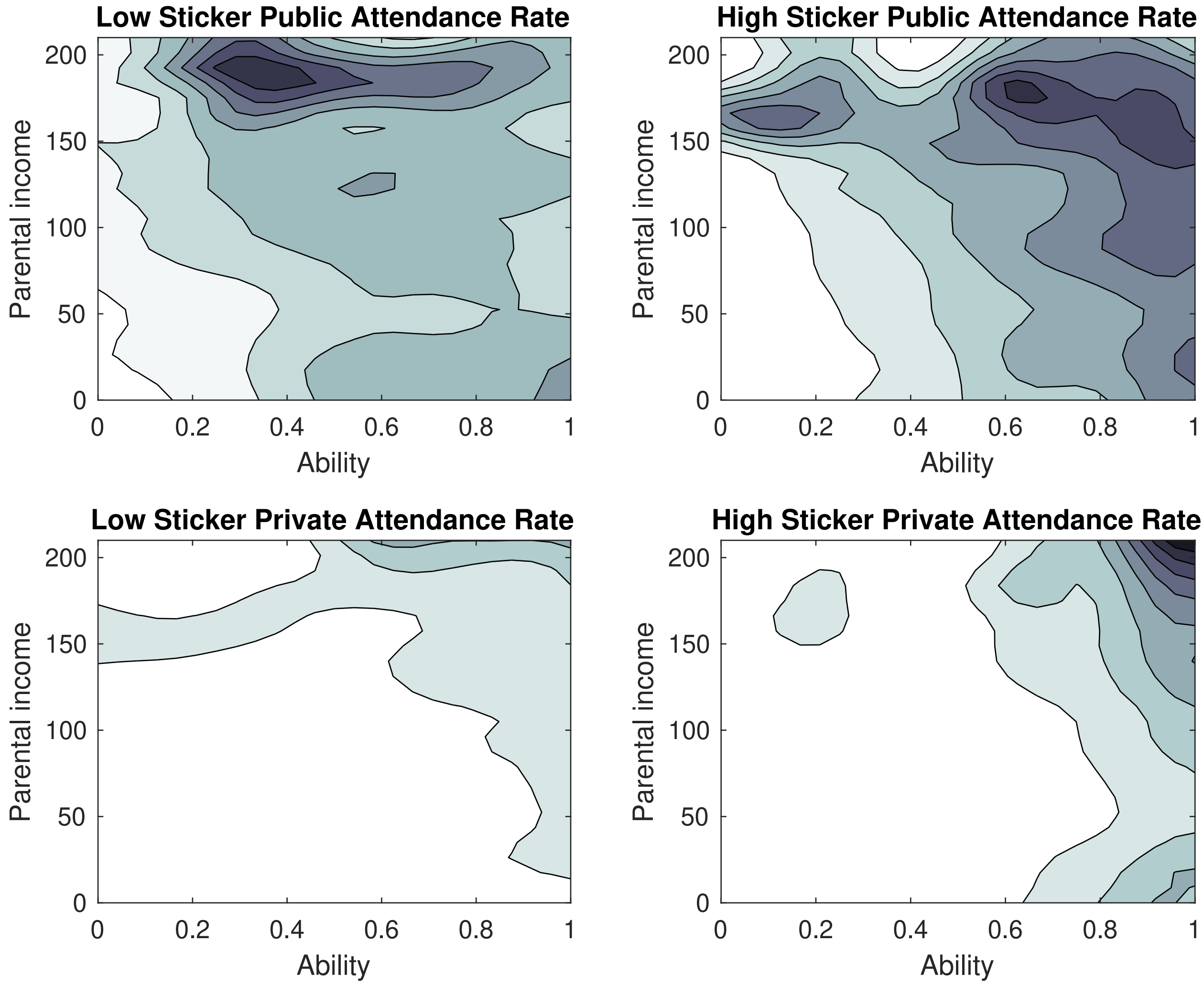

Figure 4: Sorting patterns for attendance in the NLSY97

	Net Tuition		
Experiment	Model	Data	Contribution (%)
1987	5.8	5.8	0
1987+Baumol's Cost Disease (p)	6.2	-	7
1987+Labor Market Returns (δ, λ)	9.9	-	76
1987+Bennett Hypothesis	8.1	-	42
1987+State Support (E^g)	5.5	-	-6
1987+Endowment Revenue (E^p)	4.6	-	-23
2010 (1987+Everything)	11.6	11.2	108

Table 6: The Contribution of Individual Forces to Average Net Tuition

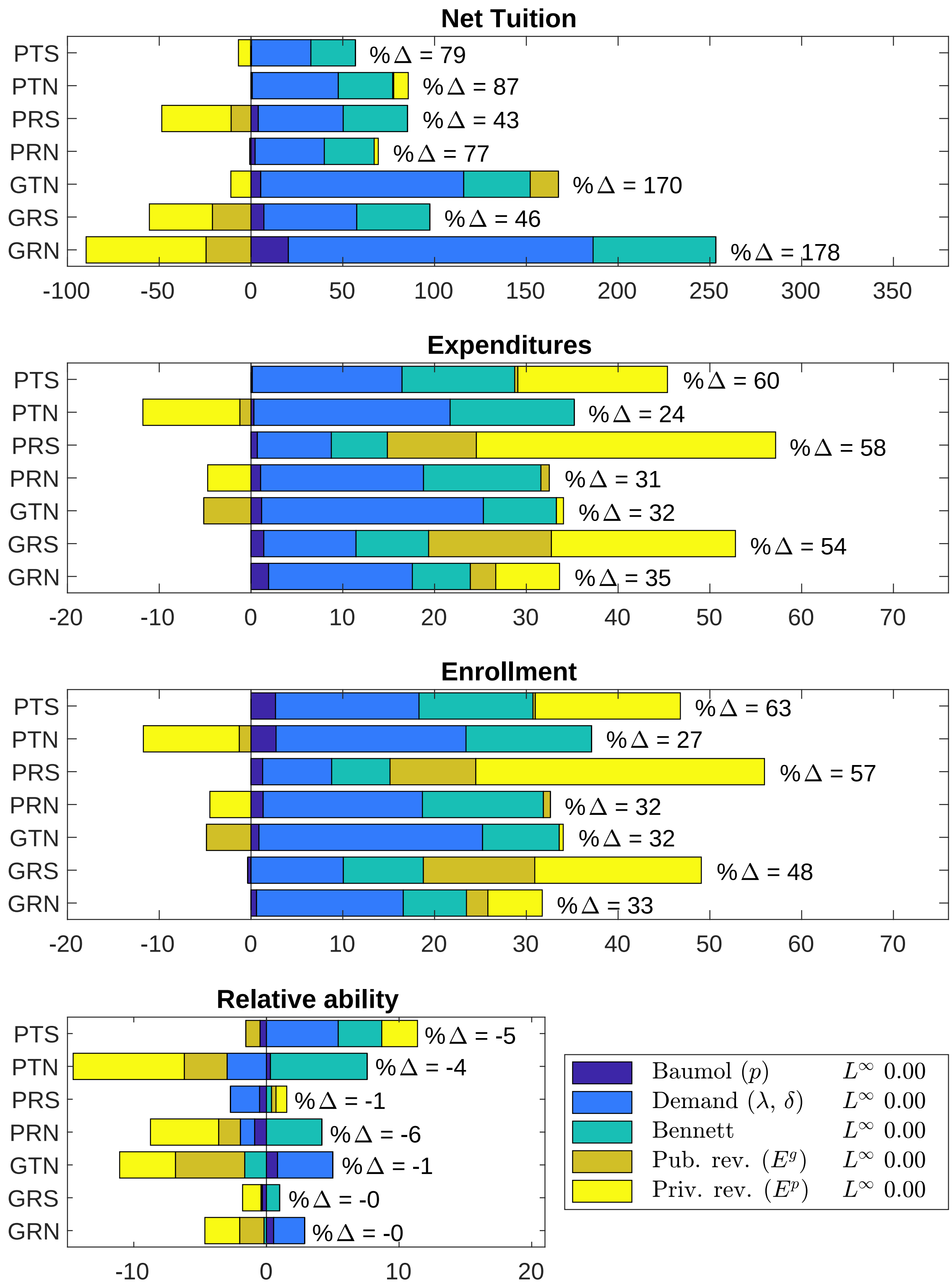

Figure 5: Percent change relative to 1987 from adding one force, else equal

while "%Δ" stands for the combined effect of all forces in the model. For example, equilibrium net tuition increases by 79% for PTS (private teaching selective) colleges and 178% for GRN (government research non-selective) institutions. Continuing this comparison, the Bennett hypothesis and all other demand-side factors contribute almost equally to higher tuition at PTS colleges, whereas the Bennett hypothesis is relatively weaker at GRN colleges. Furthermore, changes in non-tuition revenue actually prevent tuition from going even higher at GRN schools but are not important for explaining tuition inflation at PTS institutions. Figure 5 also reveals that the Bennett hypothesis—far from being a story that only applies to elite colleges—actually has the biggest impact on tuition for GRN schools.

Turning to other variables, it is apparent that higher endowment revenue is a significant driver of both increased expenditures and larger enrollment at selective institutions (whether public or private) but not elsewhere. By contrast, parental income and the rising returns to college are more salient for expenditures and enrollment at non-selective colleges. When it comes to the Bennett hypothesis, figure 5 indicates that expenditures and enrollment are more sensitive to financial aid at private colleges with the key exception of PRS (private research selective) institutions, which tend to have significantly larger revenue streams from their endowments.

Lastly, although average student quality within each institution type remains relatively stable in the model (and data) between 1987 and 2010, individual supply-side and demand-side forces can induce significant shifts in sorting by ability. For example, the "Relative ability" portion of figure 5 shows that, in isolation, higher endowment revenue increases enrollment by drawing students from further down the ability distribution. In short, the average academic ability of the student body at non-selective institutions would decline significantly if the only force at play were the rise in endowment revenue. By contrast, the increased availability of financial aid draws higher ability students into attendance at private colleges while having almost no effect for public colleges.

4.4 Intuition from a special case

To develop some intuition, suppose that q does not depend on X or Y and consider partial equilibrium where the market tightnesses θ are fixed. Then consider a two-stage problem where a college first decides how many students to admit N and second decides which students to admit. Out of the second stage problem—which simply chooses vacancy posting to maximize the average net tuition—comes an implied value $T(N)$ and quality enhancing expenditures per student $I(N) = -C(N)/N + (T(N) + \bar{E}^g + \bar{E}^p)/p$. Under the previous assumptions, $T(N)$ is necessarily decreasing. Now consider how $I(N)$ varies in N for the most attractive school. $I(0)$ will be "negative infinite" because of the fixed cost. As N increases, I first rises because the average total cost is decreasing. However, at some point $I(N)$ attains a peak and begins to decrease because $T(N)$ is decreasing and marginal custodial costs begin to rise. Hence, the graph of $I(N)$ in figure 6 is

the 2010 equilibrium and instead *removing* one force at a time.

typical, to which we have added indifference curves of the quality function such that the optimal choice is initially at the point labeled A.

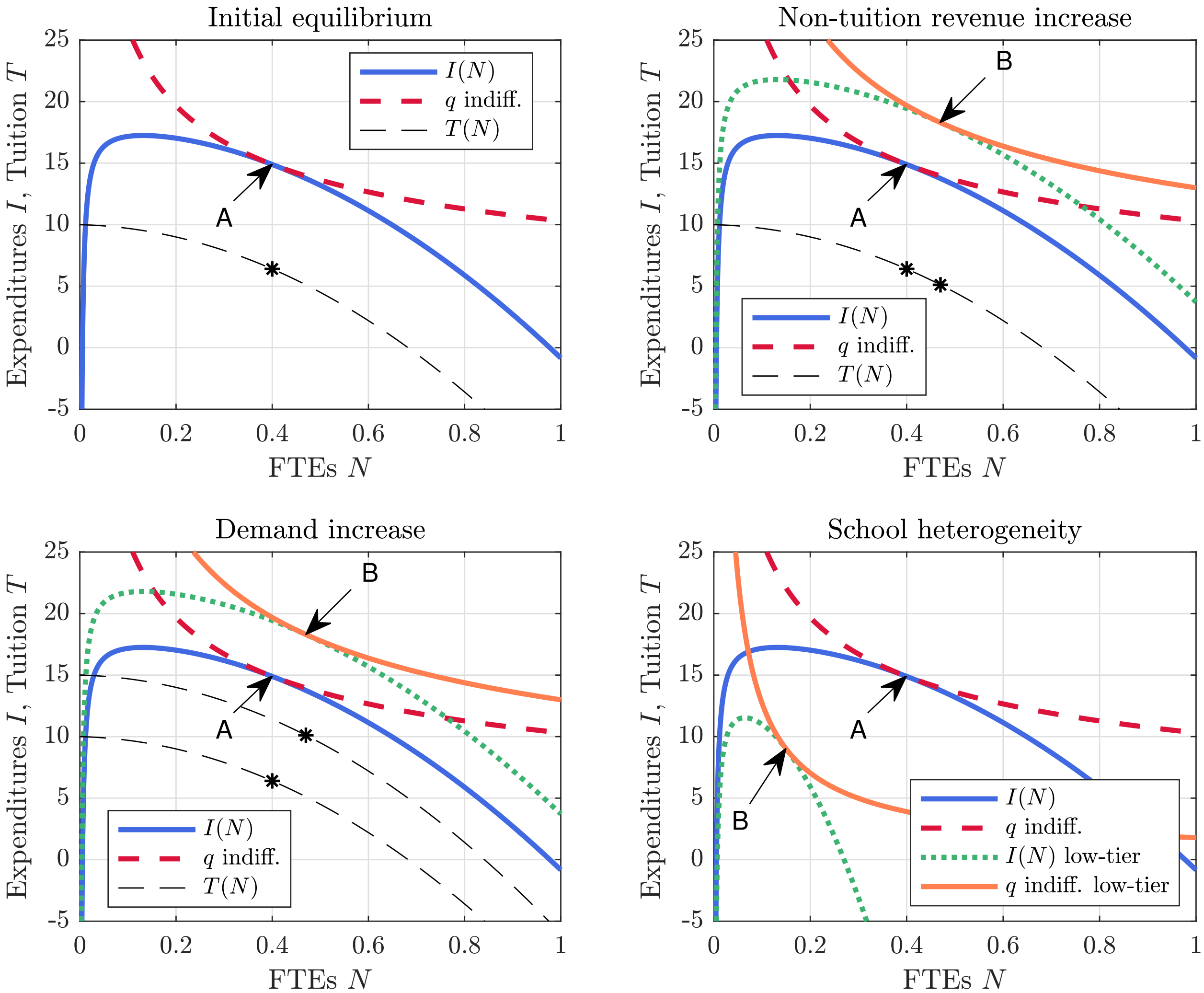

Figure 6: Tuition supply and demand curves in a simple example

Now, consider what happens if $\bar{E}^g$ or $\bar{E}^p$ increases as illustrated in the top right panel. The $I(N)$ curve shifts up uniformly to the green-dotted line. This creates a positive income effect that moves the college from point A to B, increasing both N^* and I^* (using * to denote an optimal choice). Note that because $T(N)$ is decreasing, this means net tuition T^* must fall.

How does the prediction of increases in non-tuition revenue causing increases in enrollment and expenditures and falls in net tuition accord with the quantitative model? Table 7 shows it accords perfectly for all seven school types. In particular, whether the schools had increases or decreases in $\bar{E}^g$ (as in the top panel) or $\bar{E}^p$ (as in the middle panel), the predicted change from the simple model is met with same-signed changes in the quantitative model.

		Changes in public support E^g					
		Simple intuition			Quantitative model		
College type	$\bar{E}^g$ change	T	pI	N	T	Expend.	N
Private, Research, Non-selective	+0.3	↓	↑	↑	−0.1	+0.3	+0.8
Private, Research, Selective	+8.0	↓	↑	↑	−1.3	+6.7	+9.3
Private, Teaching, Non-selective	−0.3	↑	↓	↓	+0.0	−0.2	−1.3
Private, Teaching, Selective	+0.2	↓	↑	↑	−0.0	+0.1	+0.2
Public, Research, Non-selective	+1.2	↓	↑	↑	−0.6	+0.7	+2.3
Public, Research, Selective	+7.8	↓	↑	↑	−1.9	+5.9	+12.1
Public, Teaching, Non-selective	−1.3	↑	↓	↓	+0.5	−0.8	−4.9
		Changes in private support E^p					
		Simple intuition			Quantitative model		
College type	$\bar{E}^p$ change	T	pI	N	T	Expend.	N
Private, Research, Non-selective	−1.6	↑	↓	↓	+0.3	−1.3	−4.5
Private, Research, Selective	+26.9	↓	↑	↑	−4.6	+22.4	+31.5
Private, Teaching, Non-selective	−2.7	↑	↓	↓	+0.7	−2.0	−10.4
Private, Teaching, Selective	+7.2	↓	↑	↑	−1.2	+6.0	+15.8
Public, Research, Non-selective	+3.2	↓	↑	↑	−1.5	+1.7	+5.9
Public, Research, Selective	+11.9	↓	↑	↑	−3.1	+8.9	+18.1
Public, Teaching, Non-selective	+0.5	↓	↑	↑	−0.4	+0.1	+0.4
		Bennet hypothesis changes					
		Simple intuition			Quantitative model		
College type		T	pI	N	T	Expend.	N
Private, Research, Non-selective		↑	↑	↑	+3.7	+3.6	+13.2
Private, Research, Selective		↑	↑	↑	+4.2	+4.2	+6.4
Private, Teaching, Non-selective		↑	↑	↑	+2.6	+2.6	+13.7
Private, Teaching, Selective		↑	↑	↑	+4.6	+4.5	+12.4
Public, Research, Non-selective		↑	↑	↑	+1.6	+1.6	+6.9
Public, Research, Selective		↑	↑	↑	+3.5	+3.5	+8.7
Public, Teaching, Non-selective		↑	↑	↑	+1.2	+1.2	+8.4

Note: financial variables are in thousands of 2010 dollars; enrollments are percent change from 1987 values.

Table 7: Predicted changes based on simple intuition and actual model implied changes

When it comes to a demand increase, the effects are similar in that the $I(N)$ curve, which creates a positive income effect. However, depending on precisely how $T(N)$ changes, there may be a substitution effect as well. Supposing the demand change causes $T(N)$ to increase uniformly, say by λ, again N^* and I^* will increase. But note that while I^* increases, it increases by less than λ. Consequently, T^* goes up, but by less than λ so that rents are not fully extracted by the college.

The bottom panel of table 7 compares the quantitative model predictions for the Bennet hypothesis changes with the intuition from the simple model. (Because the non-policy induced demand changes are similar to Bennet, we omit them.) Again, all of the signs are as predicted.

Turning to the last experiment, Baumol cost disease creates a negative income effect in that $I(N)$ decreases, but it also creates a substitution effect in that $I(N)$ decreases proportionally more where the average total custodial cost is smaller or where $T(N)/p$ decreases the most. Because the custodial costs are calibrated to be quite small, the $T(N)/p$ effect tends to dominate, which make $I(N)$ curve flatter in addition to shifting it down. The substitution effect tends to increase N and lower I, while the income effect tends to decrease both. The end result is that I^* should decrease, with ambiguous effects on N^*, pI^*, and $T^* = T(N^*)$. Hence, the small and sometimes ambiguous effects (such as for enrollment) that Baumol cost disease produces in the quantitative model can also be rationalized by the simple model.

Why does the intuition from a partial equilibrium formulation give such accurate predictions? In part because the college market is extremely segmented. The highest tier schools essentially get the first pick of students, followed by the second highest tier, and so on. If a lower-tier school wanted to enroll the highest ability students, it would need to spend inordinate amounts of money—compensating the student for the net present value of income gains associated with going to an elite school—in the form of negative net tuition perhaps in excess of negative one million dollars. Effectively, then, $T(\cdot)$ is mildly decreasing until it starts to fall drastically at some point (except at elite schools). This makes the $I(N)$ curve peaked in a range of N, as illustrated in the bottom right panel of figure 6, that is mostly independent of what other schools are doing.

While we have worked through the results for where q does not depend on X or Y, something similar can be done if q does not depend on N or Y. In particular, one can setup a two-stage problem where X is chosen first followed by implementing it in the second stage via admission of students. However, the second stage problem no longer reduces to just maximize average net tuition but instead involves complicated tradeoffs. Still, the second stage delivers an expenditure curve $I(X)$ and tuition curve $T(X)$. Broadly speaking, the curves will be humpshaped, looking like in figure 6 where N on the horizontal axis is replaced by X.[11] By the same logic as above, increases in E^g, E^p and demand will drive up I^* and X^*. Why then does average ability change little or even

[11] In particular, because of fixed costs, $I(X)$ goes to negative infinity as X goes to 1. On the other hand, at $X = 1/2$ (which implies everyone is admitted, $N = 1$), $I(X)$ also tends to be lower than at larger X because low ability students have greater drop out risk and smaller earnings premia which drives down the tuition they are willing to pay. Additionally, at these larger N, quadratic costs of C can be large. Hence, $I(X)$ tends to be humpshaped.

go in the opposite direction depending on the experiment? In large part it is because of the extreme market segmentation mentioned above. This segmentation makes the humps very steep and puts I^* and X^* close (but just to the right) of the peak. Consequently, when a positive income effect drives up the $I(X)$ curve, increasing X^* by any substantial amount is very costly, and it is cheaper (in quality terms) to increase I^* a lot and only increase X^* a little. Adding the dependence of q on N, then, can easily overcome this tendency to increase X^* slightly with a desire to increase N^* instead.

4.5 What Does a Taste for Enrollments Mean?

The previous section showed that a simplified setup where q depends only on I and N accurately predicts how tuition, expenditures, and enrollment change in response to non-tuition revenue and demand changes. Before closing, it is worthwhile to interpret what a taste for enrollments actually means. For this, consider the Cobb-Douglas case of $\epsilon = 1$, and maintain the assumption that q does not depend on X or Y. Then $q = I^{\alpha_I} N^{\alpha_N}$, which can be normalized to $q = I^{\alpha_I} N^{1-\alpha_I}$. If $\alpha_I = 1$, then the indifference curves in figure 6 are horizontal. In this case, the optimal choice has $I'(N) = 0$, which implies

$$T'(N) = p\frac{dC(N)/N}{dN}.$$

Hence, the college admits student up to the point where the marginal *average* tuition revenue equals the marginal average custodial cost. Importantly, note that non-tuition revenue changes in this case have *no* effect on tuition or enrollment (but rather show up as one-for-one increases in expenditures). From a price equals marginal cost perspective, this is quite a surprising result, which highlights the difference between marginal cost (which here has essentially no relation with tuition) and effective marginal cost (which has a strong, in fact perfect for $\kappa = 0$, relationship). This prediction stands in contrast to a large empirical literature that finds a negative relationship between non-tuition revenue (usually state support) and tuition. It also means that increases in demand do not necessarily increase enrollments. For instance, absent student heterogeneity, $T'(N) = 0$ and hence enrollments are entirely determined by the minimum of the average cost function. Again, this seems at odds with the empirical literature which finds enrollment changes due to, e.g., changes in public support.

On the other hand, now suppose $\alpha_I = 1/2$ so that college preferences can be represented by $q = (IN)^{1/2}$ or, equivalently, $q = IN$. In this case, colleges maximize total quality-enhancing expenditures instead of average expenditures. The quality indifference curve slope, which equals $-I/N$ in this case, must be equated to $I'(N)$ as in figure 6. One can then show

$$T(N) = \frac{1}{1+\varepsilon_{T,N}}\left(p\frac{C(N)}{N}(1+\varepsilon_{\frac{C}{N},N}) - \bar{E}^g - \bar{E}^p\right),$$

where $\varepsilon_{f,x}$ is the elasticity of f with respect to x.[12] In this case, average net tuition must equal the average custodial cost, adjusted by the elasticity $\varepsilon_{C/N,N}$, less non-tuition revenue plus a markup $\frac{1}{1+\varepsilon_{T,N}} - 1 \geq 0$. (And this markup is exactly what comes out of a typical monopolist or monopolistic competition type problem.) Now changes in marginal costs, such as changes in marginal non-tuition revenue, play a key role in determining the equilibrium level of net tuition. This specification has the potential to be consistent with the empirical literature finding that cuts in state support increase tuition. It also implies increases in demand that drive up average net tuition T uniformly increase enrollments (as in the bottom left panel of figure 6), again potentially consistent with the empirical literature.

Consequently, the taste for enrollments determines what price setting looks like. In the Epple et al. (2006) framework where q does not depend on N, the equilibrium relates marginal average tuition with marginal average cost. In contrast, with an equally weighted taste for N and I, the equilibrium looks more like a conventional profit-maximization framework where tuition prices are equated with marginal costs—even though schools are non-profits. Our calibrated model finds a middle-ground that matches tuition, expenditures, and enrollment well both cross-sectionally and longitudinally.

5 Conclusion

Many explanations have been proffered for the rise in college tuition over the past few decades, ranging from Baumol's cost disease to labor market shifts to financial aid changes, just to name a few. Ample empirical evidence points to the *existence* of all these channels—for example, the labor market premium for college graduates has clearly gone up—but what is unclear absent a structural analysis is the extent to which each one is responsible for tuition inflation. The analysis in this paper suggests that, collectively, these existing hypothesis are sufficient to explain the path that U.S. higher education has taken since at least the late 1980s. In other words, the analysis in this paper does not point to any urgent need for an entirely new theory of tuition inflation. More importantly, the framework in this paper also sheds light on which of these factors matters the most, and it turns out the answer varies to some extent by institution type. In the aggregate, demand-side forces—notably, changes in the return to college and policy-induced increases in financial aid—are the primary drivers of average tuition growth. However, in the cross-section, the return to college matters much more for tuition at public institutions than at private colleges, while increases in endowment income have actually restrained tuition growth, but only at research-intensive colleges.

Going forward, many fruitful extensions emerge for future research. First, whereas this paper

[12] In particular, $-I(N)/N = -d(C(N)/N)/dN + T'(N)/p$ or $pI(N) + T'(N)N = pNd(C(N)/N)/dN$. Substituting in the $I(N)$ curve, one has $-pC(N)/N + T(N) + \bar{E}^g + \bar{E}^p + T'(N)N = pd(C(N)/N)/dN$ or $T(N) + T'(N)N = p(C(N)/N + Nd(C(N)/N)/dN) - \bar{E}^g - \bar{E}^p$. Using $\varepsilon_{f,x} = d\log f(x)/d\log x = f'(x)x/f(x)$, one then has $T(N)(1 + \varepsilon_{T,N}) = p\frac{C(N)}{N}(1 + \varepsilon_{\frac{C}{N},N}) - \bar{E}^g - \bar{E}^p$.

studies the long-run determinants of college tuition at a national level, further work is warranted to understand the short-run dynamics of tuition at an even more disaggregated level along with the impact of different forms of state funding. In addition, numerous reforms have either been recently implemented or proposed to increase college access and reduce the burden of student loan debt, ranging from a greater array of income-based repayment options to free public college. Further study is needed to fully understand the potential impacts of these reforms both on higher education outcomes (e.g. tuition, enrollment, completion, etc.) and on the broader economy.

References

B. Abbott, G. Gallipoli, C. Meghir, and G. Violante. Education policy and intergenerational transfers in equilibrium. Mimeo, 2016.

R. J. Andrews, J. Li, and M. F. Lovenheim. Quantile treatment effects of college quality on earnings: Evidence from administrative data in texas. Mimeo, 2012.

R. B. Archibald and D. H. Feldman. Explaining increases in higher education costs. *The Journal of Higher Education*, 79(3):268–295, 2008.

K. Athreya and J. Eberly. Risk, the college premium, and aggregate human capital investment. Mimeo, 2016.

D. H. Autor, L. F. Katz, and M. S. Kearney. Trends in U.S. wage inequality: Revising the revisionists. *The Review of Economics and Statistics*, 90(2):300–323, May 2008.

W. J. Baumol. Macroeconomics of unbalanced growth: The anatomy of urban crisis. *The American Economic Review*, 57(3):415–426, 1967.

W. J. Baumol and W. G. Bowen. *Performing Arts: The Economic Dilemma; a Study of Problems Common to Theater, Opera, Music, and Dance.* Twentieth Century Fund, 1966.

P. Belley and L. Lochner. The changing role of family income and ability in determining educational achievement. *Journal of Human Capital*, 1(1):37–89, 2007.

D. Card and T. Lemieux. Can falling supply explain the rising return to college for younger men? *Quarterly Journal of Economics*, 116:705–746, 2001.

S. R. Cellini and C. Goldin. Does federal aid raise tuition? new evidence on for-profit colleges. *American Economic Journal: Economic Policy*, 6:174–206, 2014.

R. Chakrabarty, M. Mabutas, and B. Zafar. Soaring tuitions: Are public funding cuts to blame? http://libertystreeteconomics.newyorkfed.org/2012/09/

soaring-tuitions-are-public-funding-cuts-to-blame.html#.VeDDrPlVhBc, 2012. Accessed: 2015-08-28.

S. Chatterjee and F. Ionescu. Insuring student loans against the risk of college failure. *Quantitative Economics*, 3(3):393–420, 2012.

A. F. Cunningham, J. V. Wellman, M. E. Clinedinst, J. P. Merisotis, and C. D. Carroll. Study of college costs and prices, 1988 - 89 to 1997 - 98, volume 1. Report NCES 2002-157, National Center for Education Statistics, 2001a.

A. F. Cunningham, J. V. Wellman, M. E. Clinedinst, J. P. Merisotis, and C. D. Carroll. Study of college costs and prices, 1988 - 89 to 1997 - 98, volume 2: Commissioned papers. Report NCES 2002-157, National Center for Education Statistics, 2001b.

D. Epple, R. Romano, and H. Sieg. Admission, tuition, and financial aid policies in the market for higher education. *Econometrica*, 74(4):885–928, 2006.

D. Epple, R. Romano, S. Sarpca, and H. Sieg. The U.S. market for higher education: A general equilibrium analysis of state and private colleges and public funding policies. Mimeo, 2013.

I. Fillmore. Price discrimination and public policy in the U.S. college market. Mimeo, 2016.

A. B. Frederick, S. J. Schmidt, and L. S. Davis. Federal policies, state responses, and community college outcomes: Testing an augmented bennett hypothesis. *Economics of Education Review*, 31(6):908–917, 2012.

C. Fu. Equilibrium tuition, applications, admissions, and enrollment in the college market. *Journal of Political Economy*, 122(2):225–281, 2014.

C. Garriga and M. P. Keightley. A general equilibrium theory of college with education subsidies, in-school labor supply, and borrowing constraints. Mimeo, 2010.

C. Goldin and L. F. Katz. The race between education and technology: The evolution of u.s. educational wage differentials, 1890 to 2005. NBER Working Paper, 2007.

G. Gordon and A. Hedlund. Accounting for the rise in college tuition. Working Paper 21967, NBER, 2016.

D. E. Heller. The effects of tuition and state financial aid on public college enrollment. *The Review of Higher Education*, 23(1):65–89, 1999.

L. Hendricks and O. Leukhina. The return to college: Selection bias and dropout risk. Mimeo, 2016.

M. Hoekstra. The effect of attending the flagship state university on earnings. *The Review of Economics and Statistics*, 91(4):717–724, 2009.

F. Ionescu. Risky human capital and alternative bankruptcy regimes for student loans. *Journal of Human Capital*, 5(2):153–206, 2011.

J. B. Jones and F. Yang. Skill-biased technological change and the cost of higher education. *Journal of Labor Economics*, 34(3), 2016.

L. F. Katz and K. M. Murphy. Changes in relative wages, 1963 - 87: Supply and demand factors. *Quarterly Journal of Economics*, 107:35–78, 1992.

M. P. Keane and K. I. Wolpin. The effect of parental transfers and borrowing constraints on educational attainment. *International Economic Review*, 42(4):1051–1103, 2001.

R. K. Koshal and M. Koshal. State appropriation and higher education tuition: What is the relationship? *Education Economics*, 8(1), 2000.

L. J. Lochner and A. Monge-Naranjo. The nature of credit constraints and human capital. *American Economic Review*, 101(6):2487–2529, 2011.

B. T. Long. How do financial aid policies affect colleges? the institutional impact of the georgia hope scholarship. *Journal of Human Resources*, 39(4):1045–1066, 2004a.

B. T. Long. The impact of federal tax credits for higher education expenses. In C. M. Hoxby, editor, *College Choices: The Economics of Where to Go, When to Go, and How to Pay for It*, pages 101 – 168. University of Chicago Press, 2004b.

B. T. Long. College tuition pricing and federal financial aid: Is there a connection? Technical report, Testimony before the U.S. Senate Committee on Finance, 2006.

D. O. Lucca, T. Nadauld, and K. Shen. Credit supply and the rise in college tuition: Evidence from expansion in federal student aid programs. Mimeo, 2015.

M. S. McPherson and M. O. Shapiro. *Keeping College Affordable: Government and Educational Opportunity*. Brookings Institution Press, 1991.

M. J. Rizzo and R. G. Ehrenberg. Resident and nonresident tuition and enrollment at flagship state universities. In C. M. Hoxby, editor, *College Choices: The Economics of Where to Go, When to Go, and How to Pay for It*, pages 303 – 353. University of Chicago Press, 2004.

L. D. Singell, Jr. and J. A. Stone. For whom the Pell tolls: The response of university tuition to federal grants-in-aid. *Economics of Education Review*, 26:285–295, 2007.

K. Storesletten, C. Telmer, and A. Yaron. Cyclical dynamics in idiosyncratic labor market risk. *Journal of Political Economy*, 112(3):695–717, 2004.

M. A. Titus, S. Simone, and A. Gupta. Investigating state appropriations and net tuition revenue for public higher education: A vector error correction modeling approach. Working paper, Institute for Higher Education Law and Governance Institute Monograph Series, 2010.

L. J. Turner. The road to Pell is paved with good intentions: The economic incidence of federal student grant aid. Mimeo, 2013.

N. Turner. Who benefits from student aid: The economic incidence of tax-based aid. *Economics of Education Review*, 31(4):463–481, 2012.

A Detailed Data Sources and Description

A.1 IPEDS/DCP data

Balance sheet item	Model equivalent	DCP variable
Total Expenditures	$pI + pC$	eandg01_sum + auxother_cost
E&G spending**	Part of $pI + pC$	eandg01_sum
E&R spending	pI	
Instruction	Part of $pI + pC$	instruction01
Research	Part of $pI + pC$	research01
Public service	Part of $pI + pC$	pubserv01
Academic support	Part of $pI + pC$	acadsupp01
Student services	Part of $pI + pC$	studserv01
Institutional support	Part of $pI + pC$	instsupp01
Plant operation / maintenance	Part of $pI + pC$	opermain01
Scholarships and fellowships	Part of $pI + pC$	grants01,grants01_fasb
Auxiliary and "other" spending	Part of $pI + pC$	auxother_cost
Total Revenue	$T + E^g$+part of E^p	tot_rev_w_auxother_sum
Net tuition	T	nettuition01 − grants01
Directly from student	Out of pocket for T	net_student_tuition
From government	Students apply to T	nettuition01 - net_student_tuition
Pell	Students apply to T	grant01
Local, state, and other federal	Students apply to T	nettuition01 - net_student_tuition - grant01
Approp., contracts, excluding Pell	E^g	state_local_app + state_local_grant_contract + federal10_net_pell*
Auxiliary and "other" revenue	Part of E^p	auxother_rev
Endowment revenue, gifts	Part of E^p	priv_invest_endow
Gross operating margin (rev. - exp.)	Part of E^p	tot_rev_w_auxother_sum - eandg01_sum - auxother_cost

Note: E^p is the sum of "Part of E^p" and pC is the sum of "Part of pC."
*Computed as a residual: tot_rev_w_auxother_sum - nettuition01 - priv_invest_endow - auxother_rev
**A component of E&G spending is expenditures on scholarships and fellowships with the definition varying over time. Because of reporting changes, we cannot subtract this off in a consistent way, so we leave it. Post 1997 for FASB institutions and 2002 for GASB it should reflect expenses from administering scholarships and fellowships.

Table 8: Detailed college balance sheet data with DCP variable names

A.1.1 Trends

Figure 7 displays the time profile of the higher education price index p and each major spending and revenue category averaged across institutions using full-time equivalent (FTE) enrollment weights. Notably, net tuition, expenditures (operating costs plus investment), and the higher education price index demonstrate a clear upward trend. By contrast, the private component of non-tuition revenue has increased only modestly, while public non-tuition revenue has remained almost completely flat.

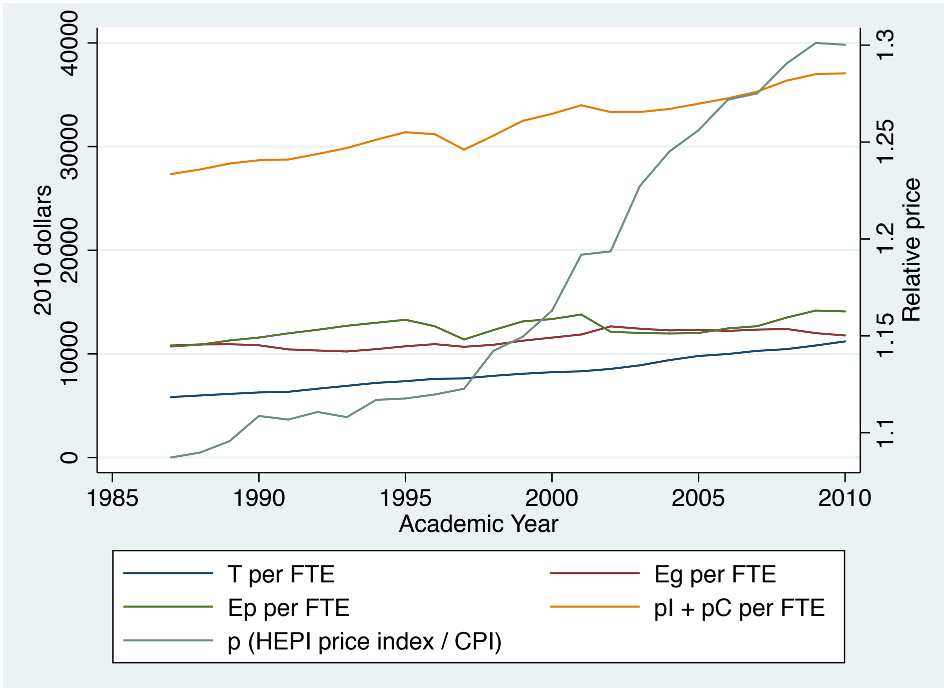

Figure 7: Trends in College Spending and Revenue

However, the average obscures wide variation in these patterns across college types. Delving deeper, figure 8 breaks down these trends by colleges' degree of selectivity, research intensity, and status as either public or private. In absolute terms, net tuition has increased the most at selective private institutions, with public research institutions (regardless of selectivity) and non-selective private institutions not far behind. Non-selective public teaching colleges have increased tuition by the least amount. However, when examined in *percentage* terms, the rate of tuition *inflation* has been highest at public institutions where attendance used to be more affordable. Table 9 in Appendix A reports additional summary statistics by school type.

A.1.2 Summary statistics by school type

	1987 financial measures and shares				
School type	T	Expend	E^g	E^p	FTE share
Public, Teaching, Non-selective	2.7	14.9	9.2	3.0	0.25
Public, Research, Non-selective	3.7	25.9	13.7	8.5	0.36
Private, Teaching, Non-selective	9.6	19.9	1.4	9.0	0.15
Private, Research, Non-selective	11.9	27.0	3.8	11.3	0.05
Public, Research, Selective	4.0	39.5	21.3	14.3	0.10
Private, Teaching, Selective	14.3	32.6	1.0	17.3	0.01
Private, Research, Selective	15.5	72.2	14.1	42.7	0.08

	2010 financial measures and shares				
School type	T	Expend	E^g	E^p	FTE share
Public, Teaching, Non-selective	6.4	17.8	7.9	3.5	0.25
Public, Research, Non-selective	8.8	35.5	14.9	11.8	0.35
Private, Teaching, Non-selective	15.1	22.5	1.1	6.3	0.18
Private, Research, Non-selective	20.3	34.0	4.1	9.6	0.05
Public, Research, Selective	10.0	65.3	29.1	26.2	0.09
Private, Teaching, Selective	24.3	50.0	1.2	24.5	0.01
Private, Research, Selective	23.7	115.4	22.0	69.6	0.07

	Additional 2010 measures				
School type	Rel. premium	Comp. rate	P. inc.	Rel. X	# schools
Public, Teaching, Non-selective	0.83	0.47	53	0.26	242
Public, Research, Non-selective	0.95	0.58	65	0.48	129
Private, Teaching, Non-selective	0.89	0.58	71	0.34	639
Private, Research, Non-selective	1.08	0.65	81	0.51	50
Public, Research, Selective	1.19	0.73	77	0.90	20
Private, Teaching, Selective	1.29	0.89	110	0.94	36
Private, Research, Selective	1.63	0.87	91	0.96	42

Note: Monetary values are in 2010 dollars deflated using the CPI.

Table 9: Data measures in 1987 and 2010

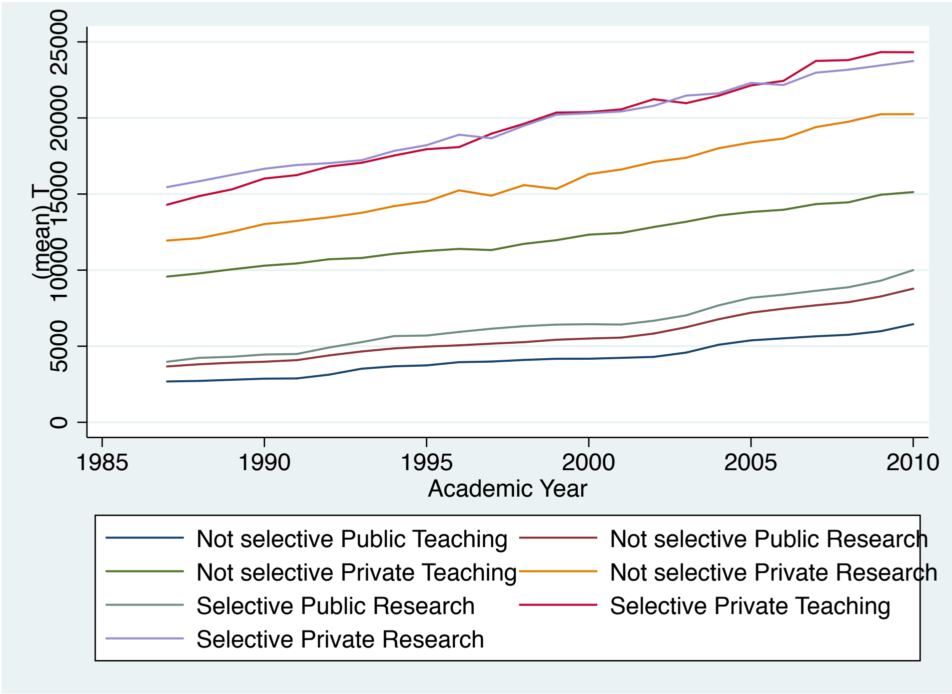

Figure 8: Net Tuition By College Type

A.2 NLSY97 Data

	(1) Mean	(2) Mean	(3) Mean	(4) Mean	(5) Mean	(6) Mean
Enrolled	0.428	1	1	0.460	1	1
Graduated	0.300	0.714	1	0.325	0.719	1
Years college	1.628	3.867	4.488	1.779	3.919	4.535
Sticker tuition estimate (real)		14.10	16.08		14.33	16.29
Net tuition estimate (real)		8.792	10.16		8.933	10.22
Family transfers (real)		3.657	4.588		3.641	4.481
Grants (school or gov.) (real)		5.311	5.920		5.401	6.069
Loans (private or gov.) (real)		3.197	3.515		3.301	3.647
Took out a loan		0.560	0.604		0.587	0.634
Ability				0.506	0.677	0.709
Household income in 1996 (real)				73.37	92.71	99.10
EFC (real)				10.86	15.48	17.04
Observations	6536	2616	1868	4102	1778	1278

Note: All estimates are means from the NLSY97 data, unweighted using the cross-section sample.
In the full sample, 21.1% are missing ASVAB scores; 26.6% are missing household income;
and 40.1% are missing ASVAB or household income.
Enrollment is defined as any enrollment in a 4-year nonprofit college while working towards a BA/BS or MA.
Sticker and net tuition are approximate and computed by adding aid from various sources.
All financial variables are in thousands of 2010 dollars.

Table 10: NLSY97 data summary

Variable name	% not missing	Mean	Median	Min	Max
pubid	100.0	3442.85	3380.50	1.00	9022.00
w	100.0	2506.64	2775.34	760.71	15761.82
crosssect	100.0	1.00	1.00	1.00	1.00
abil	80.4	0.50	0.50	0.00	1.00
hhinc	75.4	72263.25	59781.81	-66872.21	342666.56
pinc	62.6	77135.31	66038.05	-73684.56	729895.59
efc	75.4	10715.05	5787.59	0.00	90821.45
age0	100.0	13.98	14.00	12.00	16.00
avgeqinc	86.6	40955.92	33729.95	0.00	309727.68
totyearsAttendedFTE	99.2	1.64	0.00	0.00	13.75
everWorkForBABS	99.2	0.44	0.00	0.00	1.00
everGrad	96.9	0.30	0.00	0.00	1.00
everRecvBABS	96.9	0.30	0.00	0.00	1.00
sticker	40.9	14257.51	10212.82	0.00	147419.14
net	40.9	8907.42	6024.68	0.00	129767.50
grant	42.8	5278.64	2065.08	0.00	131522.78
famtran	42.5	3613.19	345.43	0.00	129767.50
loans	43.2	3194.87	994.26	0.00	70337.52

Table 11: NLSY97 data summary

B Additional Empirical and Model Results

B.1 Tuition Discounting

Table 12 provides some empirical evidence that colleges discount tuition based on both ability and parental income. Appendix B reports similar results broken out by ability decile, as well as additional regressors of net tuition or sticker tuition.

	Discount (% off)
Ability	7.472**
Parental income in 1996 (real)	-0.0972***
Constant	34.15***
Observations	1609
R^2	0.047

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

Table 12: Tuition discounting (source: IPEDS)

B.2 The Impact of Non-Tuition Revenue Sources

We now look at how non-tuition revenue influences tuition, expenditures, and enrollment in the data. The first column of the top panel of table 14 reveals strong cross-sectional relationship between tuition and non-tuition revenue per FTE. In particular, public support (E^g) per FTE is negatively correlated with net tuition (T); in contrast, private non-tuition revenue (E^p) is positive correlated with net tuition. However, after controlling for interactions between state, school type, and flagship status, these correlations disappear as can be seen in the second column. This is also true if one expands from just 1987 to 2010 provided one all has interactions with time dummies as can be seen in the third column, or with a fixed effects specification like in the fourth column.

	(1)	(2)	(3)	(4)	(5)	(6)
	% off	% off	% off	% off	% off	% off
Ability	7.472**	12.82***	2.573			
	(2.29)	(4.00)	(0.78)			
95th Abil pctile				8.576***	13.27***	4.468
				(3.13)	(4.95)	(1.61)
90-95th Abil pctile				4.445	6.866**	2.329
				(1.57)	(2.50)	(0.83)
75-90th Abil pctile				-0.474	1.724	-2.224
				(-0.22)	(0.82)	(-1.03)
50-75th Abil pctile				-1.219	-0.555	-1.934
				(-0.59)	(-0.28)	(-0.94)
Parental income in 1996 (real)	-0.0972***	-0.0776***	-0.102***	-0.0982***	-0.0782***	-0.102***
	(-8.89)	(-7.22)	(-9.43)	(-9.01)	(-7.33)	(-9.51)
Net tuition estimate (real)		-0.724***			-0.748***	
		(-10.48)			(-10.85)	
Sticker tuition estimate (real)			0.363***			0.348***
			(7.10)			(6.78)
Constant	34.15***	35.81***	32.44***	38.48***	42.48***	34.94***
	(14.27)	(15.43)	(13.69)	(21.55)	(24.09)	(19.02)
Observations	1609	1609	1609	1609	1609	1609
R^2	0.047	0.108	0.076	0.055	0.119	0.081

t statistics in parentheses

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

Table 13: Tuition discounting (source: NLSY97)

	(1) T	(2) T	(3) T	(4) T
Eg	-0.26***	-0.04*	-0.01	0.02
Ep	0.09***	0.00	-0.00	-0.00
Constant	13266.80***	12949.12***	9904.17***	7399.60***
Observations	1158	1158	27792	27792
Adjusted R^2	0.149	0.727	0.750	0.463

	(1) XPND	(2) XPND	(3) XPND	(4) XPND
Eg	0.74***	0.96***	0.99***	1.02***
Ep	1.09***	1.00***	1.00***	1.00***
Constant	13266.80***	12949.12***	9904.17***	7399.60***
Observations	1158	1158	27792	27792
Adjusted R^2	0.980	0.994	0.994	0.974

	(1) log(N)	(2) log(N)	(3) log(N)	(4) log(N)
log(Eg)	0.40***	-0.05	-0.05***	-0.06***
log(Ep)	-0.14***	-0.15***	-0.19***	-0.12***
Constant	6.37***	9.89***	10.08***	9.33***
Observations	1105	1105	26721	26721
Adjusted R^2	0.366	0.711	0.718	0.463

	(1) Ability	(2) Ability
log(Eg)	0.01*	-0.01
log(Ep)	0.14***	0.06***
Constant	-0.95***	-0.13
Observations	931	931
Adjusted R^2	0.300	0.611

Note: (1-2) are for 2010; (3-4) are full sample. (2-3) includes all interactions between school type, state, year (when applicable), and flagship status. (4) is a fixed effects regression. Standard errors are clustered at the school type, state, year (when applicable), and flagship status level. For the fixed effects regression, robust standard errors are used. The ability measure is only for one year, which precludes using the (3) and (4) specifications. * $p < .10$, ** $p < .05$, *** $p < .01$

Table 14: How tuition, expenditures, and enrollments vary with non-tuition revenue

	(1) T	(2) T	(3) T	(4) T	(5) T	(6) T	(7) T	(8) T
Eg	-0.26***	-0.04*	-0.01	0.02				
Ep	0.09***	0.00	-0.00	-0.00				
Not sel. Pub Teach × Eg					-0.39*	-0.01	-0.00	-0.09***
Not sel. Pub Res. × Eg					-0.40***	0.13*	0.05***	-0.04*
Not sel. Priv Teach × Eg					-0.14***	-0.13***	-0.06***	0.13***
Not sel. Priv Res. × Eg					-0.06	-0.28***	-0.06*	0.30**
Sel. Pub Res. × Eg					-0.14***	-0.03	0.01	0.01
Sel. Priv Teach × Eg					2.98***	-0.63**	-0.33**	-0.29
Sel. Priv Res. × Eg					0.21***	-0.02	0.02*	0.03
Not sel. Pub Teach × Ep					-0.57**	0.01	0.01	-0.08***
Not sel. Pub Res. × Ep					0.13***	-0.02	0.01	0.02
Not sel. Priv Teach × Ep					0.09*	0.07*	0.06***	-0.05**
Not sel. Priv Res. × Ep					0.18**	0.17***	0.05	0.03
Sel. Pub Res. × Ep					0.05**	0.05*	0.02***	0.03*
Sel. Priv Teach × Ep					0.15**	-0.10***	-0.01	-0.06*
Sel. Priv Res. × Ep					-0.02	-0.00	-0.01***	-0.00
Constant	13266.80***	12949.12***	9904.17***	7399.60***	13709.27***	12439.92***	9485.20***	7886.03***
Observations	1158	1158	27792	27792	1158	1158	27792	27792
Adjusted R^2	0.149	0.727	0.750	0.463	0.399	0.733	0.755	0.473

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

Table 15: How net tuition varies with non-tuition revenue

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	log(N)	log(N)	log(N)	log(N)	log(N)	log(N)	log(N)	log(N)
log(Eg)	0.40***	-0.05	-0.05***	-0.06***				
log(Ep)	-0.14***	-0.15***	-0.19***	-0.12***				
Not sel. Pub Teach × log(Eg)					-0.07	-0.92***	-1.06***	-0.32***
Not sel. Pub Res. × log(Eg)					-0.26***	0.11	-0.01	-0.19**
Not sel. Priv Teach × log(Eg)					-0.02	-0.04	-0.04***	-0.05***
Not sel. Priv Res. × log(Eg)					0.18**	-0.09	0.07*	-0.09***
Sel. Pub Res. × log(Eg)					-0.01	-1.44***	-1.65***	-0.18***
Sel. Priv Teach × log(Eg)					0.03	-0.12	-0.08***	0.01
Sel. Priv Res. × log(Eg)					-0.06	-0.08	-0.04	-0.08***
Not sel. Pub Teach × log(Ep)					-0.06	0.01	-0.01	-0.02***
Not sel. Pub Res. × log(Ep)					0.28***	0.17**	0.25***	-0.02
Not sel. Priv Teach × log(Ep)					-0.25***	-0.21***	-0.26***	-0.19***
Not sel. Priv Res. × log(Ep)					-0.27***	0.06	-0.23***	-0.15***
Sel. Pub Res. × log(Ep)					0.05	0.78***	0.73***	-0.07***
Sel. Priv Teach × log(Ep)					-0.24***	-0.83***	-0.99***	-0.24***
Sel. Priv Res. × log(Ep)					0.01	0.01	-0.06	-0.07***
Constant	6.37***	9.89***	10.08***	9.33***	9.85***	11.23***	11.82***	10.03***
Observations	1105	1105	26721	26721	1105	1105	26721	26721
Adjusted R^2	0.366	0.711	0.718	0.463	0.676	0.734	0.742	0.503

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

Table 16: How enrollment varies with non-tuition revenue

	(1) Ability	(2) Ability	(3) Ability	(4) Ability
log(Eg)	0.01*	-0.01		
log(Ep)	0.14***	0.06***		
Not sel. Pub Teach × log(Eg)			-0.00	-0.10
Not sel. Pub Res. × log(Eg)			0.04*	0.15**
Not sel. Priv Teach × log(Eg)			-0.02**	-0.01
Not sel. Priv Res. × log(Eg)			0.03	0.06*
Sel. Pub Res. × log(Eg)			0.08***	0.25
Sel. Priv Teach × log(Eg)			0.02***	-0.00
Sel. Priv Res. × log(Eg)			0.04**	0.02
Not sel. Pub Teach × log(Ep)			0.04***	0.06***
Not sel. Pub Res. × log(Ep)			0.01	-0.02
Not sel. Priv Teach × log(Ep)			0.06***	0.07***
Not sel. Priv Res. × log(Ep)			0.04*	0.10***
Sel. Pub Res. × log(Ep)			0.02	-0.09
Sel. Priv Teach × log(Ep)			0.09***	0.04***
Sel. Priv Res. × log(Ep)			0.07***	0.01
Constant	-0.95***	-0.13	-0.11	-0.07
Observations	931	931	931	931
Adjusted R^2	0.300	0.611	0.589	0.617

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

Table 17: How ability varies with non-tuition revenue

	(1) lIplusC	(2) lT	(3) abil_coll	(4) lIplusC	(5) lT	(6) abil_coll
lEp	0.444***	0.319***	0.134***	0.372***	0.167***	0.142***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lEg	0.121***	-0.222***	0.0313***	0.0723***	-0.144***	0.0119**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.008)
_cons	4.958***	7.599***	-1.068***	6.070***	8.952***	-0.953***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
N	1130	1130	954	1105	1105	931

p-values in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 18: Non-tuition revenue, tuition, expenditures, and ability

B.3 The Role of Student Characteristics

	(1) Graduated	(2) Log coll. prem
Sticker quintile=1 × Mean grad rate × Relative ability	0.0238	
	(0.37)	
Sticker quintile=2 × Mean grad rate × Relative ability	0.320***	
	(7.29)	
Sticker quintile=3 × Mean grad rate × Relative ability	0.410***	
	(10.85)	
Sticker quintile=4 × Mean grad rate × Relative ability	0.420***	
	(11.40)	
Sticker quintile=5 × Mean grad rate × Relative ability	0.457***	
	(12.74)	
Sticker quintile=1 × Mean log college prem. × Relative ability		0.878***
		(6.70)
Sticker quintile=2 × Mean log college prem. × Relative ability		0.986***
		(7.93)
Sticker quintile=3 × Mean log college prem. × Relative ability		0.904***
		(8.31)
Sticker quintile=4 × Mean log college prem. × Relative ability		0.919***
		(8.49)
Sticker quintile=5 × Mean log college prem. × Relative ability		0.925***
		(11.62)
Constant	0.456***	0.0415
	(17.49)	(0.96)
Observations	2267	2109
R^2	0.131	0.062

t statistics in parentheses
Sample is youth who enrolled and had a non-missing sticker tuition estimate.
* $p < .1$, ** $p < .05$, *** $p < .01$

Table 19: Graduation rates and college premia as a function of relative ability by sticker tuition quintile

B.4 Experiment decomposition removing one force at time

Figure 9 shows the decomposition of starting at 2010 values and removing one force at a time.

	(1) Household income in 1996 (real)
model	
Ability	60.36***
	(23.19)
Constant	40.11***
	(26.44)
sigma	
Constant	47.98***
	(87.95)
Observations	4102

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 20: Censored regression of household income on ability

	(1) Enrolled	(2) Graduated	(3) Took out a loan
Ability	0.837***	0.405***	0.165***
	(35.32)	(9.34)	(3.44)
Household income in 1996 (real)	0.00124***	0.000717***	-0.00142***
	(10.99)	(4.84)	(-8.67)
Constant	-0.0548***	0.367***	0.607***
	(-3.94)	(11.69)	(17.48)
Observations	4102	1888	1867

t statistics in parentheses

Note: (2) and (3) are conditional on enrollment.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 21: How select variables vary in initial conditions

Table 22: Correlations

Variables	Enrollment	Parental income (real)	Ability (ASVAB pctile)
Enrollment	1.000		
Parental income (real)	0.299	1.000	
Ability (ASVAB pctile)	0.475	0.310	1.000

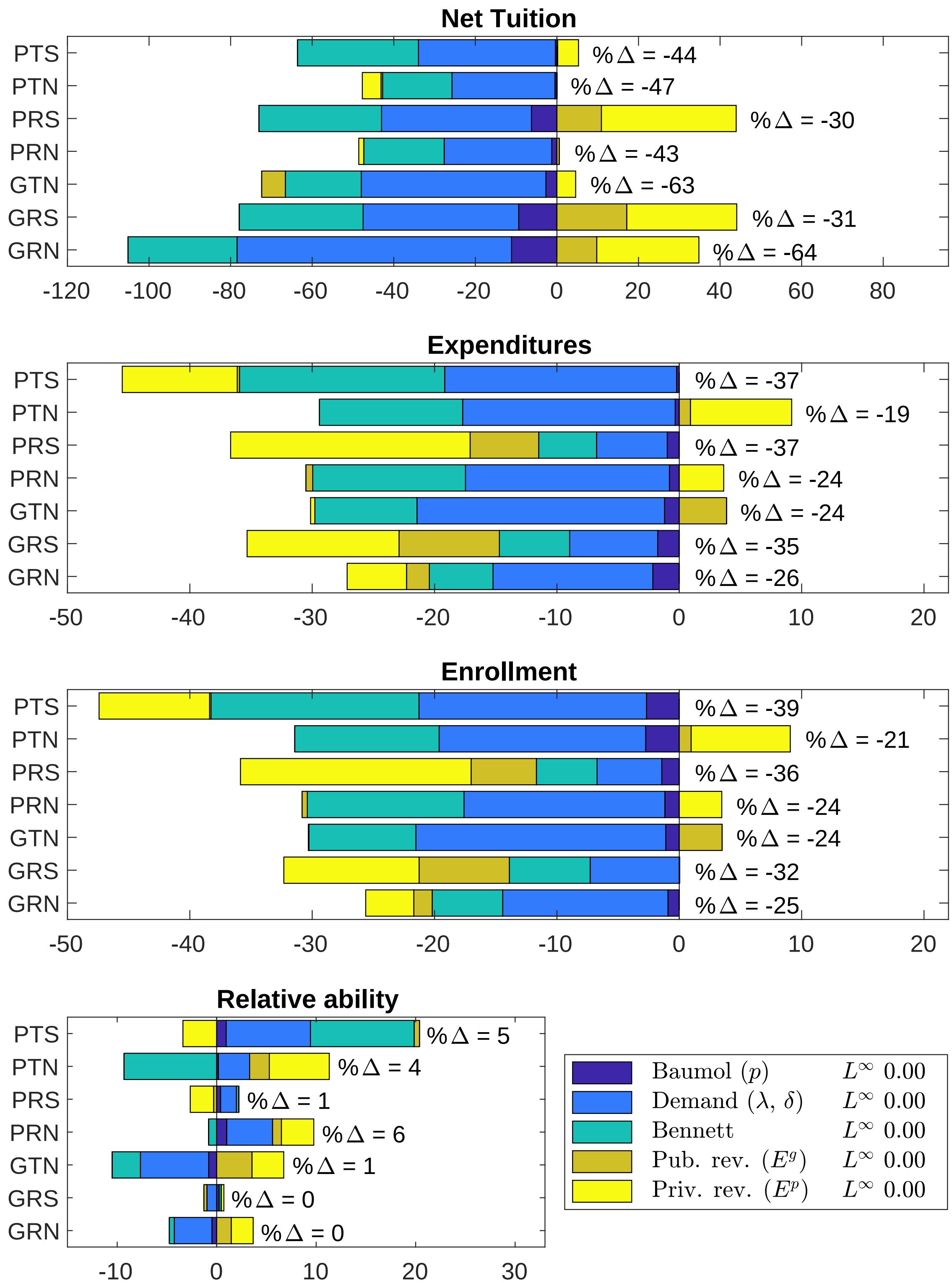

Figure 9: Percent change relative to 2010 from subtracting one force, else equal

Table 23: Correlations conditional on enrollment

Variables	Graduation	Parental income (real)	Ability (ASVAB pctile)
Graduation	1.000		
Parental income (real)	0.118	1.000	
Ability (ASVAB pctile)	0.211	0.187	1.000