Accounting for the Rise in College Tuition*

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Abstract

We develop a quantitative model of higher education to test explanations for the steep rise in college tuition between 1987 and 2010. The framework extends the paradigm in Epple, Romano, Sarpca, and Sieg (2013) of imperfectly competitive, quality maximizing colleges and embeds it in an incomplete markets, life-cycle environment. We measure how much changes in the underlying cost structure, reforms to the Federal Student Loan Program (FSLP), and the increase in the college earnings premium have contributed to tuition inflation. In the model, these changes combine to generate a 102% rise in net tuition between 1987 and 2010, which more than accounts for the 92% increase seen in the data. Our findings suggest that expanded student loan borrowing limits are the largest driving force for the increase in tuition, followed by the rise in the college premium.

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1 Introduction

Over the past thirty years, the perceived necessity of a college degree and a growing college earnings premium have led to record enrollments and greater degree attainment in higher

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education. However, a dramatic escalation in tuition looms over the heads of prospective students and their parents and serves as a stark reminder to graduates saddled with large student loans. From 1987 to 2010, sticker price tuition and fees ballooned from $6,630 to $14,510 in 2010 dollars. After subtracting institutional aid, net tuition and fees still grew by 92%, from $5,720 to $11,000. To provide perspective, had net tuition risen at the rate of much maligned *healthcare costs*, tuition would have only risen 32% to $7,550 in 2010.[1]

In this paper, we seek to account for the college tuition increase by quantitatively evaluating existing explanations using a structural model of higher education and the macroeconomy. We divide our hypotheses about driving forces into supply-side changes (Baumol's cost disease and exogenous changes to non-tuition revenue), demand-side changes (notably, expansions in grant aid and loans), and macroeconomic forces (namely, skill-biased technical change resulting in a higher college earnings premium). Our quantitative model shows that the combined effect of these changes more than accounts for the tuition increase and provides key insights about the role of individual factors as well as their complementary effects.

Existing hypotheses of why college tuition is increasing largely fall into two camps: those that emphasize the unique virtues and pathologies of higher education and those that place rising higher education costs into a broader narrative of increasing prices in many service industries. Advocates of the latter approach look to cost disease and skill-biased technical progress as drivers of higher costs in service industries that employ highly skilled labor. Cost disease, which dates back to seminal papers by Baumol and Bowen (1966) and Baumol (1967), posits that economy-wide productivity growth pushes up wages and creates cost pressures on service industries that do not share in the productivity growth. To cope, these industries increase their relative price, passing their higher costs onto consumers.

By contrast, theories emphasizing the uniqueness of higher education take several forms. Falling within our notion of supply-side shocks, state and local funding for higher education fell from $8,200 per full-time-equivalent (FTE) student in 1987 to $7,300 in 2010, all while underlying costs and expenditures were rising. Several studies, including a notable study commissioned by Congress in the 1998 re-authorization of the Higher Education Act, attribute a sizable fraction of the increase in public university tuition to these state funding cuts. We take a somewhat broader view in this paper by looking at how exogenous changes to *all* sources of non-tuition revenue impact the path of tuition.

On the demand side, several expansions in financial aid have occurred over the past several decades. During our period of analysis, annual and aggregate subsidized Stafford loan limits were increased in 1987 and five years later in 1992. The Higher Education Amendments of 1992 also established a program of supplementary unsubsidized Stafford loans and

[1]Calculations used the health care personal consumption expenditures price index deflated by the CPI.

increased the annual PLUS loan limit to the cost of attendance minus aid, thereby eliminating aggregate PLUS loan limits. Interest rates on student loans also fell considerably during the 2000s. In a famous 1987 New York Times Op-Ed titled "Our Greedy Colleges", then secretary of education William Bennett asserted that "increases in financial aid in recent years have enabled colleges and universities blithely to raise their tuitions" (Bennett, 1987). We evaluate this claim through the lens of our model, and we also cast light on the tuition impact of the 53% rise in *non-tuition* costs (such as those arising from the greater provision of student amenities), which has the effect of increasing subsidized loan eligibility.

Lastly, we quantify the impact of macroeconomic forces—specifically, rising labor market returns to college—on tuition changes. Autor, Katz, and Kearney (2008) find that, from the mid-1980s to 2005, the overall earnings premium to having a college degree increased from 58% to over 93%. Ceteris paribus, such an increase in the return to college has assuredly driven up demand for a college degree. We use our model to quantify how much this increase in demand translates to higher tuition and how much it contributes to higher enrollments.

Our quantitative findings can be summarized as follows:

1. The combined effect of the aforementioned shocks generates a 102% increase in equilibrium tuition. This result compares to a 92% increase in the data.

2. The rise in the college earnings premium alone causes tuition to increase by 21%. With all other shocks present *except* the college premium hike, tuition increases by 81%.

3. The demand-side shocks by themselves cause tuition to jump by 91%. With all other changes *except* the demand-side shocks, tuition only increases by 14%.

4. The supply-side shocks by themselves cause tuition to *decline* by 8%. With all other changes *except* the supply-side shocks, tuition increases by 116%.

The model we construct to arrive at these conclusions embeds a rich higher education framework based off of Epple, Romano, and Sieg (2006) and Epple et al. (2013) into a life-cycle environment with heterogeneous agents, incomplete markets, and student loan default. Imperfectly competitive colleges in the model set differential tuition and admissions policies to maximize quality, which, as a proxy for reputation, depends on investment per student and the average academic ability of the heterogeneous student body. In this paper, we restrict attention to the case of a representative non-profit institution that has limited market power because of unobservable student preference shocks. Even with these shocks, the representative college assumption still abstracts from important heterogeneity and strategic interactions in the higher education market. For this reason, the findings in this paper should be used to guide further research rather than viewed authoritatively. To further simplify matters, we treat all non-tuition revenue as exogenous (e.g. endowment income and state funding), which implies that the college faces a balanced budget constraint each period that equates total revenue with total spending on investment and non-quality-enhancing custodial costs. On the household side, we include several important features: heterogeneity in ability and parental income dimensions, college financing decisions, college drop-out risk, and student loan repayment decisions.

Our assumption that colleges maximize quality—in line with what Clotfelter (1996) calls the "pursuit of excellence"—implicitly incorporates another prominent hypothesis for rising tuition, namely, Bowen (1980)'s "Revenue Theory of Costs." Ehrenberg (2002) states it best:

> The objective of selective academic institutions is to be the best they can in every aspect of their activities. They aggressively seek out all possible resources and put them to use funding things they think will make them better. To look better than their competitors, the institutions wind up in an arms race of spending...

To make matters concrete, quality in our setting depends on investment per student and the average ability of the student body. As a result, students act both as customers and as inputs to the production of quality via peer effects, as described by Winston (1999). This unique feature of higher education gives colleges an additional motive to engage in price discrimination beyond the usual monetary rent extraction—namely, to attract high ability students by offering generous institutional aid.

To discipline the model, we use a combination of calibration and estimation. Rather than ex-ante assume cost disease or a particular production structure (e.g. number of faculty, administrators, etc. needed to run a college), we directly estimate a reduced-form custodial cost function and track its changes over the period 1987 – 2010. Similarly, we compute average non-tuition revenue per full-time equivalent (FTE) student using Delta Cost Project data and feed it into the model. On the household side, we use earnings premium estimates by Autor et al. (2008) and construct time-series for Federal Student Loan Program variables.

As mentioned previously, we find that the combined effects of the supply-side changes, demand-side changes, and increases in the college earnings premium can fully account for the mean net tuition increase. Looking at individual factors, we find that expansions in borrowing limits drive 54% of the tuition jump and represent the single most important factor.[2] To grasp the magnitude of the change in borrowing capacity, first note that real aggregate borrowing limits increased by 56% between 1987 and 2010, from \$26,200 to \$40,800

[2] For this calculation, we take one minus the tuition increase without the borrowing limit expansion relative to the increase with the expansion, i.e. $1-(\$9{,}066-\$6{,}146)/(\$12{,}428-\$6{,}146)$. Adding the percentage contribution from each exogenous driving force need not yield 100% because of interaction effects.

in 2010 dollars.[3] Second, the re-authorization of the Higher Education Act in 1992 introduced a major change along the extensive margin by establishing an unsubsidized loan program alongside the subsidized loans. We also find that increased grant aid contributes 18% to the rise in tuition, which mirrors the 21% impact of the higher college earnings premium. These results give credence to the Bennett (1987) hypothesis.

Lastly, our results, while preliminary and subject to the caveat mentioned above regarding the representative college assumption, paint a more nuanced picture of cost disease as a driver of higher tuition. Although our estimated cost function shifts upward from 1987 to 2010, this isolated effect *reduces* average tuition (a contribution of -16%). Importantly, our estimates suggest that the upward shift in the cost function between 1987 and 2010 comes largely in the form of higher fixed costs, rather than higher marginal costs, which has important implications for how colleges respond. Intuitively, colleges face a trade-off between raising tuition and retaining high ability students when they experience a balance sheet deterioration. If they increase tuition, fewer high ability students may enroll, which drives down quality. Alternatively, a decision to not raise tuition forces colleges to cut back on quality-enhancing investment expenditures. We find that colleges take this latter route to the tune of almost $2,800 in cuts per student as a response to higher custodial costs. This result comports with the behavior we observe among many public universities across the country of replacing tenured faculty with less expensive non-tenure-track positions. Additionally, changes in non-tuition revenue have almost no impact on tuition (a contribution of 2%).

We do not claim that Baumol's cost disease or changes in state support have no importance for tuition increases. Rather, we suspect that these factors affect some colleges more than others. For instance, if private research universities experience cost disease, they may increase their tuition. However, higher tuition may induce substitution of students into lower cost universities. Given the absence of competition and college heterogeneity in our model, our estimation implicitly incorporates substitution of households across college types and any corresponding composition effects.

1.1 Relationship to the Literature

This paper relates to two broad strands of the literature. First, the paper relates to a large empirical literature that estimates the effects of macroeconomic factors and policy interventions on tuition and enrollment. Second, this paper relates to a growing body of literature employing structural models of higher education. With a few exceptions, these models focus on student demand and abstract from many distinguishing features of the supply side.

[3] We use the limits in place from 1981 to 1986 as our figure for 1987.

1.1.1 Empirical Literature

In discussing related work, we map our categorization of supply-side shocks, demand-side shocks, and macroeconomic forces into the existing empirical literature. For supply-side shocks, we analyze the impact of upward shifts in custodial (non-quality-enhancing) costs as well as changes in non-tuition revenues. The literature on Baumol's cost disease most closely relates to the former, while the literature analyzing the effect of the decline in state appropriations for higher education addresses the latter.

Supply Shocks: Cost Disease 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."

We find that the form of the cost increase matters. In particular, our estimates uncover a large increase in the fixed cost of operating a college from \$12 billion to \$30 billion in 2010 dollars. To pay for the higher fixed cost, the college in our model lowers per-student investment and increases enrollment, which lowers average tuition by a composition effect.

Supply Shocks: Cuts in State Appropriations Heller (1999) suggests a negative relationship between state appropriations for higher education 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."

While our model fails to confirm this idea in the aggregate—that is, lumping public and private colleges together—cuts in appropriations could potentially play a role in driving up public school tuition. Extending our model to incorporate heterogeneous colleges with detailed, disaggregated funding data will shed further light on this issue.

Demand Shocks: The Bennett Hypothesis For demand-side shocks, we focus on the effects of increased financial aid. We address the extent to which changes in loan limits and interest rates under the FSLP as well as expansions in state and federal grants to students drive up tuition—famously known as the Bennett hypothesis. A long line of empirical research has studied this hypothesis with mixed results.

Broadly speaking, we can divide the literature into those papers that find at least *some* support for this hypothesis and those that are highly skeptical. In the first group, McPherson and Shapiro (1991) use institutional data from 1978 – 1985 and find a positive relationship between aid and tuition at public universities but not at private universities. Singell and Stone (2007), using panel data from 1983 – 1996, find evidence for the Bennett hypothesis among top-ranked private institutions but not among public and lower-ranked private universities. They also found evidence in favor of the Bennett hypothesis for public *out-of-state* tuition. Rizzo and Ehrenberg (2004) come to the mirror opposite conclusion: "We find substantial evidence that increases in the generosity of the federal Pell Grant program, access to subsidized loans, and state need-based grant aid awards lead to increases in in-state tuition levels. However, we find no evidence that nonresident tuition is increased as a result of these programs." Turner (2012) shows that tax-based aid crowds out institutional aid almost one-for-one. Turner (2014) also finds that institutions capture some of the benefits of financial aid, but at a more modest 12% pass-through rate. Long (2004a) and Long (2004b) uncover evidence that institutions respond to greater aid by increasing charges, in some cases by up to 30% of the aid. Cellini and Goldin (2014) compare for-profit institutions that participate in federal student aid programs to those that do not participate. Institutions in the former group charge tuition that is about 78% higher than those in the latter group. 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.

In contrast to the previous literature, several papers reject or find little evidence for the Bennett hypothesis. For example, 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." These sentiments are echoed by Long (2006). Lastly, Frederick, Schmidt, and Davis (2012) study the response of community colleges to changes in federal aid and find little evidence of capture.

Our model likely exaggerates the impact of the Bennett hypothesis. As we discuss in section 4, the representative college engages in an implausibly high degree of rent extraction despite the presence of preference shocks. We suspect that more competition in our model of the higher education market would temper the magnitude of the tuition increase attributable to the Bennett hypothesis.

Macroeconomic Forces: Rising College Earnings Premia According to data from Autor et al. (2008), the college earnings premium increased from 58% in the mid-1980s to 93% in 2005. While we remain agnostic about the cause of the increasing premium, several papers, including Autor et al. (2008), Katz and Murphy (1992), Goldin and Katz (2007), and Card and Lemieux (2001), ascribe it to skill-biased technological change combined with a fall in the relative supply of college graduates.

In recent work, Andrews, Li, and Lovenheim (2012) study the *distribution* of college earnings premia and find substantial heterogeneity attributable to variation in college quality. Hoekstra (2009) looks at earnings of white males ten to fifteen years after high school graduation and finds a premium of 20% for students who attended the most selective state university relative to those who barely missed the admissions cutoff and went elsewhere. Incorporating this heterogeneity in college earnings premia may help explain why tuition increases at selective schools (such as public and private research universities) have outpaced those at less selective schools.

1.1.2 Quantitative Models of Higher Education

Our paper also fits into a growing body of papers that employ structural models of higher education, such as Abbott, Gallipoli, Meghir, and Violante (2013), Athreya and Eberly (2013), Ionescu and Simpson (2015), Ionescu (2011), Garriga and Keightley (2010), Lochner and Monge-Naranjo (2011), Belley and Lochner (2007), and Keane and Wolpin (2001). In the interest of space, we discuss only the most closely related papers.

Recent work by Jones and Yang (2015) closely mirrors the objectives of this paper. They explore the role of skill-biased technical change in explaining the rise in college costs from 1961 to 2009. Their paper differs from ours in several ways. First, whereas they explore the effect of cost disease on higher college costs, we quantify the role of supply-side as well as demand-side shocks. Second, Jones and Yang (2015) analyze college costs—which increased by 35% in real terms between 1987 and 2010—whereas we address the increase in net tuition, which went up by 92%. Also, whereas they use a competitive framework, we employ a model with peer effects, imperfect competition with price discrimination, and student loan borrowing with default. Fillmore (2014) also analyzes a model of price discriminating colleges, but he treats peer effects in a reduced form way. Fu (2014) considers a rich game-theoretic framework of college admissions and enrollment but does not allow for price discrimination.

2 The Model

The model embeds a college sector into a discrete time open economy. A fixed measure of heterogeneous households enter the economy upon graduating high school, make college enrollment decisions, and then progress through their working life and into retirement. A monopolistic college with the ability to price discriminate transforms students into college graduates (with dropout risk), and the government levies taxes to finance student loans.

2.1 Households

We describe sequentially the environment faced by youths, college students, and, finally, workers and retirees. We immediately follow this discussion with a description of colleges in the model. Section 2.4 gives the decision problems for all agents in the economy.

2.1.1 Youths

Youths enter the economy at $j = 1$ (corresponding to high school graduation at age 18), at which point they draw a two-dimensional vector of characteristics $s_Y = (x, y_p)$ consisting of academic ability x and parental income y_p from a distribution G. Youths make a once-and-for-all choice to either enroll in college or enter the workforce. In addition to the explicit pecuniary and non-pecuniary benefits of college that we will describe momentarily, youths receive a preference shock $\frac{1}{\alpha}\epsilon$ of attending college, where $\alpha > 0$ and ϵ comes from a type 1 extreme distribution. Colleges cannot condition tuition on the preference shock.

2.1.2 College Students

Newly enrolled students enter college with their vector of characteristics s_Y and a zero initial student loan balance, $l = 0$. Colleges charge type-specific net tuition $T(s_Y)$—equal to sticker price $\overline{T}$ minus institutional aid—which they hold fixed for the duration of enrollment.

Students also face non-tuition expenses ϕ that act as perfect substitutes for consumption c. Direct government grants $\zeta(T + \phi, EFC(s_Y))$ offset some of the cost of attendance, where $EFC(s_Y)$ represents the expected family contribution—a formula used by the government to determine eligibility for need-based grants and loans. After taking into account both forms of aid, the net cost of attendance comes out to $NCOA(s_Y) = T(s_Y) + \phi - \zeta(T(s_Y) + \phi, EFC(s_Y))$.

While enrolled, college students receive additively-separable flow utility $v(q)$ which increases in college quality q.[4] In order to graduate, students must complete J_Y years of college.

[4] To improve tractability while computing the transition path, we assume students receive $v(q)$ each year

Students in class j return to college each year with probability $\pi_{j+1} \equiv \pi \mathbf{1}_{[j+1 \leq J_Y]}$; otherwise, they either drop out or graduate.[5]

Students can borrow through the Federal Student Loan Program (FLSP). Of primary interest, the FSLP features subsidized loans that do not accrue interest while the student is in college, where eligibility depends on financial need ($NCOA$ less EFC). Since 1993, students can borrow additional funds up to the net cost of attendance using unsubsidized loans. Students face annual and aggregate limits for subsidized and combined borrowing.

Denote the annual and aggregate combined limits by $\bar{b}_j$ and $\bar{l}$, respectively.[6] Because students can borrow only up to the net cost of attendance, their annual combined subsidized borrowing b_s and unsubsidized borrowing b_u must satisfy

$$b_s + b_u \leq \min\{\bar{b}_j, NCOA(s_Y)\}. \tag{1}$$

Similarly, define $\bar{b}_j^s$ as the statutory annual subsidized limit and $\bar{l}_j^s$ as the statutory aggregate subsidized limit. The actual amount $\tilde{b}_j^s(s_Y)$ that students can borrow in subsidized loans depends on their net cost of attendance and the expected family contribution, both of which vary with student type. Lastly, define $\tilde{l}_j^s(s_Y)$ as the maximum amount of subsidized loans that students can accumulate by year j in college. Mathematically,

$$\begin{aligned} \tilde{b}_j^s(s_Y) &= \min\{\bar{b}_j^s, \max\{0, NCOA(s_Y) - EFC(s_Y)\}\} \\ \tilde{l}_j^s(s_Y) &= \min\{\bar{l}^s, \sum_{i=1}^{j} \tilde{b}_i^s(s_Y)\}. \end{aligned} \tag{2}$$

Given the superior financial terms of subsidized loans, we assume that students always exhaust their subsidized borrowing capacity before taking out any unsubsidized loans. Furthermore, to increase tractability, we assume that borrowers can carry over unused *subsidized* borrowing capacity into subsequent years. These two assumptions reduce the state space and significantly simplify the student's debt portfolio choice problem.

Apart from loans, students have two other means of paying for college. First, they have earnings e_Y, which we treat as an endowment.[7] Second, they receive a parental transfer $\xi EFC(s_Y)$, where $0 \leq \xi \leq 1$ is a parameter.

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based on the college's quality q at the time of *initial* enrollment. In the computation, we make the isomorphic assumption that students receive the net present value of $v(q)$ at the time of enrollment.

[5]We do not allow endogenous dropout for reasons of tractability.

[6]The aggregate limit caps maximum loan balances the period after borrowing, inclusive of interest.

[7]We abstract from labor supply choice and the trade-off between increased earnings and studying.

2.1.3 Workers/Retirees

Working and retired households receive earnings e that depend on a vector of characteristics s that includes their level of education, age/retirement status, and a stochastic component. Each period, households face a proportional earnings tax τ.

These households value consumption according to a period utility function $u(c)$ and discount the future at rate β. Workers with student loans face a loan interest rate of i and amortization payments of $p(l,t) = l\frac{i(1+i)^{t-1}}{(1+i)^{t}-1}$, where l represents the loan balance and t the remaining duration. All households can use a discount bond to save at the risk-free rate r^* and borrow up to the natural borrowing limit $\overline{a}$ at rate $r^* + \iota$, where ι is the interest premium on borrowing. The price of the bond is denoted $(1 + r(a'))^{-1}$.

2.2 Colleges

There is one representative college. Following Epple et al. (2006), the college seeks to maximize its quality (or prestige), q, which depends on the average academic ability θ of the student body and on investment expenditures per student, I. The college's other expenses include non-quality-enhancing custodial costs $F + C(\{N_j\}_{j=1}^{J_Y})$, where F represents a fixed cost and C is an increasing, twice-differentiable, convex function of enrollment $\{N_j\}_{j=1}^{J_Y}$.

The college finances its expenditures with two sources of revenue. First, the college has exogenous non-tuition revenue per student E, which includes endowment income, government appropriations, and revenues from auxiliary enterprises. Second, the college has endogenous tuition revenue, a function of enrollment decisions and type-specific net tuition $T(s_Y)$. The college is a non-profit and, given our assumption of an exogenous endowment stream, runs a balanced budget period-by-period.[8]

In order to avoid dealing with issues such as the college's discount factor—not to mention other difficulties associated with the transition path computation—we make the college problem static through four assumptions. First, we assume that college quality $q(\theta, I)$ depends on the academic ability of *freshmen* and investment expenditures per *freshman* student.[9] Second, we assume that colleges face a quadratic cost function for each *class* given by

$$F + C(\{N_j\}_{j=1}^{J_Y}) = F + \sum_{j=1}^{J_Y} c\,(n_j) \tag{3}$$

where N_j is the population measure in class j ($j = 1$ for freshmen, $j = 2$ for sophomores, etc.)

[8]Technically, the non-profit status of the college only implies that it cannot distribute dividends. However, we abstract from strategic decisions regarding endowment accumulation.

[9]We assume the college commits to a level of I for the duration of each incoming cohort's enrollment.

and $n_j \equiv \frac{N_j}{1/J}$ is the measure relative to the age-18 population (for scaling purposes in the estimation). Third, we assume the college has no access to credit markets. Last, we isolate the effect of current tuition and spending decisions on *future* budget conditions. Specifically, we assume that each year the college exchanges the rights to all future budget flows generated by contemporaneous tuition and expenditure decisions in exchange for an immediate net present value payment from the government. This last assumption implicitly rules out any "quality smoothing" on the part of the college and captures the fact that administrators typically have short tenures that may make borrowing against expected future flows challenging.[10]

2.3 Legal Environment and Government Policy

Consistent with U.S. law, workers in the model cannot liquidate their student loan debt through bankruptcy. However, they *can* skip payments and become delinquent. Upon initial default, workers enter delinquency status and face a proportional loan penalty of η that accrues to their existing balance. In subsequent periods, delinquent workers face a proportional wage garnishment of γ until they rehabilitate their loan by making a payment. Upon rehabilitation, the loan duration resets to the statutory value $t_{\max}$ and the amortization schedule adjusts accordingly.

The government operates the student loan program and finances itself with a combination of taxation on labor earnings, funds from loan repayments and wage garnishments, and the revenue flows generated by colleges discussed above. We assume that the government sets the tax rate τ to balance its budget period by period.

2.4 Decision Problems

Now we work backwards through the life cycle to describe the household decision problem. Afterward, we describe the college's optimization problem.

2.4.1 Workers/Retirees

Households start each period with asset position a, student loan balance l and duration t, characteristics s, and delinquency status $f \in \{0, 1\}$, where $f = 0$ indicates good standing. Households in good standing on their student loans choose consumption, savings, and whether to make their scheduled loan payment. These households have the value function

$$V(a, l, t, s, f = 0) = \max\{V^R(a, l, t, s), V^D(a, l(1 + \eta), s)\} \tag{4}$$

[10] The average tenure of a dean is five years (Wolverton, Gmeich, Montez, and Nies, 2001).

where V^R is the utility of repayment and V^D is the utility of delinquency. Note that η increases the stock of outstanding debt in the case of a default.

Households in bad standing face the decision of whether to rehabilitate their loan or remain delinquent. Their value function is

$$V(a, l, s, f = 1) = \max\{V^R(a, l, t_{max}, s), V^D(a, l, s)\}. \tag{5}$$

Household utility conditional on repayment or rehabilitation is given by

$$\begin{gathered} V^R(a, l, t, s) = \max_{c \geq 0, a' \geq \underline{a}} u(c) + \beta \mathbb{E}_{s'|s} V(a', l', t', s', f' = 0) \\ \text{subject to} \\ c + a'/(1 + r(a')) + p(l, t) \leq e(s)(1 - \tau) + a \\ l' = (l - p(l, t))(1 + i), \; t' = \max\{t - 1, 0\}. \end{gathered} \tag{6}$$

The value of defaulting (if $f = 0$) or not rehabilitating a loan (if $f = 1$) is[11]

$$\begin{gathered} V^D(a, l, s) = \max_{c \geq 0, a' \geq \underline{a}} u(c) + \beta \mathbb{E}_{s'|s} V(a', l', s', f' = 1) \\ \text{subject to} \\ c + a'/(1 + r(a')) \leq e(s)(1 - \tau)(1 - \gamma) + a \\ l' = \max\{0, (l - e(s)(1 - \tau)\gamma)(1 + i)\}. \end{gathered} \tag{7}$$

In the last period of life, households have no continuation utility and no ability to borrow or save. We allow households to die with student loan debt.

2.4.2 College Students

College students with characteristics $s_Y = (x, y_p)$ and debt l choose consumption and additional loans, $l' \geq l$ (to speed up computation, we assume that students do not pay back their loans while in college). We also introduce an annual *unsubsidized* borrowing limit $\bar{b}^u_j$ that equals either the combined limit or zero (the latter case captures the pre-1993 environment).

[11] In the case of a default, note that η has already been applied to the loan balance in (4).

Taking college quality q and the net tuition function $T(\cdot)$ as given, students solve

$$Y_j(l, s_Y; T, q) = \max_{c \geq 0, l' \geq l} u(c + \phi) + v(q) + \beta \left[\begin{array}{c} \pi_{j+1} Y_{j+1}(l', s_Y; T) + (1 - \pi_{j+1}) \\ \times \mathbb{E}_{s'|j,s_Y} V(a' = 0, l', t_{max}, s', 0) \end{array} \right]$$

$$\text{subject to}$$

$$\begin{gathered} c + NCOA(s_Y) \leq e_Y + \xi EFC(s_Y) + b_s + b_u \\ (l'_s, l'_u) = \begin{cases} (l', 0) & \text{if } l' \leq \tilde{l}^s_j(s_Y) \\ (\tilde{l}^s_j(s_Y), l' - \tilde{l}^s_j(s_Y)) & \text{otherwise} \end{cases} \\ (l_s, l_u) = \begin{cases} (l, 0) & \text{if } l \leq \tilde{l}^s_{j-1}(s_Y) \\ (\tilde{l}^s_{j-1}(s_Y), l - \tilde{l}^s_{j-1}(s_Y)) & \text{otherwise} \end{cases} \\ b_s = l'_s - l_s \\ b_u = \frac{l'_u}{1+i} - l_u \\ l'_s + \frac{l'_u}{1+i} \leq \bar{l} \\ b_u \leq \min\{\bar{b}^u_j, NCOA(s_Y)\} \\ b_s + b_u \leq \min\{\bar{b}_j, NCOA(s_Y)\} \end{gathered} \tag{8}$$

Note from these equations that our setup allows us to easily decompose student debt into its subsidized and unsubsidized components. We deflate l'_u by $1 + i$ in the aggregate borrowing constraint because the loan limit is inclusive of interest accrued by unsubsidized loans.

2.4.3 Youth

Youth making their college enrollment decisions have value function

$$\max \left\{ \underbrace{\mathbb{E}_{s|s_Y} V_1(a = 0, l = 0, t = 0, s)}_{\text{enter the labor force}}, \underbrace{Y_1(l = 0, s_Y; T, q) + \frac{1}{\alpha}\epsilon}_{\text{attend college}} \right\} \tag{9}$$

where ϵ denotes the college preference shock and s is the initial worker characteristics draw.

2.4.4 Colleges

The college problem can be written as

$$\max_{I\geq 0, T(\cdot)} q(\theta, I)$$

subject to

$$\begin{aligned}
\mathcal{E} + \mathcal{T} &= F + \mathcal{C}(N_1) + \mathcal{I} \\
N_1 &= \int \mathbb{P}(\text{enroll}|s_Y; T(\cdot), q) d\mu_0(s_Y) \\
\theta N_1 &= \int x(s_Y)\mathbb{P}(\text{enroll}|s_Y; T(\cdot), q) d\mu_0(s_Y) \\
\mathcal{T} &= \sum_{j=1}^{J_Y} \frac{\pi^{j-1} \int T(s_Y)\mathbb{P}(\text{enroll}|s_Y; T(\cdot), q) d\mu_0(s_Y)}{(1+r^*)^{j-1}} \\
\mathcal{E} &= E \sum_{j=1}^{J_Y} \frac{\pi^{j-1} N_1}{(1+r^*)^{j-1}} \\
\mathcal{C}(N_1) &= \sum_{j=1}^{J_Y} \frac{c\left(\pi^{j-1}\frac{N_1}{1/J}\right)}{(1+r^*)^{j-1}} \\
\mathcal{I} &= I \sum_{j=1}^{J_Y} \frac{\pi^{j-1} N_1}{(1+r^*)^{j-1}}
\end{aligned} \tag{10}$$

where $\mu_0(s_Y) \equiv G(s_Y)/J$ is the distribution of characteristics across the age-18 population.

The first constraint reflects the college balanced budget requirement, while the remaining constraints establish the definitions of enrollment, average freshman ability, tuition revenues, non-tuition revenues, custodial costs, and investment expenditures, respectively.

2.5 Steady State Equilibrium

A steady state equilibrium consists of household value and policy functions, a tax rate, college policies and quality, and a distribution of households such that:

1. The household value and policy functions satisfy (4 – 9).
2. The college policies and quality satisfy (10).
3. The government budget balances.
4. The distribution is invariant.

3 Data and Estimation

We calibrate the model to replicate key features of the U.S. economy and higher education sector in 1987. These initial conditions set the stage for the results section, which feeds in the observed changes between 1987 and 2010 described in the introduction to assess their impact on equilibrium tuition. We proceed through our description of the calibration and estimation in the same order as we described the model.

3.1 Households

3.1.1 Youths

We determine the distribution G of youth characteristics $s_Y = (x, y_p)$ using data from the NLSY97. The ability measure comes from percentiles on the ASVAB aptitude test. For parental income, we use the household income measure from 1997 in those cases where the data correspond to the parents rather than the youth (98.0% of cases).

Conditional on our ability measure, parental income resembles a truncated normal distribution. This can be seen in Figure 1 of Web Appendix A. To handle truncation from above due to top-coding and truncation from below, we estimate a Tobit model where parental income depends on ability. Specifically, we estimate

$$\begin{aligned} y_i^* &= \beta_0 + \beta_1 x_i + \varepsilon_i \\ y_i &= \min\{\max\{0, y_i^*\}, \overline{y}\} \end{aligned} \tag{11}$$

where y_i is the observed parental income, y_i^* is the "true" parental income, and $\varepsilon_i \sim N(0, \sigma^2)$.[12] The parameter $\overline{y}$ corresponds to the 2% top-coded level implemented in the NLSY97 (we find $\overline{y}$ = \$226,546 in 2010 dollars). In 2010 dollars, we find β_0 = \$40,006, β_1 = \$614.6, and σ = \$48,012, with standard errors of \$1,529, \$25.95, and \$543.4, respectively. By the construction of x in NLSY97, $x \sim U[0, 100]$. Hence, our estimation implies that, all else equal, parents of children at the top of the ability distribution earn \$152,900 more on average than parents of children at the bottom of the ability distribution. We assume the joint distribution is time invariant.

Table 1 reports the correlation between ability, observed parental income, and enrollment. All the correlations are significant at more than a 99.9% confidence level. We use the correlation between ability and enrollment as a calibration target and the correlation between enrollment and parental income as an untargeted prediction of the model.

[12] The NLSY79 top-codes at the 2% level by replacing the true value with the conditional mean of the top 2%. In this estimation, we bound the observed value at the 2% threshold value.

	Ability	Parental Income	Enrollment
Ability	1.0000		
Parental Income	0.3164	1.0000	
Enrollment	0.5216	0.2952	1.0000

Table 1: Correlations Between Ability, Parental Income, and Enrollment

3.1.2 College Students

For our specification of the expected family contribution function $EFC(s_Y)$, we use an approximation from Epple et al. (2013) to the true statutory formula. Specifically, we assume a mapping between raw and adjusted gross parental income of $\tilde{y}(y_p) = y(1 + .07 \cdot \mathbf{1}[y \geq \$50000])$ and an EFC formula given by $EFC(y_p) = \max\{\tilde{y}(y_p)/5.5 - \$5{,}000, \tilde{y}(y_p)/3.2 - \$16{,}000, 0\}$ in 2009 dollars.

We assume that the government grants $\zeta(T + \phi, EFC(s_Y))$ are given by

$$\zeta(T(s_Y) + \phi, EFC(s_Y)) = \begin{cases} \zeta^F\overline{\zeta} & \text{if } \zeta^F\overline{\zeta} \leq T(s_Y) + \phi - EFC(s_Y) \\ 0 & \text{otherwise} \end{cases}, \tag{12}$$

which reflects their progressive nature. First, we estimate the average value of government grants $\overline{\zeta}$ from the college-level Integrated Postsecondary Education Data (IPEDS) published by the National Center for Education Statistics (NCES). Then, we calibrate $\zeta^F \geq 1$ to match average grants per student, $\overline{\zeta}$, in the initial steady state. Over the transition path we keep ζ^F constant but vary $\overline{\zeta}$.

The utility function $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$ for students as well as workers and retirees features constant relative risk aversion. We use the standard parametrization of $\sigma = 2$ and $\beta = 0.96$. We assume utility from college quality is linear, $v(q) = q$ (and so all curvature comes from the production function $q(\theta, I)$).

To determine student earnings e_Y while in college, we again turn to the NLSY97. For our sample, students enrolled in a 4-year college earn on average \$7,128 (in 2010 dollars).[13] We convert this to model units and set e^Y equal to it. The mapping from dollars into model units is discussed in section Web Appendix B.1 .

Recall that the annual retention rate satisfies $\pi_{j+1} = \pi\mathbf{1}[j + 1 \leq J_Y]$, which implies constant progression probabilities for students in years $1, \cdots, J_Y - 1$. Students in their last year, which we set to $J_Y = 5$, successfully graduate and earn a diploma with this same probability. We set $\pi = 0.556^{1/J_Y}$ to match the aggregate completion rate of 55.6% reported

[13] Students work an average of 824 hours a year in the NLSY97. Using different data, Ionescu (2011) reports similar results of 46% of full-time students working with mean worker earnings of \$20,431 in 2007 dollars.

by Ionescu and Simpson (2015).

Lastly, we allow the non-tuition cost of attending college ϕ, which plays a significant part in determining eligibility for subsidized loans, to vary over the transition path. We measure ϕ using room-and-board estimates from the NCES (NCES, c).

3.1.3 Workers/Retirees

The earnings process for working households follows

$$\begin{aligned} \log e_{ijt} &= \lambda_t h_i / J_Y + \mu_j + z_{ij} + \nu \\ z_{i,j+1} &= \rho z_{ij} + \eta_{i,j+1} \\ \eta_{i,j+1} &\sim N(0, \sigma_z^2) \end{aligned} \tag{13}$$

where h_i is the number of completed years of college, i is an individual identifier, j is age, and t is time. Households who begin working at age j draw z_{ij} from an unconditional distribution with mean zero and and variance $\sigma_z^2(1 + \ldots + \rho^{2(j-1)})$. For the persistent shock, we use Storesletten, Telmer, and Yaron (2004)'s estimates in setting $(\rho, \sigma_z) = (0.952, 0.168)$.[14] The deterministic earnings profile μ_j is a cubic function of age with coefficients also taken from Storesletten et al. (2004).[15]

In the model, λ_t represents the earnings premium for college graduates relative to high school graduates. We compute λ_t using the estimates from Autor et al. (2008), which range from roughly 0.43 in the 1960s and 1970s to 0.65 in the early 2000s. To deal with the fact that Autor et al. (2008) estimate values only up until 2005, we fit a quadratic polynomial over 1988–2005 and extrapolate for 2006–2010.[16] We use the fitted values (both in-sample and out-of-sample) for λ_t, and they are presented in Web Appendix A (Web Appendix B gives a comparison of the raw and fitted values).

Retired households ($j > J_R = 48$) have constant earnings given by $\log e_{ijt} = \log(0.5) + \lambda_t h_i / J_Y + \mu_{J_R} + \nu$, which yields an average replacement rate of roughly 50%.

3.2 Legal Environment and Government Policy

We set the duration of loan repayment to its value in the Federal Student Loan Program, $t_{max} = 10$. Two parameters—the loan balance penalty η and garnishment rate γ—control

[14] Storesletten et al. (2004) let σ vary with the business cycle and estimate $\sigma = .211$ for recessions and $\sigma = .125$ for expansions. We average these.

[15] In principle, one could include a cohort-specific term that allows for average log earnings in the economy to grow over time. However, we found that such a term is negligible in the data as we show in Web Appendix B.1 .

[16] The "1987" college premium corresponds to the average from 1981 to 1987.

the cost of student loan delinquency. Various changes in student loan default laws between 1987 and 2010 render obtaining values for these parameters less than straightforward.[17] Our approach sets $\eta = 0.05$, (which is half the value in Ionescu, 2011, and only a fifth of the current statutory maximum) and then pins down γ in the joint calibration to match the 17.6% student loan default rate in 1987.

3.3 Colleges

We need to parametrize and provide estimates for the per-student endowment E, the quality production function $q(\theta, I)$, and custodial costs $F + C(\{N_j\}_{j=1}^{J_Y})$.

3.3.1 Institution-Level Data

Our primary source for college revenue and expenditures is institution-level data from the Delta Cost Project (DCP), which is drawn from the National Center for Education Statistics' Integrated Postsecondary Education Data System (IPEDS). One important distinction between our DCP-based average tuition measures and those reported by the NCES (in Table 330.10) is that, for public colleges, the NCES only uses in-state tuition.[18] Consequently, the gross tuition and fees in our data are larger than those reported by the NCES. However, despite this discrepancy in levels, figure 1 shows that the trend growth in gross tuition and fees between the two measures is nearly identical.

For sample selection, we restrict attention to four-year, non-profit, non-specialty institutions (according to their Carnegie classification) that have non-missing enrollment and tuition data in every year of the DCP data from 1987 to 2010.[19] Additionally, we drop institutions with fewer than 100 full-time-equivalent (FTE) students or net tuition per FTE outside of the 1-99th percentile range.

The college budget constraint in the model features custodial costs, endowment income, quality-enhancing investment, and tuition. The corresponding data measures are as follows:

- Endowment: total non-tuition revenue, which is the sum of (non-Pell) grants at the federal, state, and local levels plus all auxiliary revenue.

- Investment: total education and general expenditures including sponsored research but excluding auxiliary enterprises.

[17] See Ionescu (2011) for changes in student loan default laws.

[18] This difference in methodologies accounts for the mismatch in reported tuition numbers brought up by our discussant, Sandy Baum.

[19] DCP data is released at a multi-year lag, and all indications are that changes in college tuition continue to outpace inflation.

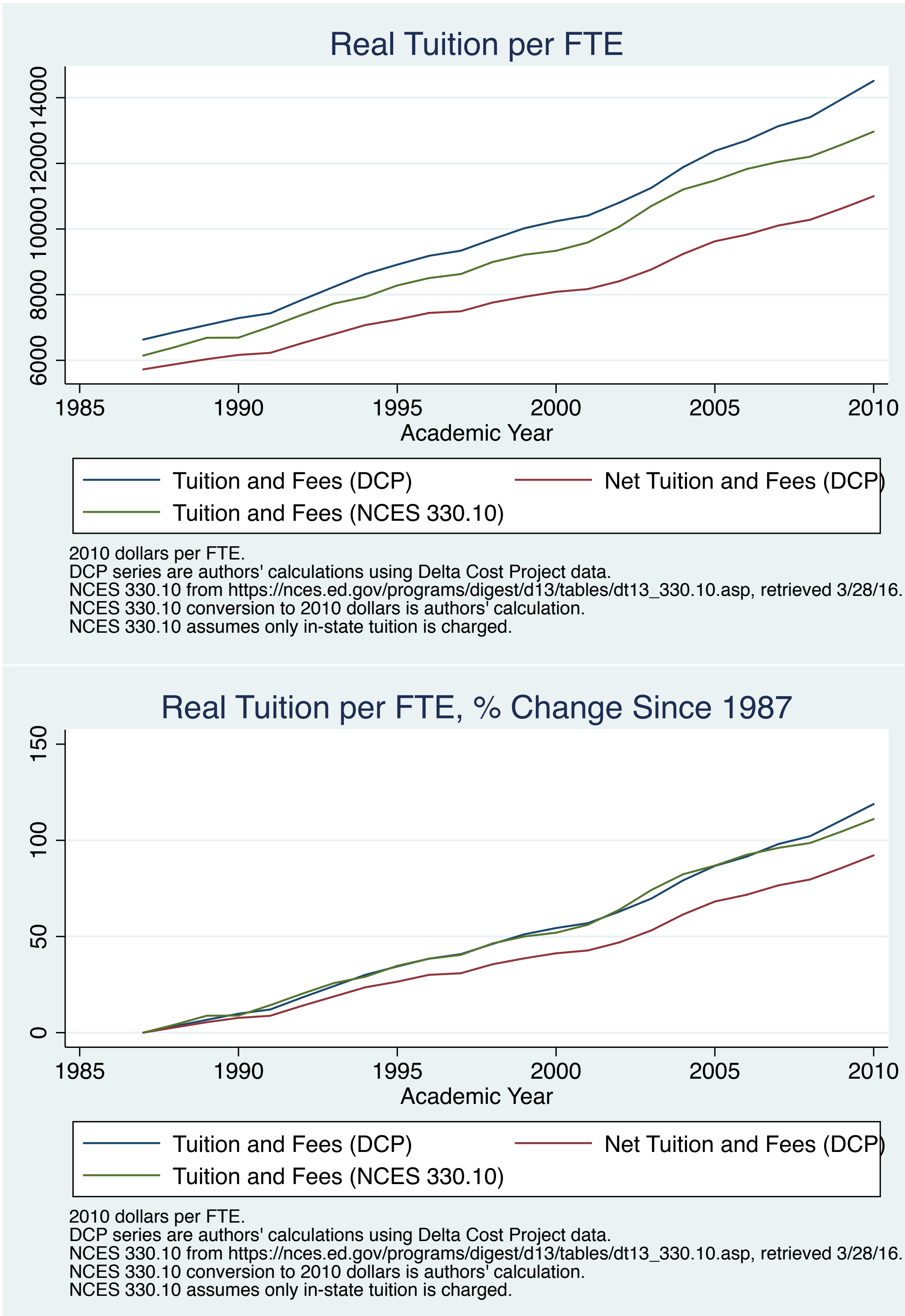

Figure 1: College Tuition Trends: DCP vs. NCES.

- Tuition: net tuition and fees revenue.
- Custodial costs: a residual computed as the endowment plus tuition less investment.

Web Appendix A provides more details on our use of the DCP data.

3.3.2 Calibrated Parameters

We set the per-student endowment E equal to non-tuition revenues per FTE student in the 1987 IPEDS data, and then we vary E along the transition path. Figure 2 plots the time series for E and other key aggregates. For college quality, we follow Epple et al. (2013) and choose a Cobb Douglas functional form, $q(\theta, I) = \chi_q \theta^{\chi_\theta} I^{\chi_I}$, where $\chi_I = 1 - \chi_\theta$.[20]

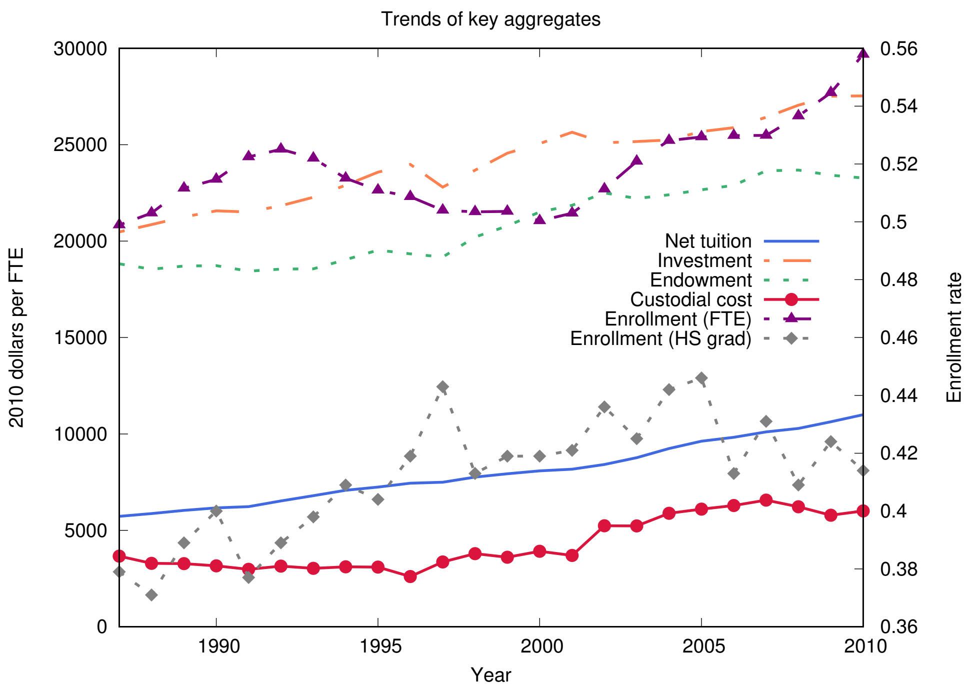

Figure 2: College Cost, Expenditure, and Enrollment Trends.

The local first-order conditions of the college problem provide some insight into calibrating χ_θ and χ_q. The key tuition-pricing condition comes out to

$$T(s_Y) + \frac{\mathbb{P}(\text{enroll}|s_Y; T(\cdot), q)}{\partial \mathbb{P}(\text{enroll}|s_Y; T(\cdot), q)/\partial T} = C'(N) + I + \frac{q_\theta}{q_I}(\theta - x(s_Y)) \tag{14}$$

[20]In principle, $q(\theta, I)$ need not satisfy constant returns to scale. With one college, it is difficult to pin down—using only steady state information—what the returns should be. With multiple colleges, dispersion in θ and I translates into dispersion in q that is controlled by returns to scale.

where $\mathbb{P}(\text{enroll}|s_Y;T(\cdot),q)$ comes from the decision rule of youths for whether to attend college, taking into account the idiosyncratic preference shock ϵ. Epple et al. (2013) label the collected right-hand side terms the "effective marginal cost" EMC of a type-s_Y student, which captures the fact that students act both as customers *and* as inputs to the production of quality (an argument put forth by Winston, 1999, and others). The above equation states that colleges admit any student to whom they can charge at least $EMC(s_Y)$.

With our Cobb-Douglas specification, $\frac{q_\theta}{q_I} = \frac{\chi_\theta}{\chi_I}\frac{I}{\theta} = \frac{\chi_\theta}{1-\chi_\theta}\frac{I}{\theta}$. The degree to which $EMC(s_Y)$, and therefore tuition $T(s_Y)$, varies by student type depends on χ_θ. This price discrimination generates cross-sectional enrollment patterns that we use to target χ_θ and χ_q. Specifically, we target overall enrollment and the correlation between parental income and enrollment.

3.3.3 Cost Function Estimation

Like in Epple et al. (2006), we estimate the college's custodial cost function directly. In particular, we assume that the custodial costs by class, $c(n)$, have the functional form $C^1 n + C^2 n^2$. When we explicitly allow for time-varying coefficients, custodial costs satisfy

$$F_t + C_t(\{N_{jt}\}_{j=1}^{J_Y}) = F_t + C_t^1 \sum_{j=1}^{J_Y} n_{jt} + C_t^2 \sum_{j=1}^{J_Y} n_{jt}^2 \tag{15}$$

where $n_{jt} \equiv \frac{N_{jt}}{1/J}$ is class j enrollment in year t relative to the age-18 population.

To identify F_t, C_t^1, and C_t^2, we estimate cost functions for individual colleges using IPEDS data and then aggregate them. Let college i's cost function at time t be given by

$$\mathfrak{c}_{it} = \alpha_i + \mathfrak{c}_t^0 + \mathfrak{c}_t^1 \sum_{j=1}^{J_Y} n_{ijt} + \mathfrak{c}_t^2 \sum_{j=1}^{J_Y} n_{ijt}^2 + \varepsilon_{it}. \tag{16}$$

Here, α_i is a fixed effect and both α_i and ε_{it} are i.i.d. normally distributed with mean zero.

The IPEDS data contains enrollment information but not its composition by class. To deal with this problem and to create consistency with the model, we assume a constant retention rate π and a five-year college term, $J_Y = 5$. Given π, J_Y, and total FTE enrollment data by school relative to the age 18 population, we calculate implied class j enrollment as $n_{ijt} = \pi^{j-1} FTE_{it} / \sum_{\iota=1}^{J_Y} \pi^{\iota-1}$. Thus, the two summation terms in the cost function come out to $\sum_{j=1}^{J_Y} n_{ijt} = FTE_{it}$ and $\sum_{j=1}^{J_Y} n_{ijt}^2 = FTE_{it}^2 \sum_{j=1}^{J_Y} \pi^{2(j-1)} / (\sum_{j=1}^{J_Y} \pi^{j-1})^2$. As a result,

$$\mathfrak{c}_{it} = \alpha_i + \mathfrak{c}_t^0 + \mathfrak{c}_t^1 FTE_{it} + \mathfrak{c}_t^2 FTE_{it}^2 \frac{\sum_{j=1}^{J_Y} \pi^{2(j-1)}}{(\sum_{j=1}^{J_Y} \pi^{j-1})^2} + \varepsilon_{it}. \tag{17}$$

As in Epple et al. (2006), we measure custodial costs as a residual in the college budget constraint, which gives us

$$\mathfrak{c}_{it} \equiv \mathfrak{e}_{it} + \mathfrak{t}_{it} - \mathfrak{i}_{it}. \tag{18}$$

The first term, $\mathfrak{e}_{it}$, represents total non-tuition revenue in IPEDS (which consists mostly of endowment revenue and government appropriations), while $\mathfrak{t}_{it}$ and $\mathfrak{i}_{it}$ equal net tuition revenues and total education and general (E&G) expenditures, respectively. Intuitively, our cost measure reflects the fact that, holding investment $\mathfrak{i}_{it}$ constant, higher costs must accompany any observed increase in revenues in order to maintain a balanced budget. Using these definitions, we run the fixed effects panel regression above to obtain $\{(\mathfrak{c}_t^0, \mathfrak{c}_t^1, \mathfrak{c}_t^2)\}_{t=1987}^{2010}$.

To translate the individual cost function estimates into the aggregate cost function, we sum costs over colleges. In particular, to calculate the total cost of educating $\{N_{jt}\}_{j=1}^{J_Y}$ students, we assume students sort across colleges $i = 1, \ldots, K$ in proportion to the observed share in the data.[21] Define $s_{ijt} \equiv N_{ijt}/N_{jt} = n_{ijt}/n_{jt}$ as the share of students in class j at time t who attend college i. From our assumption of geometric retention probabilities, this share does not vary with j, i.e., $s_{ijt} = s_{it}$. Thus, $N_{ijt} = s_{it}N_{jt}$ and $n_{ijt} = s_{it}n_{jt}$ for all j, which gives us[22]

$$F_t + C_t(\{N_{jt}\}_{j=1}^{J_Y}) = K\mathfrak{c}_t^0 + \mathfrak{c}_t^1 \sum_{j=1}^{J_Y} n_{jt} + \left(\mathfrak{c}_t^2 \sum_{i=1}^{K} s_{it}^2\right) \sum_{j=1}^{J_Y} n_{jt}^2. \tag{19}$$

This mapping between individual colleges and the representative college yields $F_t = K\mathfrak{c}_t^0$, $C_t^1 = \mathfrak{c}_t^1$, and $C_t^2 = \mathfrak{c}_t^2 \sum_i s_{it}^2$.

The web appendix presents the estimates. We found it necessary to impose $\mathfrak{c}_t^1 = 0$ to ensure an increasing aggregate cost function over the relevant range of N. Figure 3 plots the aggregate cost function over time and circles the realized values from each year.

3.4 Joint Calibration

We determine the remaining parameters $(\nu, \xi, \gamma, \chi_\theta, \chi_q, \zeta^F, \alpha)$ jointly such that the initial steady state matches the following moments in 1987: average earnings, average net tuition, the two-year cohort default rate, the correlation between parental income and enrollment, the enrollment rate, the average grant size, and the percent of students with loans.[23]

[21] We allow K to vary over time in the estimation (it is the number of colleges in the sample) but treat it as fixed here to simplify the exposition.

[22] We assume that $\sum_i \alpha_i = 0$ and $\sum_i \varepsilon_{it} = 0$, where the first assumption is required for identification in the fixed effects regression.

[23] The correlation between parental income and enrollment is from NLSY97 (and so is not a 1987 moment).

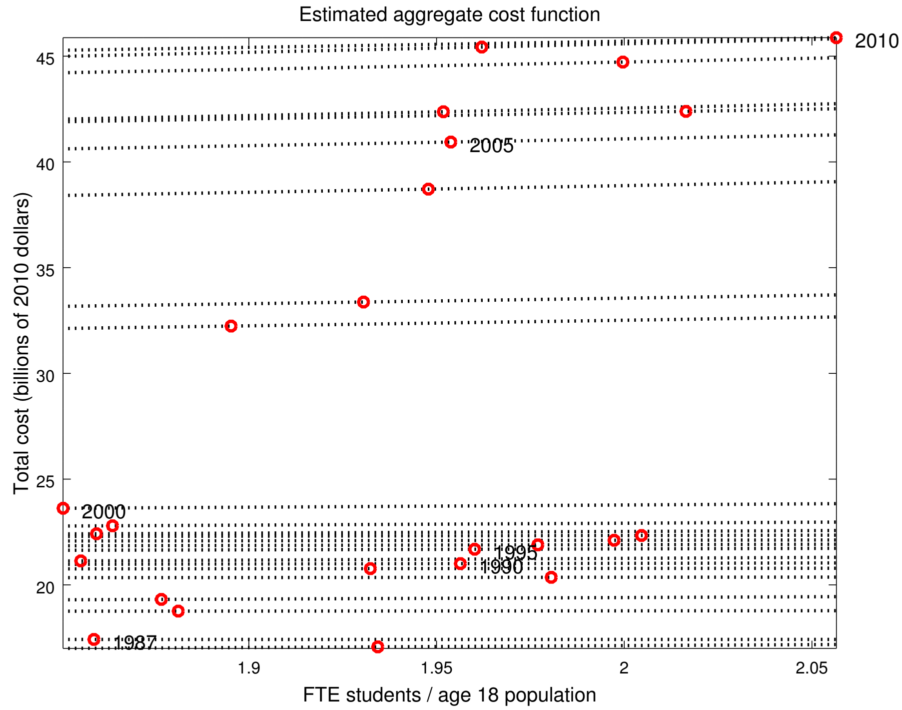

Figure 3: Estimated Aggregate Cost Function by Year

Table 2 summarizes the calibration. Note that, while the table associates each parameter in the joint calibration with an individual moment, the calibration identifies the parameters simultaneously, rather than separately. We discuss model fit next.

3.5 Model Fit

Table 3 presents key higher education statistics from the model and the data. The calibration of the initial steady state directly targets the first set of statistics from 1987, while the remaining statistics act as an informal test of the model. Note that, while the calibration matches mean earnings, net tuition, and the two-year default rate from 1987 quite well, the model generates too little enrollment and too many students with loans.

We pinpoint two sources for these shortcomings. First, the presence of only one college in the model generates too much market power, which results in a small calibrated value for the parental transfers parameter ξ in order to still match average net tuition. Thus, students rely more on borrowing. Second, by omitting ability terms in the post-college earnings process, we implicitly attribute the entire college premium to the sheepskin effect of a diploma (as opposed to selection effects). This exaggerated sheepskin effect generates a larger surplus from attending college, which the college partially captures through higher tuition.

Table 2: Model Calibration

Description	Parameter	Value	Data	Model	Target/Reason
Calibration: Independent Parameters					
Discount factor	β	0.96			Standard
Risk aversion	σ	2			Standard
Savings interest rate	r^*	0.02			Standard
Borrowing premium	ι	0.107			12.7% rate on borrowing
Earnings in college	e_Y	$\$7{,}128_{2010}$			NLSY97
Loan balance penalty	η	0.05			Ionescu (2011)
Loan duration	t_{max}	10			Statutory
Retention probability	π	$0.554^{1/5}$			55.4% completion rate
Earnings shocks	(ρ, σ_z)	(0.952,0.168)			Storesletten et al. (2004)
Age-earnings profile	μ_j	Cubic			Storesletten et al. (2004)
College premium	$\{\lambda\}$	Web Appendix A			Autor et al. (2008)
Non-tuition costs	$\{\phi\}$	Web Appendix A			IPEDS
Student loan rate	$\{i\}$	Web Appendix A			Statutory
Annual loan limits	$\{\bar{b}^s_j, \bar{b}^u_j, \bar{b}_j\}$	Web Appendix A			Statutory
Aggregate loan limits	$\{\bar{l}^s, \bar{l}^u, \bar{l}\}$	Web Appendix A			Statutory
Custodial costs	$\{F, C^2\}$	Web Appendix A			IPEDS regression
Endowment flow	$\{E\}$	Web Appendix A			IPEDS
Grant aid	$\{\bar{\zeta}\}$	Web Appendix A			IPEDS
Calibration: Jointly Determined Parameters					
Earnings normalization	ν	-1.25	31385	31686	Mean earnings
Parental transfers	ξ	0.208	5723	6146	Mean net tuition
Garnishment rate	γ	0.158	0.176	0.165	Two-year default rate
Ability input to quality	χ_θ	0.252	0.295	0.244	Corr(p. income,enroll)
College quality loading	χ_q	2.68	0.379	0.358	Enrollment rate
Grant progressivity	ζ^F	1.85	0.027	0.025	Average grant size
Preference shock size	α	290	0.357	0.488	Percent with loans

Note: $\{x\}$ means x has a transition path given in Table 2 in web appendix A; $\$x_{yyyy}$ means $\$x$, measured nominally in $yyyy$ dollars, converted to model units.

Despite the presence of too many student borrowers, the model actually generates smaller average loans than in the data—$4,600 vs. $7,100. Lastly, the model nearly matches investment per student of $20,300 in 1987 and the ratio of assets to income of about 3. The matching of the asset-to-income ratio reflects the fact that our model of households is, at its core, a standard incomplete markets life-cycle model.

4 Results

Now we present the main results. First, we compare the model's initial and terminal steady states to the data from 1987 and 2010. Next, we evaluate the transition path of the model in light of the time series data. Lastly, we undertake a number of counterfactual experiments to quantify the explanatory power of each tuition inflation theory.

4.1 Steady State Comparisons

4.1.1 Tuition

Of central importance, the model generates a 102% increase in average net tuition—from approximately $6,100 to $12,400—between the initial and terminal steady states. This jump compares to a 92% increase in the data. To illustrate how tuition changes, figure 4 plots slices of the tuition function (Web Appendix C gives the entire function).

In both steady states, tuition does not move monotonically with income. Instead, tuition in the initial steady state first increases with parental income before it starts to decline at income levels between $50,000 and $100,000 as financial aid eligibility tightens and grants decline. After $100,000, tuition resumes its ascent as student ability to pay increases. The tuition curves shift up noticeably between the two steady states, though not in a parallel fashion. In particular, the region of declining tuition compresses to the range between $75,000 and $100,000, which is largely due to the expansion in aid between 1987 and 2010.

The college engages in less price discrimination by academic ability than by parental income.[24] Inspection of the 100th percentile and 75th curves in 1987 reveals that tuition never differs by more than $700 between moderate and high ability students. By 2000, the largest tuition difference between the 75th and 100th percentiles of the ability distribution rises to $2,000.

When weighing whether to offer tuition discounts to high ability students, colleges face

[24] In fact, theoretically, tuition should be monotonically decreasing in ability. However, due to computational cost, we have parametrized the tuition function more flexibly in the income dimension to account for more variation there. See Web Appendix C for computation details.

	Model 1987	Data 1987	Model Final SS	Data 2010
Statistics Targeted in 1987				
Mean earnings[z]	$31686	$31385*	$37301	$36200
Mean net tuition[z]	$6146	$5723*	$12428	$10999
Two-year default rate[a]	0.165	0.176*	0.167	0.091
Enrollment rate[b]	0.358	0.379*	0.560	0.414
Graduation rate[c]	0.554	0.554*	0.554	0.594
Attainment rate (grad×enroll)[z]	0.198	0.210*	0.310	0.246
Percent taking out loans[ef]	48.8	35.7*	100.0	52.9
Corr(parental income,enrollment)	0.244	-	0.301	0.295*
Untargeted Statistics				
Investment per student[z]	$21921	$20475	$30701	$27534
Average EFC[defz]	$18288	$16270	$16514	$13042
Average annual loan size for recipients[defz]	$4589	$7144	$6873	$8414
Total assets / total income[dgz]	3.05	2.94	3.07	3.06
Student loan volume / total income[dhz]	0.012	-	0.053	0.050
Newly defaulted / non-defaulted loans[hz]	0.045	-	0.054	0.019
Newly defaulted / good standing borrowers[hz]	0.029	-	0.046	0.032
Pop with loans / age 18+ pop[hiz]	0.040	-	0.140	0.146
Ability of college graduates[z]	0.728	-	0.701	0.716
Corr(ability,enrollment)	0.588	-	0.782	0.522
Non-garnishment payments / total income	0.002	-	0.006	-
Garnishments / total income	0.000	-	0.001	-

*Targeted. Note: Unknown values are marked with "-".

Sources: [a]Dept. of Ed. (b); [b]NCES (a); [c]NCES (b); [d]FRED; [e]Tables 2 and 7 in Wei et al. (2004); [f]Tables 2.1-C and 3.3 Bersudskaya and Wei (2011); [g]BEA; [h]Dept. of Ed. (a); [i]Howden and Meyer (2011); and [z]authors' calculations.

Table 3: Steady State Statistics

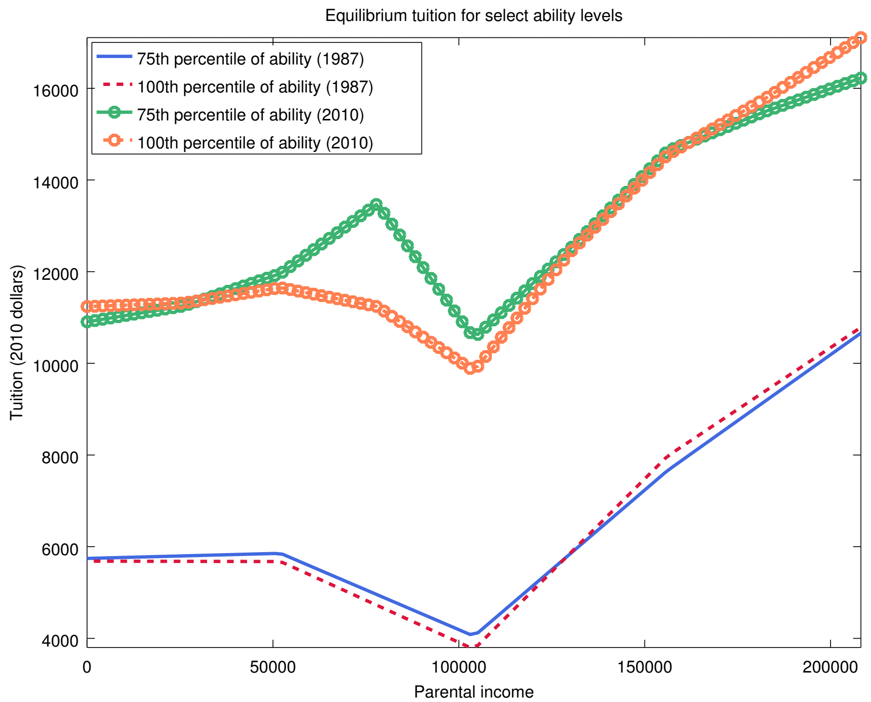

Figure 4: Slices of the Tuition Function

the trade-off between a higher ability student body and the need for resources to fund quality-enhancing investment expenditures. In our calibration, the latter effect dominates. The data provides supporting evidence. For instance, table 3, which presents selected statistics from the data and the initial and terminal steady states, shows that investment in the model increases by 40% between the two steady states. This increase approximates well the untargeted 34% rise in the data. While we lack data on student ability in 1987, the model's mean college graduate ability of 0.701 in 2010 closely matches the untargeted 0.716 from the data.

4.1.2 Enrollment

Figure 5 reveals how the enrollment patterns change between the steady states. Recall that the calibration targets the correlation between parental income and enrollment, and observe that average student ability aligns closely with the data in table 3. However, figure 5 unveils a striking polarization of enrollment by income in the initial steady state. Specifically, middle-income students find themselves priced out of college, enrolling at a rate of less than 50%.

As shown in equation 14, colleges set tuition by charging each student their type-specific effective marginal cost $EMC(s_Y)$ plus a markup that reflects the student's willingness to pay. Given that effective marginal cost only depends on the ability component $x(s_Y)$ of each student's type, all tuition variation within ability types derives from the impact of

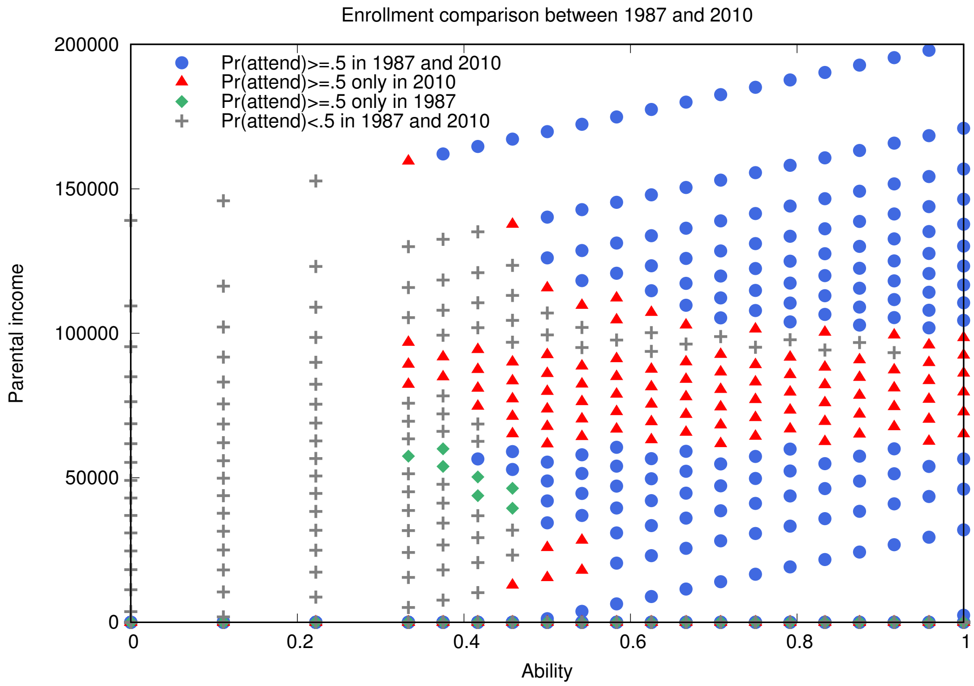

Figure 5: Attendance

parental income and access to financial aid on student willingness to pay.[25] Furthermore, in the absence of preference shocks (the limiting case as $\alpha \to \infty$), colleges first only admit students that have a willingness to pay that exceeds their effective marginal cost, and then they proceed to charge tuition that extracts the entire surplus.

High-income students have a high willingness to pay because of parental transfers, while low-income students, despite lacking parental resources, have a high willingness to pay because of access to financial aid. Middle-income students find both of these avenues closed, in large part because each \$1 increase in parental income reduces access to subsidized borrowing by \$1 but only delivers $\xi \approx .21$ dollars of additional resources to the student. Consequently, these students cannot afford to pay the full net tuition directly and also lack eligibility for subsidized loan borrowing, which represents the only form of student loans accessible in 1987. The college responds to the higher demand elasticity of these students by reducing their tuition, but the decrease does not prove sufficient to prevent low enrollment of middle-income students in the initial steady state.

By 2010, the introduction of unsubsidized loans and repeated expansions in grants and subsidized borrowing induces middle-income students to flood into higher education. These

[25] Replicated here: $T(s_Y) + \underbrace{\frac{\mathbb{P}(\text{enroll}|s_Y; T(\cdot), q)}{\partial \mathbb{P}(\text{enroll}|s_Y; T(\cdot), q)/\partial T}}_{(\partial \log \mathbb{P}/\partial T)^{-1}} = \underbrace{C'(N) + I + \frac{q_\theta}{q_I}(\theta - x)}_{EMC(s_Y)}$

innovations partly explain the increase in enrollment from 36% to 56% across steady states, as reported in table 3. The data show a more subdued rise from 38% to 41%.

4.1.3 Borrowing and Default

As we just explained, the enrollment surge between the initial and terminal steady states comes primarily from high-ability, middle-income youths who benefit from the introduction of unsubsidized loans and expansion of subsidized aid. In fact, in the terminal steady state, every single college student participates at least minimally in student borrowing (recall that $\beta = 0.96$ and the loan interest rate in 2010 is 3%, which makes student loans an attractive form of borrowing). Empirically, the percentage of students with loans increases more moderately from 35.7% to 52.9%. That said, although the model greatly overestimates participation in the student loan program, it generates an average loan size of only \$6,900 compared to \$8,400 in the 2010 data.

The model delivers almost no change in the 17% student loan default rate across steady states. The data, by contrast, show a significant fall from 17.6% to 9.1%. This discrepancy largely comes from the fact that legal changes between 1987 and 2010 increased the cost of student loan default, whereas we abstract from such changes in the model.

4.2 Transition Path Dynamics

Given that we have constructed a rich time series of borrowing limits, the college premium, college endowments, and measured custodial costs, we can gain further insights by analyzing the entire transition path of the model. Figure 6 plots the path of net tuition, enrollment, and investment expenditures in both the model and the data.

While investment per student in the model lines up well with the data, equilibrium net tuition follows a different trajectory than net tuition in the data. In particular, equilibrium net tuition in the model rises by a similar amount to the data, but whereas model net tuition rises rapidly between 1993 and 1997 before stagnating, empirical net tuition increases gradually during the entire time period. As the next section will make clear, equilibrium net tuition in the model reacts strongly to the expansion in financial aid (especially the introduction of unsubsidized loans) following the re-authorization of the Higher Education Act in 1992. Although the college premium increased from 0.46 to 0.58 log points between 1987 and 1993, many middle-income households lacked the resources or borrowing capacity to take advantage by enrolling in college.

We can only speculate as to why net tuition in the data does not accelerate in 1993. To the extent that political concerns partially govern the setting of tuition, colleges may

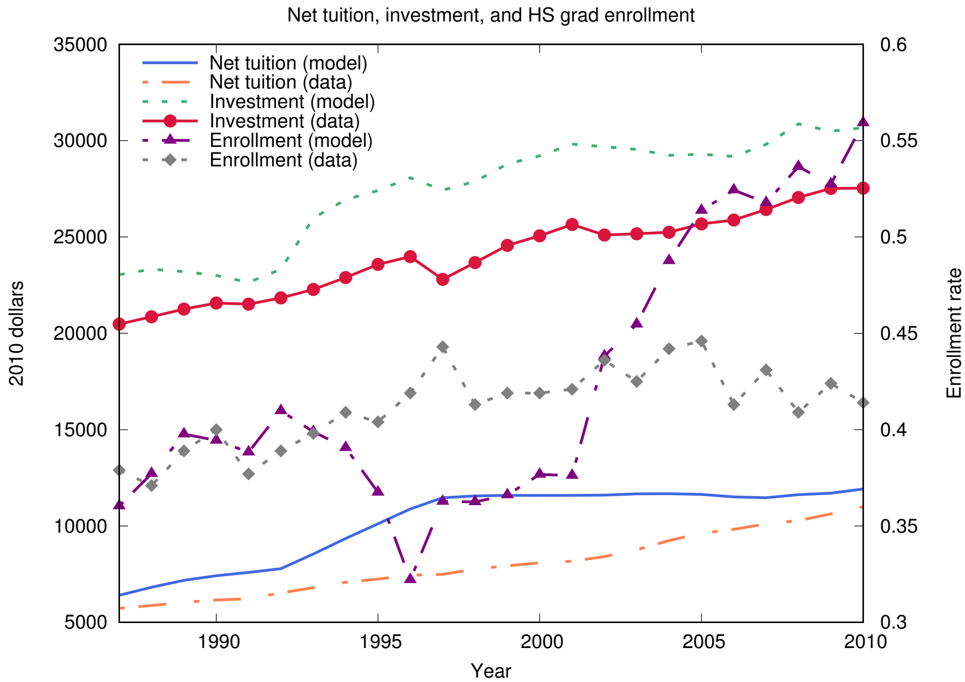

Figure 6: Comparison of Model and Data Over the Transition

prefer to spread out tuition increases over longer time horizons rather than announce rapid escalations. Alternatively, students may not have accurately forecasted the persistent rise in the college premium, whereas our solution method assumes perfect foresight. Lastly, colleges may engage in some form of tacit collusion that takes time to implement, which our model does not capture because of the representative college assumption.

The overly rapid tuition increases in model may also explain the divergent pattern in enrollments between 1993 and 1998. In particular, the data enrollments increase steadily whereas model enrollments fall substantially. Had the college in the model "smoothed" tuition over this period, enrollments might not have fallen so sharply.

4.3 Assessing the Theories of Tuition Inflation

Our model successfully replicates the rapid increase in net tuition, and hence it is useful to now ask our main question of *why* net tuition has almost doubled since 1987. We quantify the role of the following factors in this tuition rise: i) changes in custodial costs and non-tuition sources of revenue, such as endowments and state support (supply shocks); ii) changes in student loan borrowing limits, interest rates, grant aid, and non-tuition costs, such as room and board (demand shocks); and iii) macroeconomic forces, namely, the rise in the college wage premium.

We undertake the tuition decomposition from two different angles. First, we progressively solve the model by implementing only *one* of the broad categories of shocks at a time, which answers the question "How much would tuition have gone up if *only* X had occurred?" Then we sequentially shut down the supply shocks, demand shocks, and the college wage premium one at a time. This approach allows us to answer the question "How much would tuition have gone up if X had *not* occurred?" Lastly, we break down the effect of the individual factors that constitute our categorizations. In all the experiments, we solve for the tax rate that ensures a balanced budget for the government.

4.3.1 Demand Shocks: The Bennett Hypothesis

Table 4 summarizes the decomposition through some key statistics. With all factors present, net tuition increases from \$6,100 to \$12,400. As column 4 demonstrates, the demand shocks—which consist mostly of changes in financial aid—account for the lion's share of the higher tuition. Specifically, with demand shocks alone, equilibrium tuition rises by 91%, almost fully matching the 102% from the benchmark. By contrast, with all factors present *except* the demand shocks (column 7), net tuition only rises by 14%.

These results accord strongly with the Bennett hypothesis, which asserts that colleges respond to expansions of financial aid by increasing tuition. In fact, the net tuition response to the demand shocks in isolation restrains enrollment to only grow from 36% to 38%. Furthermore, the students who *do* enroll take out \$6,900 in loans compared to \$4,600 in the initial steady state. The college, in turn, uses these funds to finance an increase of investment expenditures from \$21,900 to \$27,700 and to enhance the quality of the student body. In particular, the average ability of graduates increases by 4 percentage points (pp). Lastly, the model predicts that demand shocks in isolation generate a surge in the default rate from 17% to 32%. Essentially, demand shocks lead to higher costs of attendance and more debt, and in the absence of higher labor market returns, more loan default inevitably occurs.

Importantly, we view this effect as an upper bound for the Bennett hypothesis. Given our representative college assumption, only the unobservable preference shocks prevent the college from extracting the entire surplus from its student body. Table 4 illustrates this market power in the small variation in ex-ante utility across the decompositions (for any experiment, the consumption equivalent variation is less than 2% relative to 1987). Greater competition would restrict rent extraction and give rise to different pricing patterns.

Statistic	1987	Experiment						2010
College costs				*		*	*	*
College endowment				*		*	*	*
Borrowing limits			*		*		*	*
Interest rates			*		*		*	*
Non-tuition cost			*		*		*	*
Grants			*		*		*	*
College premium		*			*	*		*
Mean net tuition	$6146	$7412	$11733	$5681	$13274	$7020	$11131	$12428
Std. net tuition	$1263	$1328	$1347	$1558	$1270	$1138	$1405	$1320
Enrollment rate	0.36	0.37	0.38	0.53	0.35	0.54	0.52	0.56
Two-year default rate	0.17	0.15	0.32	0.17	0.17	0.15	0.32	0.17
Mean loan (recipients)	$4589	$4690	$6876	$4692	$6872	$4676	$6877	$6873
Pct. taking out loans	48.8	54.1	100.00	49.6	100.00	58.6	100.00	100.00
Mean earnings	$31686	$34179	$31870	$33445	$33884	$37001	$33306	$37301
Corr(p.income,enroll)	0.24	0.20	0.36	0.20	0.33	0.10	0.32	0.30
Corr(ability,enroll)	0.59	0.63	0.73	0.51	0.68	0.51	0.78	0.78
Ability of graduates	0.73	0.74	0.77	0.64	0.77	0.64	0.72	0.70
Investment	$21921	$23304	$27653	$23684	$29019	$25140	$29007	$30701
Average EFC	$18288	$17140	$18892	$16509	$18487	$14833	$16992	$16514
Ex-ante utility	-40.98	-40.92	-40.84	-40.61	-40.72	-40.49	-40.51	-40.19

* means the value change over the transition

Table 4: Experiments

4.3.2 Macroeconomic Forces: The Rising College Wage Premium

The rise in the college wage premium also contributes to higher tuition, albeit more modestly. If only the college wage premium had changed between 1987 and 2010, the model predicts that net tuition would have gone up by 21%. In its absence, but with all other shocks present, tuition would have gone up by 81%. Interestingly, the rise in the college wage premium generates barely any increase in enrollment. Instead, average student body ability rises by 1 pp, and the correlation between ability and enrollment increases from 0.59 to 0.63, while the correlation between parental income and enrollment falls from 0.24 to 0.2. Limitations in borrowing capacity for (mostly middle-income) students in 1987 act as a binding constraint that prevents enrollments from responding strongly to labor market changes.

4.3.3 Supply Shocks: Cost Disease and Changing Non-Tuition Revenue

Lastly, our results paint a nuanced picture of how cost disease and movements in non-tuition revenue (e.g. state support) affect tuition. In the model, tuition actually *falls* in response to the supply shocks alone. Specifically, when we feed in the empirical time series estimates for custodial costs and college endowments (which summarize all non-tuition revenue) but leave all other parameters at their initial 1987 levels, equilibrium tuition decreases from $6,100 to $5,700. Enrollment, by contrast, surges from 36% to 53%.

Table 5 decomposes the impact of each supply shock. As shown in column 2 of the experiments, omitting the change in college endowments has no impact on average net tuition relative to the 2010 equilibrium which incorporates the endowment change. Note, however, that by aggregating all sources of non-tuition revenue and lumping together public and private institutions, this analysis does not directly address the issue of stagnant state support raised by our discussant, Sandy Baum. In fact, according to figure 2, total non-tuition revenue actually *increases* by approximately $4,500 between 1987 and 2010. Even restricting attention to public institutions, figure 7 shows that the growth in auxiliary revenues dominates the initially stagnant and subsequently declining trend in state support. In future work, we plan to directly address the impact of declining state support in a disaggregated framework that explicitly distinguishes between public and private institutions.[26]

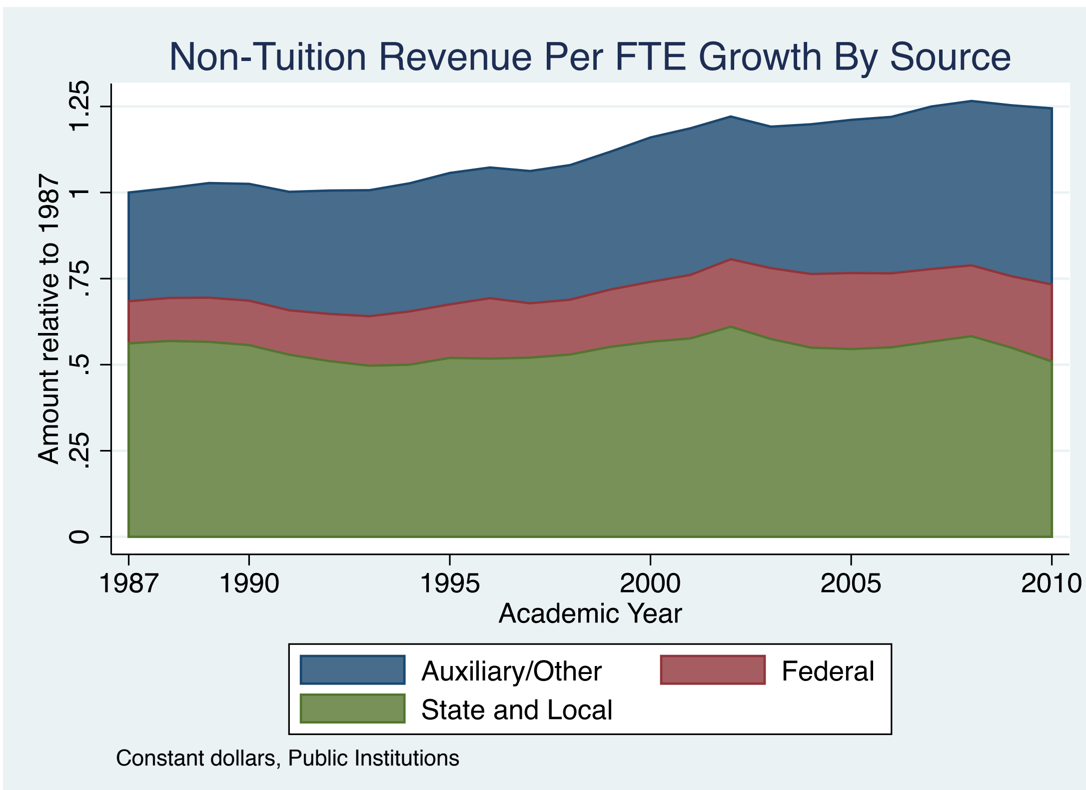

Figure 7: Non-Tuition Revenue at Public Institutions

[26] The negative relationship between tuition/fees and state funding per FTE mentioned by Sandy Baum—which can also be found in figure 12A of Ma, Baum, Pender, and Welch (2017)—has multiple possible interpretations. One way is to view state funding reductions as a causal mechanism for tuition hikes. Alternatively, legislative delays that cause state appropriations to be adjusted with a lag may explain the correlation. In this scenario, if demand increases, students are willing to pay higher tuition while state funding per FTE falls mechanically because of higher enrollment. The countercyclicality of enrollment (established by Betts and McFarland (1995) and Dellas and Koubi (2003)) and procyclicality of public appropriations lend some credibility to this argument, but more research is needed to weigh the merits of each interpretation.

Table 5 also addresses the isolated impact of custodial costs. Perhaps surprisingly, upward shifts in the custodial cost function between 1987 and 2010 actually *reduce* tuition inflation by approximately \$1,000, as seen by comparing the first experiment with the 2010 column. Rather than raise tuition, the college responds to higher custodial costs by cutting quality through reduced investment and expanded enrollment of lower ability students. Two factors account for this divergence from the familiar cost disease narrative: the quality-maximizing objective function of the college and the role of fixed costs.

For intuition, consider a simplified framework with homogeneous students who each have ability x and some fixed parental income. Further, assume there are no preference shocks. In this context, the college sets tuition T to extract the entire student surplus, independent of the custodial cost function. Thus, given T (which is common across students due to their homogeneity), the college simply chooses the number of students to admit:

$$\max_{I,N} q(x, I) \text{ s.t. } IN + C(N) = TN + EN \Leftrightarrow \max_{N} q\left(x, T + E - \frac{C(N)}{N}\right).$$

With x constant, quality is effectively only a function of investment I, which the college maximizes by minimizing average costs $C(N)/N$. In the case of a quadratic cost function, $C(N) = c_0 + c_1 N + c_2 N^2$, average costs are minimized at $N = \sqrt{c_0/c_2}$, which is *increasing* in the fixed cost term and *does not depend* on the marginal cost term c_1. Consequently, in this simple model, higher fixed costs lead to increased enrollment, unchanged tuition, and reduced investment. By contrast, if the college were to maximize *total* investment IN, enrollment would satisfy $T + E = C'(N)$, which more closely resembles the familiar optimality condition of a profit-maximizing firm where changes in fixed costs have no effect on the optimal quantity (here, enrollment) choice.

Our regression estimates show that rising fixed costs between 1987 and 2010 are the dominant cost trend, and the simple model provides some intuition as to why the college responds by increasing enrollment. With student heterogeneity, the increased enrollment results in admission of lower ability students and/or students with lower willingness to pay. The result is lower expenditures I (as in the simple example) and lower average ability θ.

Several factors caution us from boldly claiming that Baumol's cost disease is unimportant for tuition increases. First, the current model abstracts from the possibility of a rising relative price of college investment (i.e. pI instead of I). Second, we assume that colleges can freely re-optimize each period without regard for their previous investment and hiring choices. In reality, the need to pay the salaries of tenured faculty and cover maintenance on existing buildings may alter a college's response to shifting costs. Lastly, even if Baumol's cost disease were to cause higher tuition at an individual college, aggregate tuition may be unaffected

Statistic	Experiment							2010
College costs		*	*	*	*	*	*	*
College endowment	*		*	*	*	*	*	*
Borrowing limits	*	*		*	*	*	*	*
Interest rates	*	*	*		*	*	*	*
Non-tuition cost	*	*	*	*		*	*	*
Grants	*	*	*	*	*		*	*
College premium	*	*	*	*	*	*		*
Mean net tuition	$13424	$12432	$9066	$12397	$12289	$11319	$11131	$12428
Std. net tuition	$1182	$1265	$1958	$1312	$1463	$1916	$1405	$1320
Enrollment rate	0.34	0.56	0.53	0.52	0.52	0.56	0.52	0.56
Two-year default rate	0.17	0.17	0.07	0.19	0.17	0.17	0.32	0.17
Mean loan (recipients)	$6873	$6873	$4746	$6856	$6872	$6871	$6877	$6873
Pct. taking out loans	100.00	100.00	73.8	100.00	100.00	100.00	100.00	100.00
Mean earnings	$33605	$37256	$36767	$36681	$36594	$37217	$33306	$37301
Corr(p.income,enroll)	0.27	0.26	-0.07	0.28	0.28	0.48	0.32	0.30
Corr(ability,enroll)	0.67	0.77	0.52	0.77	0.76	0.79	0.78	0.78
Ability of graduates	0.77	0.70	0.64	0.71	0.71	0.71	0.72	0.70
Investment	$33467	$26230	$27060	$30344	$30186	$29550	$29007	$30701
Average EFC	$17620	$16041	$12256	$16412	$16640	$18331	$16992	$16514
Ex-ante utility	-40.76	-40.35	-40.30	-40.37	-40.38	-40.36	-40.51	-40.19
* means the value change over the transition								

Table 5: Experiments

if students substitute into lower cost colleges. Our representative college framework does not allow us to explore the heterogeneous response of tuition across different college types. Even with these caveats, however, our finding that the *form* of cost increases (i.e. fixed vs. marginal) matters for tuition is an important and novel finding.

5 Conclusion

Existing demand-side and supply-side theories can explain the full increase in net tuition between 1987 and 2010. However, our model suggests that demand-side theories—namely, the role of financial aid expansions and the rise in the college premium—generate the strongest effects. However, given the limitation of our representative college assumption, the results likely exaggerate the quantitative sensitivity of tuition to changes in students' willingness to pay. Interestingly, upward shifts in the cost structure consistent with Baumol's cost disease have different effects on tuition depending on whether marginal costs or fixed costs move by more. We plan on addressing issues related to college heterogeneity in future work.

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