Accounting for Tuition Increases at U.S. Colleges*

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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 college costs, reforms to the Federal Student Loan Program (FSLP), and the returns to college have contributed to tuition inflation. Taken together, the changes can fully explain the tuition increases seen at U.S. colleges. Our findings suggest that the FSLP and college costs are the main drivers of college tuition.

Keywords: Higher Education, College Costs, Tuition, Student Loans
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1 Introduction

For thirty years, college tuition has risen steadily across all types of colleges. Selective private research colleges, many with large private endowments, have seen net tuition increase 50% going from $15,500 to $23,700 (in 2010 dollars).[1] At the same time, non-selective public teaching colleges almost totally reliant on government support and tuition have seen their increase 140% from $2700 to $6400. In fact, of 1160 colleges in our sample, only 39 have seen tuition decreases, and these range from the University of Arkansas at Pine Bluff, the only public school having tuition decreases with it falling from $4,000 to $3,750, to Princeton, which has seen their tuition fall from $15,900 to $9,400.

Many theories have been put forth to explain why tuition has been increasing, and in this paper we aim to quantify how much each theory has contributed to tuition changes at U.S. colleges by using a structural model of higher education and the macroeconomy. We find the theories combined can explain all the changes in tuition and in some cases explain too much. The theories we consider can be broadly categorized into supply-side changes (Baumol's cost disease and changes in colleges' non-tuition funding, public and private), demand-side changes directly affecting students (notably, changes in the FSLP), and demand-side indirectly 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.

The variety of circumstances schools face means there is not a single factor causing tuition increases across all school types. However, our results indicate the FSLP, the increase in the college premium, and Baumol cost disease seem to contribute the most to net tuition overall. In fact, overall our results suggest that changes in public and private non-tuition revenue have restrained tuition increases.

The higher education market functions quite differently than many other markets with its combination of extensive public subsidies, complicated financial aid rules, oligopolistic market structure, and widespread use of price discrimination. Furthermore, colleges are predominantly non-profit institutions that pursue different objectives and face different incentives than profit maximizing firms. To capture these features, our work builds on a series of static models developed by Epple, Romano, and Sieg (2006) and Epple et al. (2013) (which extend the work of Rothschild and White, 1995). In their framework, colleges seek to maximize "quality," which is formally a function of spending per student and the average academic qualifications of the student body, both of which are endogenous. Colleges optimally engage in price discrimination, offering tuition discounts to higher-ability students. Students, in turn, choose from among the set of colleges to which they receive an offer of admission, and they weigh the benefits of attending a higher quality institution against the potentially higher net cost of attendance. The sorting of students across colleges affects the distribution

[1] Net tuition is sticker price tuition net of institutional grants to students, and throughout we use real measures.

of college quality, and a computationally challenging fixed point problem emerges because the college quality distribution also drives enrollment decisions. Our calibration, which targets ability and parental income across schools, does well at capturing this sorting.

By embedding the framework above in a dynamic macroeconomic model with rich life cycle, labor market, and general equilibrium elements, we able to assess the quantitative importance of all the tuition increase hypotheses. First, students differing in their ability and parental income choose to either forgo college or matriculate at one of the colleges to which they receive an offer of admission. Students then finance college with a combination of direct family contributions, income earned while in college, institutional aid, and student loan borrowing. After students either graduate or drop-out from college, they enter the labor market and face a life-cycle wage profile subject to idiosyncratic earnings risk. During the repayment phase, workers can choose to be delinquent on their student loans, but debt discharge is prohibited, consistent with laws that omit student loan debt from bankruptcy proceedings.

Key to our research question is the response of college to changes in the economic environment. The main tradeoff colleges face is that every dollar used to recruit high ability students via institutional aid is a dollar that cannot be used to increase quality via spending. So, when a college's finances change, say because of reduced state support, how they cope with the reduced resources hinges on the degree of substitutability or complementarity between ability and spending. As we show, the data provide a strong cross-sectional relationship that lets us identify the degree of complementarity. This lets us validate the model by checking its untargeted predictions with respect to time. The model's performance along this dimension allows us to have confidence in our counterfactual experiments.

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 Fang and Jones (2016) 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. However, their paper differs from this project in several ways. First, this project 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 Fang and Jones (2016) is college costs, which increased by 35% in real terms between 1987 and 2010, whereas this project addresses the much larger 92% increase in net tuition. Also, whereas they use a competitive, representative college framework, this project 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 bestows exaggerated market power on the college and ignores competitive pressures. This project takes the important step of adding heterogeneous colleges, which allows for rich competitive interactions and sorting.

This project 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 Data

Colleges are complex organizations with sizable balance sheets. We break down their balance sheets by key revenue and expenditure categories in Table 1. In the spirit of Epple et al. (2006), we will further refine these categories into endogenous tuition revenue T, exogenous non-tuition revenue E, exogenous expenditures C that are necessary for educating but do not increase quality, and endogenous expenditures I that do increase quality. Hence, the model's budget constraint is essentially

$$pI + pC = T + E^g + E^p$$

where p is the relative price of college expenditures (for which we will use the HEPI index), and we have further broken non-tuition revenue E into public and private sources, E^g and E^p, respectively. Most of these major categories line up naturally with Table 1. For instance, T is net tuition (and it does not matter to the college whether this is received from students or from the government on behalf of students. However, others are perhaps less clear, so we use the mapping in the second rightmost column of Table 1. E^p is the sum of "Part of E^p" and pC is the sum of "Part of pC."

Balance sheet item	Model equivalent
Total Revenue	$T + E^p + E^g$
Net tuition	T
Directly from student	Out of pocket expenses for T
From government	Used by students to pay T
Pell	Used by students to pay T
Local, state, and other federal	Used by students to pay T
Appropriations, contracts, excluding Pell	E^g
Auxiliary and "other" revenue	Part of E^p
Endowment revenue, gifts	Part of E^p
Residual revenue	Part of E^p
Total Expenditures	$pI + pC$
E&G spending	pI + part of pC
E&R spending	pI
Other	Part of pC
Auxiliary and "other" spending	Part of pC
Residual expenditures	Part of pC
Gross operating margin (revenue - expenditures)	Part of E^p

Note: E^p is the sum of "Part of E^p" and pC is the sum of "Part of pC."

Table 1: College balance sheet

Figure 1 shows how the major financial categories per student have varied over time when averaged across schools and weighted by FTE counts (consequently, these are the same as the total of the variables over the total number of FTEs). Also reported is our measure of the relative price p. In terms of non-tuition revenue, E^g has been roughly constant over time and E^p has increased modestly. Put together, $E^p + E^g$ (not pictured) has varied little. In contrast, T and pI have trended secularly upward. The "non-quality enhancing expenditures" pC have also risen risen, but not-secularly. Taking into account the 20% increase in p, there is no increase in the real measure I (not pictured) and a decline in the real measure C (not pictured).

Of course, looking at averages across schools could hide hugely disperse patterns across schools. To examine these differences, Figure 2 shows the patterns in net tuition for seven school types (reflecting a breakdown by whether a school is public or private, by research intensity, and by selectivity). For instance, trends in levels (the top panel) are virtually indistinguishable across the types. However, considering percent changes (the bottom panel) does reveal some significant differences. Specifically, public schools of all types (there are 3 public types and 4 private) have

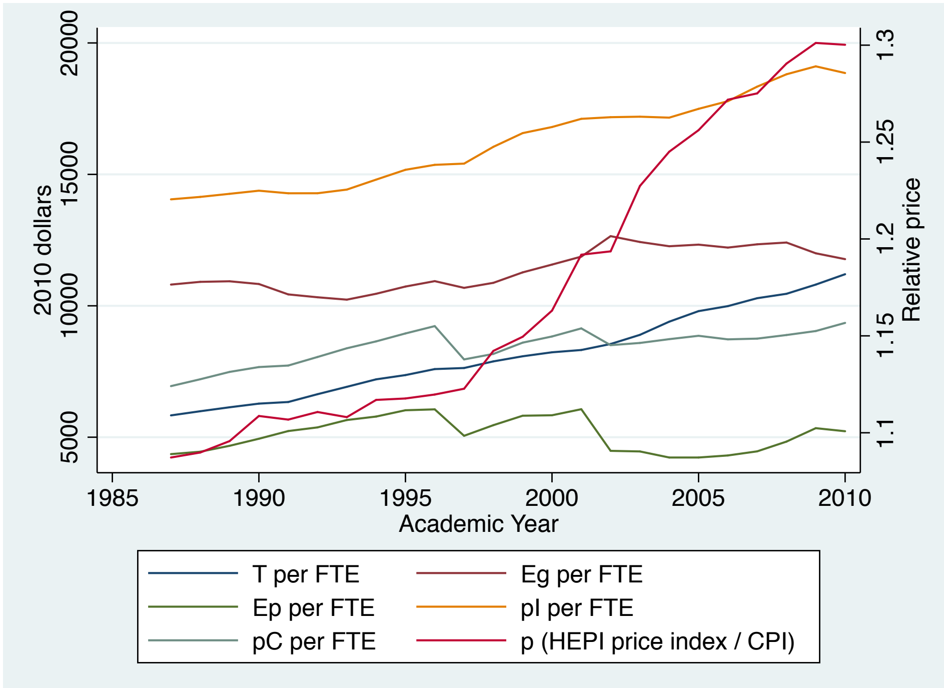

Figure 1: Budget constraint components over time

seen increases of around 140% (on a much smaller base) while other school types increases have been much more modest at around 60%. Public school tuition began growing at a faster rate in 2002.

Figure 3 shows the relationship between spending per student and one measure of ability (the marker size indicates FTE enrollment at the school).[2] This cross-sectional variation is essential for disciplining our college quality function as it provides a link between the ability and spending inputs for a wide-array of college-specific circumstances. Colleges seem to first focus almost singularly on increasing college ability, seemingly substituting into spending when additional increases in ability become too difficult.

3 Model

This section describes the model, which consists of households, colleges, and the government.

[2]For this dataset (IPEDS) we have the mean SAT scores. We then compute an implied distribution of SAT scores conditional on college attendance. The ability measure is the percentile of this conditional distribution assuming it is normally distributed. The mean score (out of 1600) is 1128 and the standard deviation is 135 (with a minimum of 735 and maximum of 1545).

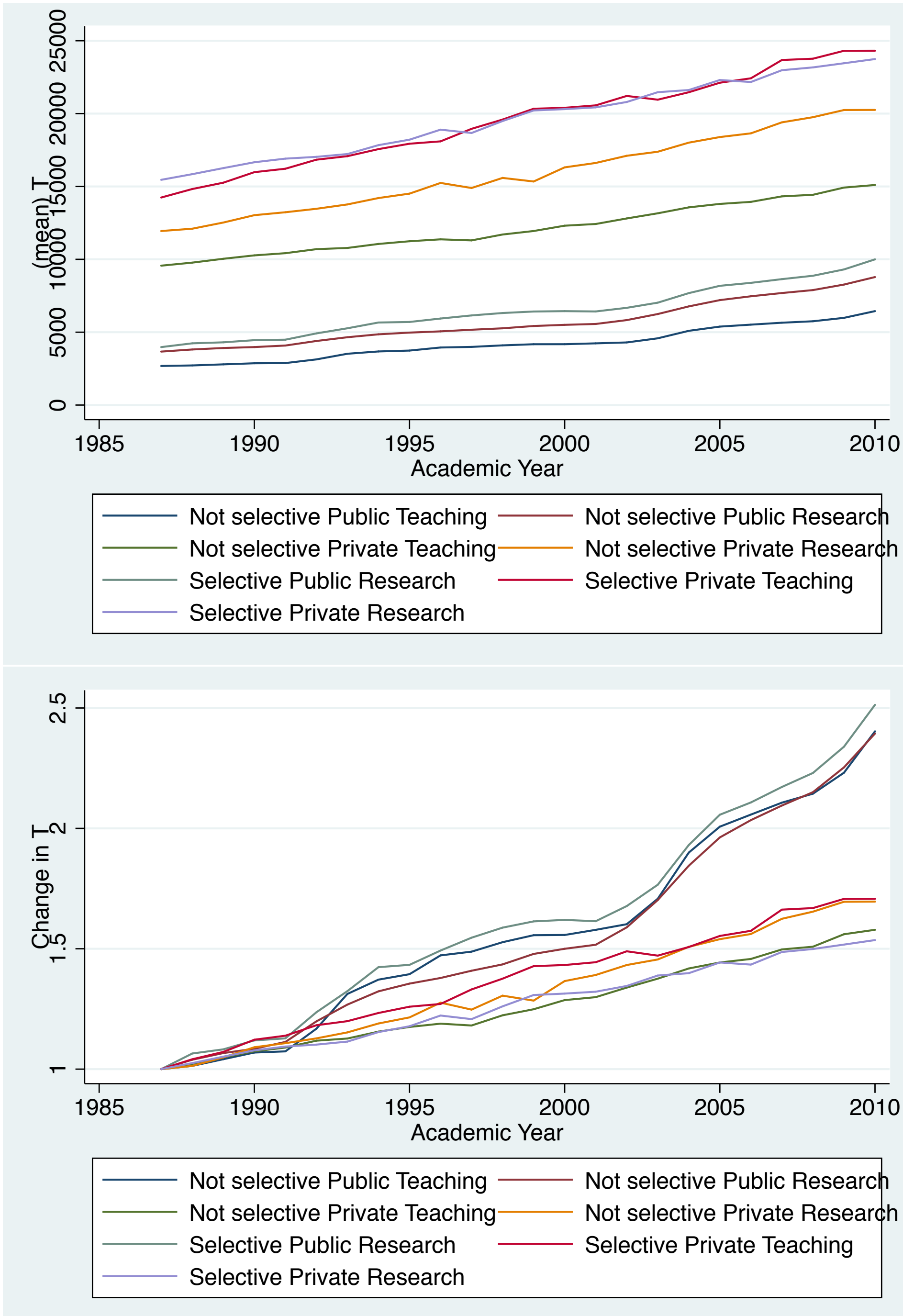

Figure 2: Net student tuition over time in levels (top) and relative to 1987 (bottom)

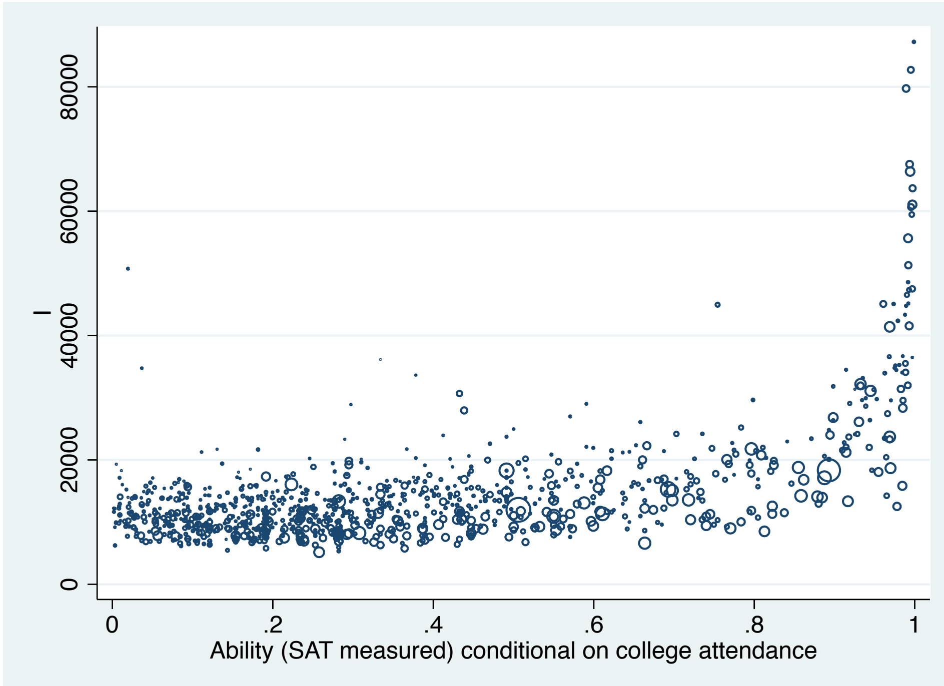

Figure 3: Spending per student against an SAT-based ability measure in 2010

3.1 Households

We break the discussion of the household problem into a student and youths problem (the latter being potential students who have not yet made a college decision) and workers and retirees.

3.1.1 Students and Youths

Each period, a fixed measure of youths with heterogeneous characteristics $s_Y = (x, y_p)$ consisting of academic ability x and parental income y_p enter the economy at age $j = 1$ (corresponding to high school graduation). Youth choose between skipping college ($k = 0$) and attending one of the colleges to which they receive admission, $k \in K(s_Y)$. College k charges type-specific net tuition $T^k(s_Y)$ equal to sticker price $\overline{T}$ minus institutional aid, and students also face non-tuition expenses ϕ. Government grants $\zeta(T^k(s_Y) + \phi, EFC(s_Y))$ offset some of the cost of attendance, where $EFC(s_Y)$ is the expected family contribution formula that dictates eligibility for government need-based grants and loans. The net cost of attendance comes out to $NCOA^k(s_Y) = T^k(s_Y) + \phi - \zeta(T^k(s_Y) + \phi, EFC(s_Y))$.

While enrolled, college students receive additively-separable flow utility $v(q^k)$ which increases in college quality q^k. To graduate, students must complete J_Y years of college. Students in class j return to college each year with probability $\pi_{j+1}(q^k) \equiv \pi(q^k)\mathbf{1}_{[j+1 \leq J_Y]}$, which also increases in q^k; otherwise, they either drop out or graduate. We eventually plan to allow drop-out probabilities to depend also on individual student ability. Students can borrow through the Federal Student Loan

Program (FLSP). 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 given by $\bar{b}_j$ and $\bar{l}$, respectively. 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

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

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 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. 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 $0 \leq \xi \leq 1$ is a parameter. The budget constraint for a college student of type s_Y is

$$c + NCOA^k(s_Y) \leq e_Y + \xi EFC(s_Y) + b_s + b_u \tag{2}$$

Let $\mathbf{T}$ and $\mathbf{Q}$ denote the vectors of net tuition functions and college qualities, respectively. Prior to their college choice, youth receive independent preference shocks $\varepsilon = \{\varepsilon^k\}$ for each college from the joint pdf φ and begin with zero student loan debt, $l = 0$. Thus, youth solve

$$\max_{k \in K(s_Y) \cup \{0\}} Y^k(s_Y; \mathbf{T}, \mathbf{Q}) + \frac{1}{\alpha}\varepsilon^k,\ \alpha > 0, \tag{3}$$

where $Y^k(s_Y; \mathbf{T}, \mathbf{Q})$ is the value function of attending school k (where $k = 0$ means skipping college), which takes into account the utility experienced during and after college. Let $k(s_Y, \varepsilon; \mathbf{T}, \mathbf{Q})$ denote the youth's college choice and define the enrollment probability

$$P^k(s_Y; \mathbf{T}, \mathbf{Q}) = \int \mathbf{1}_{[k(s_Y,\varepsilon;\mathbf{T},\mathbf{Q})=k]}\varphi(\varepsilon)d\varepsilon. \tag{4}$$

3.1.2 Workers and Retirees

Working and retired households receive earnings $e(s)$ 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. Let $q(a')$ denote the price of such bonds.

Workers with student loans in good standing face the budget constraint

$$c + q(a')a' + p(l,t) \leq e(s)(1-\tau) + a. \tag{5}$$

Workers who are delinquent on their loans face principal penalties and wage garnishment γ,

$$c + q(a')a' \leq e(s)(1-\tau)(1-\gamma) + a. \tag{6}$$

3.2 Colleges

Colleges $k \in K$ are differentiated by their exogenous financial endowments E^k and their endogenous quality. College quality $q(\theta^k, I^k)$ depends on average ability θ^k of the student body and per-student expenditures I^k. College k chooses a net tuition function $T^k(s_Y)$ and spending I^k to maximize quality subject to a balanced budget constraint and students' college choice behavior. Each college faces an increasing, twice differentiable, convex cost function $C(N^k)$ in total enrollment.

College k's state is enrollment $\{n_j^k\}_{j=2}^{J_Y}$, aggregate student ability $\{\Omega_j^k\}_{j=2}^{J_Y}$, and aggregate tuition revenues $\{\mathcal{T}_j^k\}_{j=2}^{J_Y}$ of students in years 2 through J_Y. Given $\mathbf{T}^{-k}$ and $\mathbf{Q}^{-k}$, college k solves (suppressing the k notation)

$$W\left(\{(n_j,\Omega_j,\mathcal{T}_j)\}_{j=2}^{J_Y}\right) = \max_{\substack{I,\theta,\\ T(s_Y)}} q(\theta, I) + \beta_W W\left(\{\pi_{j+1}(q)(n_j,\Omega_j,\mathcal{T}_j)\}_{j=1}^{J_Y-1}\right)$$

subject to

$$E + \mathcal{T}_1(\mathbf{T},\mathbf{Q}) + \sum_{j=2}^{J_Y} \mathcal{T}_j = F + C\left(n_1(\mathbf{T},\mathbf{Q}) + \sum_{j=2}^{J_Y} n_j\right) + I\cdot\left(n_1(\mathbf{T},\mathbf{Q}) + \sum_{j=2}^{J_Y} n_j\right) \tag{7}$$

$$\Omega_1(\mathbf{T},\mathbf{Q}) + \sum_{j=2}^{J_Y}\Omega_j = \theta\cdot\left(n_1(\mathbf{T},\mathbf{Q}) + \sum_{j=2}^{J_Y} n_j\right)$$

where freshman enrollment $n_1(\mathbf{T},\mathbf{Q})$, total ability $\Omega_1(\mathbf{T},\mathbf{Q})$, and net tuition revenue $\mathcal{T}_1(\mathbf{T},\mathbf{Q})$ are

$$\begin{aligned} n_1(\mathbf{T},\mathbf{Q}) &= \int P(s_Y;\mathbf{T},\mathbf{Q})dG(s_Y) \\ \Omega_1(\mathbf{T},\mathbf{Q}) &= \int xP(s_Y;\mathbf{T},\mathbf{Q})dG(s_Y) \\ \mathcal{T}_1(\mathbf{T},\mathbf{Q}) &= \int T(s_Y)P(s_Y;\mathbf{T},\mathbf{Q})dG(s_Y) \end{aligned} \tag{8}$$

and $P(s_Y;\mathbf{T},\mathbf{Q})$ is as in (4).

The first constraint is the balanced budget constraint, which equates endowment extractions plus net tuition revenue to costs. The law of motion for the student body depends only on the current student body and the retention probabilities $\pi_{j+1}(q^k)$. We do not give students the *choice* to drop-out or transfer colleges because doing so would necessitate keeping track of the distribution of student-types within each college. As a result, the only flows into college are freshman admissions and the only flows out are graduates and exogenous drop-outs.

3.3 Characterizing the College Problem Solution

Taking the first-order conditions and applying the envelope theorem in steady state yields the following equation for tuition-pricing:

$$T^k(s_Y) + \frac{P^k(s_Y; \mathbf{T}, \mathbf{Q})}{\partial P^k / \partial T^k} = \underbrace{C'(N^k) + I^k + \frac{q_\theta^k}{q_I^k}(\theta^k - x)}_{EMC^k(x)}, \tag{9}$$

where $EMC^k(x)$ is the effective marginal cost of enrolling an ability-x student. In words, colleges have the incentive to offer tuition discounts to high ability students, and colleges charge a mark-up that varies with the willingness to pay of the student's family.

Assuming $\{\varepsilon^k\}$ are drawn from a Type I Extreme Value distribution, this equation becomes

$$T^k(s_Y) + \left\{ \alpha \frac{\partial Y^k(s_Y; \mathbf{T}, \mathbf{Q})}{\partial T^k} \Big[1 - P^k(s_Y; \mathbf{T}, \mathbf{Q}) \Big] \right\}^{-1} = EMC^k(x). \tag{10}$$

3.4 Equilibrium

We now define a steady state equilibrium. The only remaining piece is the government, which must balance its budget. The government levies proportional taxes on labor earnings to fund transfers and loans (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. Thus, a steady state equilibrium consists of tuition functions $\mathbf{T} = \{T^k(s_Y)\}$ and college qualities $\mathbf{Q} = \{q^k\}$ with corresponding college characteristics $\{N^k, \theta^k, I^k\}$; enrollment probabilities $P^k(s_Y; \mathbf{T}, \mathbf{Q})$; student policy functions for consumption, labor, and loan borrowing; worker value functions and policy functions for consumption, assets, student loan delinquency/rehabilitation, and loan repayment; and an earnings tax rate such that

1. The tuition function, quality, and characteristics of college k are consistent with quality maximization given $(\mathbf{T}^{-k}, \mathbf{Q}^{-k})$ and $P^k(s_Y; \mathbf{T}, \mathbf{Q})$;
2. Students and workers are optimizing taking $(\mathbf{T}, \mathbf{Q})$ as given;
3. Enrollment probabilities are consistent with student utility maximization; and
4. The government balances its budget.

4 Calibration and estimation

Several data sources are used to set the parameters of the model. Importantly, the model is calibrated to match features of the data in 1987 (including average net tuition), but explaining the dynamics of tuition over time are a central goal of the paper, which are thus untargeted. The NLSY97 is used to determine the distribution of academic ability and parental income as well as the earnings for college students. The Integrated Postsecondary Education Data System (IPEDS) provides the necessary information to calibrate the government grants function as well as the parameters for the college quality function and cost function over time.

Currently, the calibration and to some extent the model are still in flux. However, Table 2 summarizes the calibration used in Gordon and Hedlund (2016), and many of the non-college-specific parameters carry over here. Additionally, we are currently using 9 free parameters to target the 28 moments listed in Table 3.[3] The model does well at capturing the large variance in tuition, parental income, and ability (conditional on college attendance) seen in the data. A main failing is that FTE shares are far too uniform across schools, and we are considering ways of fixing this.

Figure 4 shows equilibrium heat maps for enrollment in 1987 across the 7 college types and the decision to skip college. The calibration gives that research-intensive and selective colleges are more likely to attract high ability students, and this sorting is starker at private institutions. By contrast, low ability students disproportionately skip college entirely, regardless of parental income. Students coming from the lowest income families almost never attend selective private colleges, no matter their academic ability. Instead, such students either attend selective public research institutions or non-selective institutions. While we have not constructed the corresponding heat maps in the data yet, the implied sorting seems sensible.

5 Results

Analogous to Table 3, Table 4 reports net tuition, parental income, the percentile rank of average college student ability, and FTE shares for each college type. The top panel reports the model's predictions of how the statistics change from 1987 to 2010. There are substantial increases in net tuition for every school type. The bottom panel of Table 4 compares the model's predictions for 2010 with the untargeted data moments, and the model does quite well.

Given that the model successfully replicates the overall rise in net tuition between 1987 and 2010, it is useful to assess the role of each of the main exogenous driving forces. Table 5 presents the tuition decomposition first by implementing the forces one at a time and then by removing one force at a time. Because the computational algorithm is sensitive to the choice of initial guess, we

[3] The parameters are a preference shock size (1), the share of parental income captured by students (1), how much ability influences dropout rates and college premia (1), and college quality function parameters (6). We are using a CES quality function and allow for exogenous differences in weights on ability and school size. However, the degree of complementarity between ability and spending is forced to be the same across all schools.

Calibration: Independent Parameters

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
Retention probability	$0.554^{1/5}$	55.4% completion rate
Earnings shocks	(0.952,0.168)	STY (2004)*
Age-earnings profile	Cubic	STY (2004)*
College premium	GH (2016)**	Autor et al. (2008)
Non-tuition costs	GH (2016)**	IPEDS
Student loan rate	GH (2016)**	Statutory
Annual loan limits	GH (2016)**	Statutory
Aggregate loan limits	GH (2016)**	Statutory
Cost function	GH (2016)**	IPEDS regression
Endowment flow	GH (2016)**	IPEDS
Grant aid	GH (2016)**	IPEDS

Calibration: Jointly Determined Parameters

Description	Model	Data	Target
Earnings normalization	31,686	31,385	Mean earnings
Parental transfers	6,146	5,723	Mean net tuition
Garnishment rate	0.165	0.176	Two-year default rate
Ability input to quality	0.244	0.295	Corr(parental income,enrollment)
College quality loading	0.358	0.379	Enrollment rate
Grant progressivity	0.025	0.027	Average grant size
Preference shock size	0.488	0.357	Percent with loans

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

Table 2: Model Parameters from Gordon and Hedlund (2016)

			Calibration (1987 model — 1987 data)							
			Net tuition		P. income*		Rel. ability*		FTE share	
Public	Non-research	Non-selective	1.2	2.7	75.1	53.0	25.1	25.6	0.16	0.25
Public	Research	Non-selective	3.0	3.7	81.7	65.1	40.8	47.9	0.14	0.36
Private	Non-research	Non-selective	6.7	9.6	81.9	70.5	32.0	35.9	0.15	0.15
Private	Research	Non-selective	9.3	11.9	94.9	81.4	54.2	51.1	0.14	0.05
Public	Research	Selective	6.4	4.0	98.4	76.6	66.8	89.6	0.13	0.10
Private	Non-research	Selective	14.8	14.2	109.8	110.0	76.6	93.7	0.13	0.01
Private	Research	Selective	18.4	15.5	118.7	91.5	89.2	95.8	0.15	0.08

Note: Data series marked with * are only for 2010 (1987 data is unavailable).

Table 3: Calibration

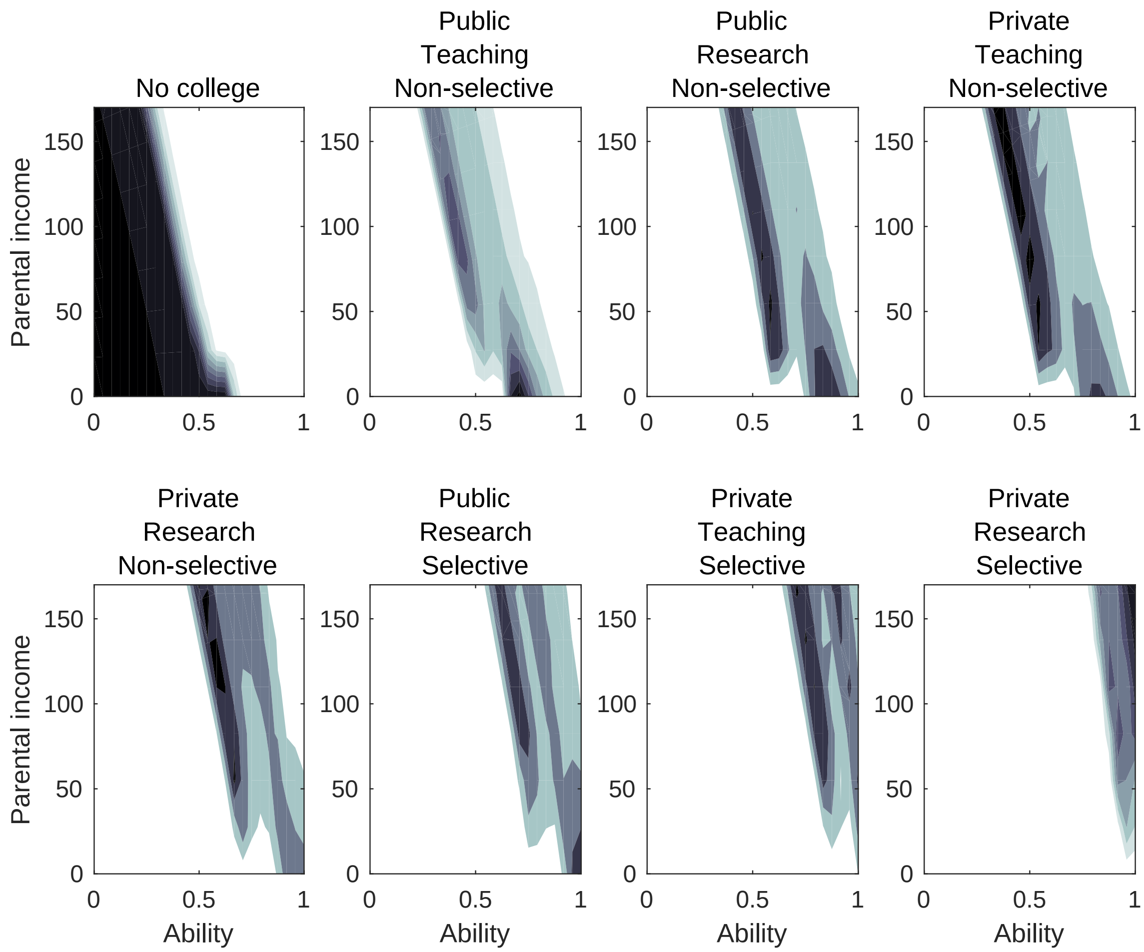

Figure 4: Sorting in 1987

			Results (1987 model — 2010 model)							
			Net tuition		P. income*		Rel. ability*		FTE share	
Public	Non-research	Non-selective	1.2	5.3	75.1	63.5	25.1	28.0	0.16	0.15
Public	Research	Non-selective	3.0	8.0	81.7	74.5	40.8	41.7	0.14	0.15
Private	Non-research	Non-selective	6.7	9.7	81.9	71.0	32.0	33.5	0.15	0.17
Private	Research	Non-selective	9.3	13.1	94.9	85.9	54.2	53.6	0.14	0.17
Public	Research	Selective	6.4	13.1	98.4	97.7	66.8	68.1	0.13	0.12
Private	Non-research	Selective	14.8	18.3	109.8	106.2	76.6	79.4	0.13	0.12
Private	Research	Selective	18.4	24.4	118.7	116.1	89.2	91.3	0.15	0.13
			Results (2010 model — 2010 data)							
			Net tuition		P. income*		Rel. ability*		FTE share	
Public	Non-research	Non-selective	5.3	6.4	63.5	53.0	28.0	25.8	0.15	0.25
Public	Research	Non-selective	8.0	8.8	74.5	65.1	41.7	47.8	0.15	0.35
Private	Non-research	Non-selective	9.7	15.1	71.0	70.5	33.5	34.3	0.17	0.18
Private	Research	Non-selective	13.1	20.3	85.9	81.4	53.6	50.9	0.17	0.05
Public	Research	Selective	13.1	10.0	97.7	76.6	68.1	89.5	0.12	0.09
Private	Non-research	Selective	18.3	24.3	106.2	110.0	79.4	93.8	0.12	0.01
Private	Research	Selective	24.4	23.7	116.1	91.5	91.3	95.8	0.13	0.07

Note: Data series marked with * are only for 2010 (1987 data is unavailable).

Table 4: Change from 1987 to 2010 and main experiment

have not currently been able to compute the solution to all the experiments. However, the results for the computed ones show the FSLP and Baumol cost disease and, to a less extent, the college earnings premium ("Demand") contribute significantly to tuition increases. In fact, the changes in financial aid or Baumol can fully account for the tuition increases. However, there is a strong complementarity in that, while both FSLP and Baumol can fully explain the tuition increase, jointly they do not cause tuition to be too large. In contrast, changes in non-tuition revenue ("Approp" and "Priv Fund") funding seem to have restrained tuition.

			1987 values except for				
	1987	2010	FSLP	Baumol	Demand	Approp	Priv Fund
Net tuition	8.1	12.2	13.6	–	9.1	6.2	6.9
Enrollment rate	54.3	71.4	58.0	–	52.9	57.0	53.7
Graduation rate	62.4	65.8	61.2	–	67.0	62.1	63.0
Average ability	0.73	0.65	0.71	–	0.74	0.71	0.73
Corr(ability,enrollment)	0.61	0.49	0.59	–	0.61	0.59	0.61
Max residual log X, I, N	0.08	0.18	0.08	2.29	0.09	0.09	0.16
			2010 values except for				
	1987	2010	FSLP	Baumol	Demand	Approp	Priv Fund
Net tuition	8.1	12.2	–	8.0	16.1	14.2	13.8
Enrollment rate	54.3	71.4	–	77.0	52.2	67.3	67.2
Graduation rate	62.4	65.8	–	64.4	61.4	64.8	65.1
Average ability	0.73	0.65	–	0.62	0.74	0.67	0.67
Corr(ability,enrollment)	0.61	0.49	–	0.42	0.62	0.53	0.53
Max residual log X, I, N	0.08	0.18	1.67	0.11	0.07	0.08	0.08

Note: Values listed as "–" have been suppressed due to excessive numerical error (the computational algorithm employs a Newton-type algorithm, which necessitates good initial guesses for convergence).

Table 5: Experiments

Relative to the results in Gordon and Hedlund (2016), Baumol cost disease plays an important role. We suspect the key difference here is that in Gordon and Hedlund (2016), costs went up but the relative price of education goos did not change. Here, we allow for changes in p. This induces a substitution effect in addition to an income effect. We are still in the process of understanding this mechanism.

6 Conclusion

[To be completed]

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.

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

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.

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.

M. Rothschild and L. J. White. The analytics of the pricing of higher education and other services in which customers are inputs. *Journal of Political Economy*, 103(3):573–586, 1995.

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 Additional Results

Figure 5 reports the heat map of enrollments for 2010. It is analogous to Figure 4 but for 2010 rather than 1987. The qualitative patterns are mostly unchanged. Quantitatively, enrollments have "shifted left" in that median ability levels have fallen for almost all schools.

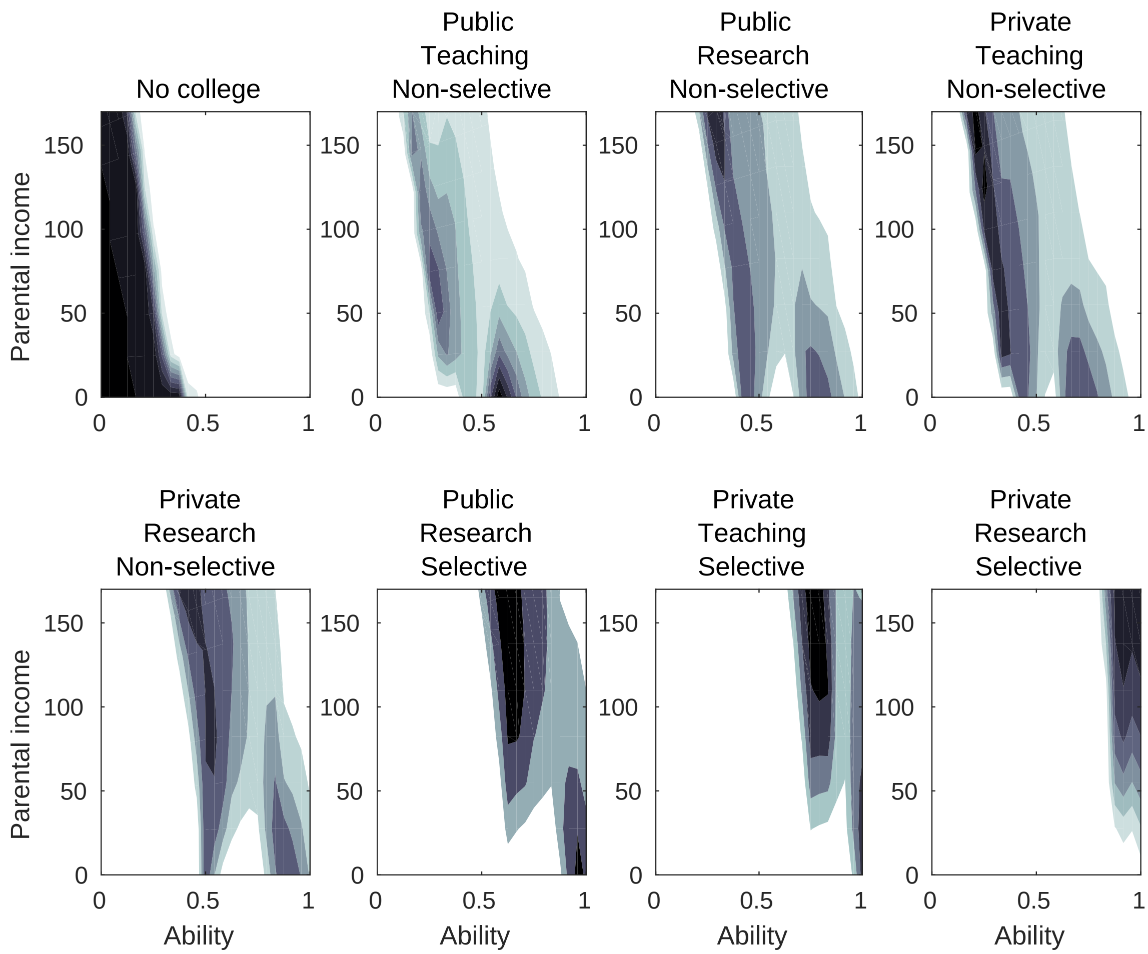

Figure 5: Sorting in 2010