The Rise of For-Profit Higher Education: A General Equilibrium Analysis

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Abstract

For-profit colleges have grown to a sizeable share of the U.S. four-year college market, particularly for nontraditional and online students, but the outcomes of their graduates have attracted policymaker scrutiny. We set up and calibrate a general equilibrium model to understand how these institutions compete with public and private nonprofit colleges. We quantify the response of for-profits to changes in Pell Grants and public university subsidies, and the effects of "gainful employment" legislation linking access to federal funding to graduates' debt-to-earnings ratios. We find that for-profit colleges prefer to comply with gainful employment standards but do so by lowering tuition and instructional quality.

JEL Codes: D40, D58, I28

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1 Introduction

In recent decades, for-profit colleges have risen to prominence in U.S. higher education policy. Despite enrolling at most ten percent of four-year undergraduates, the for-profit sector has accounted for a disproportionately large fraction of federal aid, student lending, and loan defaults,[1] and educates a large share of first-generation and minority students.[2] Following a series of investigations, bankruptcies, and increasing regulatory pressure, the growth of the for-profit sector stalled after the Great Recession,[3] but in 2019 the U.S. Department of Education repealed regulations that held for-profit colleges accountable to gainful employment standards in order to maintain access to financial aid. The current administration is considering reinstating gainful employment legislation[4], in conjunction with partial student loan forgiveness. In the meantime, for-profit colleges have continued to compete for federal funding, and to educate a large share of low-income, first-generation college students, who accumulate substantial student loan balances.

Aiming to understand how the for-profit sector competes with public and nonprofit universities, we set up and calibrate a general equilibrium model of competition in the four-year college market. We build on the framework of Epple and Romano (1998), Epple, Romano, and Sieg (2006) and Epple et al. (2019) by adding the market for online education, modeling the decisions of nontraditional students, and the interactions between for-profit, public and

[1]In the 2009/2010 academic year, for example, for-profit colleges accounted for about 10 percent of total undergraduate enrollment, but received 32 billion dollars in federal student financial aid, or 25 percent of the total aid. At the same time, for-profit college graduates accounted for 42 percent of borrowers in default (U.S. Senate, 2012).

[2]In the 2011-2012 academic year, Black or African American students represented 29.8 percent of for-profit four-year college enrollment, and 15.21 percent of public college enrollment. At the same time, 61.47 percent of students at for-profit colleges were first-generation college-goers, compared with 36.95 percent at public colleges. [Authors' calculations, data from the National Postsecondary Student Aid Study: 2012 Undergraduates]

[3]A U.S. Senate (2012) investigaton was triggered by the poor labor market outcomes experienced by veterans benefitting from Post-9/11 educational benefits. Several for-profit colleges were sanctioned for deceptive marketing and recruiting practices, reaching settlements with the Department of Education.

[4]United States Department of Education, Office of Postsecondary Education. Issue Paper 3: Gainful Employment. Session 3: March 14-18, 2022. available at https://www2.ed.gov/policy/highered/reg/hearulemaking/2021/isspap3gainempl.pdf

private nonprofit institutions. Our model introduces for-profit colleges as profit-maximizing higher education providers, in contrast to public and nonprofit colleges, which generally operate with balanced budgets, and aim to maximize a combination of academic quality/student achievement and quantity of graduates.[5] We focus on the competition between higher education providers in the four-year college market. While many for-profit colleges started out by providing vocational training and two-year degrees, their educational offerings have grown, particularly through career oriented bachelor's and masters degrees in business administration, nursing or information technology, but also through liberal arts offerings such as bachelor's degrees in history, philosophy, sociology and the arts. While the for-profit share of four-year enrollment in degree granting institutions was only 2.7 percent in 2000, it had reached 12 percent by Fall 2010.[6]

Our model features two groups of students: *traditional* and *nontraditional*. Students are also heterogeneous in ability and income. Traditional students are aged 18-24 and have dependent status in financial aid applications. Nontraditional students are older than 24, and independent for purposes of financial aid calculations. While the for-profit market share for traditional students remains low, the rise of for-profit colleges coincided with, and has in turn fueled the growth in nontraditional student enrollment. For example, in 2011, for-profit colleges enrolled about 912,000 nontraditional students in four-year bachelor's degree programs, a 31 percent market share. In the market for nontraditional students, for-profit colleges compete mainly with public colleges, which had a 48 percent market share in 2011, and to a lesser extent with nonprofit colleges. Competition between for-profit colleges and the public sector has been spurred by the increasing availability of student loans and financial aid, and rising price tags at public universities, which have become more reliant on net tuition

[5]Many for-profit institutions are owned by exchange traded corporations which report profits and have an explicit mandate to increase shareholder value. In contrast, state universities respond to public mandates to increase access to higher education, while private nonprofit institutions (hereinafter called nonprofit, for brevity) generally place a higher weight on academic quality, through selective admission policies and higher instructional spending.

[6]National Center for Educational Statistis, Digest of Educational Statistics 2019, Table 303.25.

revenue, as they faced decreasing support in the form of public subsidies. We document these developments in more detail in Section 2.

Agents can choose to enroll in *online* or *presential* instruction. In 2012, about 12.5 percent of four-year students were attending a four-year higher education institution exclusively through 'distance learning', delivered largely through online instruction. We model competition between online and presential higher education providers using a nested logit structure: conditional on the students' online/presential choice, they have a further choice of institutions differentiated by public/private control.

In our model, four-year for-profit colleges maximize profits by choosing levels of tuition and instructional spending, responding to the prices and spending observed at competing public and private nonprofit institutions. We model the public sector as constrained by the level of state-mandated tuition and subsidies, but choosing an optimal level of instructional spending to reach its objective of maximizing student achievement.

We calibrate a quantitative version of the model, which delivers predictions about levels of instructional spending, equilibrium student body ability and earnings premia in the labor market by type of college. Pricing at for-profit colleges also emerges as an equilibrium outcome of the model. The model matches enrollment market shares, ability rankings across types of students and universities, and observed levels of student borrowing, federal and institutional financial aid. Our analysis focuses on 2012-2014, a period when for-profit colleges experienced a relatively steady market share. At the same time, under gainful employment legislation, cohorts graduating during this period were the first to be evaluated in terms of student debt-to-earnings ratios.

We conduct a gainful employment policy experiment, in which for-profit colleges lose eligibility for federal funding if the debt-to-earnings ratio of their graduates is below a threshold of 12 percent. We find that for-profit colleges prefer to comply with the debt-to-earnings ratios that allow them continued access to federal funding, but do so by lowering tuition and instructional spending. While counterfactual loan default rates decrease, the policy scenario indicates immediate negative welfare effects because of the deterioration in instructional quality.

In other counterfactual analyses, we consider the effect of changes in public subsidies for higher education and quantify the effects of these policies on for-profit market shares, instructional spending and average student ability. Another set of counterfactual analyses considers increases in the maximal Pell Grant cap. We find that for-profit colleges capture a large share of the federal Pell Grant increase. This result is partly driven by the fact that for-profit institutions generally attract students with higher eligibility for Pell grants. Our simulations further indicate that for-profit colleges would significantly reduce their tuition in order to enroll more Pell Grant eligible students, to whom they would deliver lower levels of instructional spending. Our welfare analysis indicates that a doubling of the Pell Grant maximal cap (a Biden campaign promise) leads to lower welfare gains than more modest increases in the award cap.

Our work contributes to the general equilibrium modelling of education markets. While Epple and Romano (1998) studies competition between private and public schools in primary and secondary education markets, Epple, Romano, and Sieg (2006) develops and estimates a general equilibrium model of the not-for-profit higher education market. Epple, Romano, Sarpça, and Sieg (2017) and Epple, Romano, Sarpça, Sieg, and Zaber (2019) extend these frameworks by including interactions between public and not-for-profit universities. Kaganovich and Su (2019) analyze university competition in curriculum standards, where universities' objectives differ in the weight placed on quantity of graduates relative to their overall human capital.

Our paper differs from previous work in a few significant dimensions. We introduce the for-profit sector and estimate the cost and elasticity parameters that govern its competitive behavior. Our model distinguishes online and presential instruction, as well as nontraditional students, whose average abilities, incomes, outside options and financial aid packages vary considerably from those of traditional students. Our model features college drop-out, which allows us to link the enrollment decision with student outcomes. We use our framework to study policy questions such as the effects of changes in federal aid and public university subsidies on enrollment and pricing in the for-profit sector. We find the response of the for-profit sector in our policy experiments to be quantitatively important. In counterfactual Pell Grant increase scenarios, for-profit universities see significant market share increases, which they achieve by lowering tuition and instructional spending, and attracting lower income and lower ability students. The policy leads to a decrease in academic quality, associated with lower instructional spending. This result, driven by the objective of for-profit institutions, stands in contrast to findings from a model where all institutions seek to maximize student achievement. For example, maximal federal aid policy experiments in Epple, Romano, Sarpça, and Sieg (2017) lead to increased attendance among low income and middle- and high-ability students, and increases in instructional spending at private nonprofit institutions.

Our paper also contributes to the literature analyzing the effects of higher education policies in quantitative models. Caucutt and Kumar (2003), Akyol and Athreya (2005), Chatterjee and Ionescu (2012), and Johnson (2013) analyze the effects of tuition subsidies. Ionescu (2009), Lochner and Monge-Naranjo (2011), Chatterjee and Ionescu (2012), Ionescu and Simpson (2016) examine the impact of student loan policies in the context of borrowing constraints. Abbott, Gallipoli, Meghir, and Violante (2019) compare the effects of ability-tested grants and expansion of student loans in a model of inter-generational transfers. We complement this literature by modelling the competition between various types of higher education institutions, which allows us to compare funding policies that target both students and universities. This paper is also related to an empirical literature that has analyzed for-profit colleges and the outcomes of their graduates. Armona, Chakrabarti, and Lovenheim

(2018) use an instrumental variable aproach that exploits the interaction of labor demand shocks and the local supply of for-profit colleges to evaluate the effects of for-profit attendance on student outcomes. They find that for-profit enrollment results in higher loan balances and worse labor market outcomes. Our counterfactual results on the effect of subsidy cuts at public schools are similar to findings by Goodman and Henriques Volz (2020), who show that decreases in state appropriations to higher education institutions between 2000 and 2010 led to decreases in enrollment at public colleges, coupled with higher enrollment at for-profit colleges and rising student loan balances. Our paper is also related to work on modeling competition between the public and private sector in pre-college markets, which has been shown to be quantitatively important for equilibrium school quality and student outcomes, particularly in developing countries that have a large private education sector. Neilson (2013) shows a voucher policy targeted at low-income students has a positive effect on private school quality in Chile. Dinerstein et al. (2020) estimate that public school construction in the Dominican Republic led to private school exits and increases in quality for the remaining private schools. Allende (2019) considers a range of policies in terms of equity and efficiency, finding that entry subsidies to high-quality private schools in Peru are the most efficient, while targeted vouchers the most equitable.

More broadly, our paper contributes to the literature analyzing price and quality competition in other markets with nonprofit and profit providers, such as healthcare, child care and long-term care. Our model captures the competitive pressures that keep checks on the prices and quality of for-profit providers, which have been noted in the healthcare industry (Kunz et al. (2020)). Our findings on the cost parameters of for-profit colleges indicate they can quickly scale enrollment, a similar finding to that of Chakravarty, Gaynor, Klepper, and Vogt (2006), who document that for-profits are quicker to enter and more responsive to changes in demand. A key feature of for-profit educational providers is that they provide access, a well understood benefit of for-profit providers in healthcare markets (Beckert and Kelly (2021)).

The paper is structured as follows. In section 2, we present a series of stylized facts on the growth of the for-profit sector. Section 3 lays out our model. We provide details on the calibration exercise in Section 4. We report the results of our counterfactual analyses in Section 5, and conclude in Section 6.

2 The Fast Growth of For-Profit Colleges: Recent Literature and Stylized Facts

In this section, we briefly review the literature on the growth of the for-profit sector, and provide a series of stylized facts on its determinants: increases in online and nontraditional student enrollment; declining levels of state subsidies at public institutions; increasing availability of federal financial aid and student loans. We also present the institutional background for gainful employment legislation.

Nontraditional students represent a large fraction of the total population of four-year college undergraduates (Figure 1, panel A). Between 2001 and 2009, the total enrollment of undergraduate nontraditional students increased from 3.2 million to 4.9 million. The growth of for-profit colleges is closely linked to the participation of nontraditional students, as shown in Figure 1, panel B. The share of for-profit colleges in the nontraditional student market increased considerably, from five percent in 2001 to 31 percent in 2011. While for-profit colleges attracted a large share of nontraditional students, they reached at most five percent of the traditional student market, in 2009 (Figure 1, panel C). One explanation for the fast rise in market share in the nontraditional student market is that for-profit colleges are offering learning environments suitable for older, nontraditional students, who may have work and family responsibilities. For example, for-profit colleges have lower admission requirements and many for-profit institutions have specialized in offering exclusively distance education. In the market for four-year students attending exclusively online courses, for-profit colleges held a dominant 52 per cent market share in 2012,[7] followed by public institutions (28 per cent) and nonprofits (20 per cent). In 2012, the share of four-year undergraduates attending exclusively online was 12.5 per cent (this fraction reached 14.6 per cent in 2019, before the COVID-19 pandemic). This represented a considerable increase from the 1.75 per cent of undergradutates enrolled in a bachelor's program exclusively online in 2000.[8] While the growth in online education was sustained by the increasing availability of broadband Internet, it was also boosted by the repeal of the "50 percent rule": prior to 2006, U.S. Department of Education regulations did not allow the share of distance learning students to exceed 50 percent at institutions receiving federal financial aid. While both for-profit and public colleges enrolled less than seven percent of students in distance education in 2000, by 2012, 57.5 percent of students at for-profit colleges were taking exclusively distance education courses, compared to 5.5 percent of students in the public sector.[9]

Another factor explaining why for-profit colleges captured a larger share of the nontraditional and online student markets was that competing institutions raised prices. Figure 1, panel D shows that nonprofit universities saw the fastest increases in tuition between 2003 and 2013. At the same time, public schools were facing a significant shift in their funding structure. The average per capita subsidy at public universities saw considerable decreases, while tuition increased, driving the price of public universities closer to the sticker price charged by for-profit colleges. The effects of public spending cuts on for-profit enrollment have been documented in reduced form analyses. Goodman and Henriques Volz (2020) estimate that for-profit college attendance increases about 2 percent for a 10 percent cut in

[7] U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), Table 311.15

[8] U.S. Department of Education, National Center for Education Statistics. A Profile of Participation in Distance Education, NCES 2003–154. Washington, DC: 2002., Table 3.

[9] Data from from 1999-2000 National Postsecondary Student Aid Study indicate that 3.8 percent of for-profit students were enrolled in distance education, compared to 6.9 percent of public four-year students. 2012 figures come from NCES Education Digest Table 311.15.Number and percentage of students enrolled in degree-granting postsecondary institutions, by distance education participation, location of student, level of enrollment, and control and level of institution: Fall 2012.

state appropriations. Deming and Walters (2017) find that enrollment and graduation rates at public universities decrease following state policies that decrease subsidies while freezing tuition at public schools. Several authors have pointed out that capacity constraints at public schools have allowed for-profit schools to capture rising demand. Turner (2006) found higher responsiveness at for-profit colleges than at public schools in adapting enrollment to indicators of aggregate student demand such as the change in the college age population. Cellini (2009) compared Californian communities which either barely passed or barely rejected initiatives to supplement funding for public college education through the issuing of bonds. For-profit colleges were more likely to enter local markets where such initiatives were voted down. In our model, capacity constraints arise because of the convexity of the university cost function, which we allow to vary between public and for-profit colleges, as well as from the educational quality concerns which implicitly limit the growth of public and nonprofit colleges.

The growth of for-profit colleges was also spurred by the increasing availability of federal financial aid and student loans. Federal expenditure on Pell Grants increased from 11.2 to 40 billion dollars between 2000 and 2011, and the number of beneficiaries increased from 3.9 million to 9.3 million over the same period.[10] When the for-profit market share peaked, in 2007-2008, over 40 percent of students attending for-profit colleges were financing their studies with private loans, compared to 25 percent of students in nonprofit colleges and 14 percent of students in public schools.[11]

Gainful employment

The Gainful Employment rule, passed in its final version in 2014 under the Obama Administration, and repealed in July 2019 under the Trump administration, established standards that career-oriented educational programs needed to maintain in order to access federal student aid. In practice, providers of career-oriented programs included the vast majority of

[10] College Board, Federal Aid per Recipient by Program over Time in Current and Constant Dollars.
[11] College Board, Share of Undergraduate Students with Private Loans, 1999-00 to 2015-16.

for-profit colleges, as well as non-degree programs at public colleges, primarily community colleges. This legislation was motivated by concerns over the high levels of student debt and loan defaults experienced by graduates of for-profit colleges.[12] In particular, a U.S. Senate (2012) investigation found that while for-profit colleges advertised their programs as career-oriented, few of their graduates found employment in the field of study or the occupation they had received training for. In turn, this was associated with low earnings, and an inability to repay student loans. The gainful employment legislation required career-oriented programs to provide applicants with more transparent information about the post-graduation experiences of past cohorts, and to comply with a set of metrics related to the debt-to-earnings ratio of their graduates. The standard was a ratio of expected debt payments to total income of no more than eight percent (or 12 percent in the "warning zone"), and a ratio of debt payments to discretionary income of no more than 20 percent. Programs that failed these metrics were given a three year period to improve before losing eligibility for federal financial aid. In 2017, the Department of Education released estimates that showed about eight percent of programs failed to meet the debt-to-earnings measure. According to an independent analysis (TICAS, 2017), these programs enrolled 354,002 students, which had cumulatively borrowed 7.45 billion dollars to attend the programs deemed to be failing or in the warning zone.

3 The Model

The potential student population, normalized to 1, consists of two groups of agents: traditional (denoted t) and nontraditional (denoted nt), whose levels of ability, income, and financial aid differ. Let π_t and π_{nt} indicate the proportions of traditional and respectively nontraditional agents in the total population. Potential students are heterogeneous in after-

[12] The discussion in this paragraph draws from Department of Education. 2014. "Program Integrity: Gainful Employment; Final Rule", Federal Register, vol.79, no. 211, 34 CFR Parts 600 and 668.

tax income y and ability a. Let $f_t(a, y)$ and $f_{nt}(a, y)$ denote the joint densities of (a, y) for traditional and nontraditional agents, respectively. An agent is characterized by (a, y, g), where g is an indicator denoting the group the agent belongs to (t or nt).

The higher education sector consists of three types of higher education institutions, public, nonprofit and for-profit, which offer different levels of educational quality and also differ in their objectives. In our empirical application, we model one public university that offers both presential and online instruction, two nonprofit colleges, and two for-profit colleges, one offering presential instruction and another offering exclusively online courses. Agents decide first whether to enroll in presential or online institutions, and then they choose the type of institution. Thus, we use a nested logit structure to model enrollment decisions, with separate nests for presential and online instruction, and a degenerate nest for the outside option (no college), as described below.

The duration of college education is four years. Let J the set of all college alternatives. An agent graduating from college $j \in J$ with quality q_j acquires human capital $h_j = q_j a^{\beta}$, where $\beta > 0$. This specification captures the fact that more able students will accumulate more skills for the same level of educational quality.

College graduation is uncertain. With probability $d_j(a, g)$, the agent drops out of college and receives human capital $h^d = B_d a^{\beta}$, where $B_d > 0$.

The achievement of an agent that does not pursue higher education is $h_{0,t} = B_t$ for traditional students and $h_{0,nt} = B_{nt}$ for nontraditional students.

3.1 Agents' preferences and choices

The agents derive utility from consumption and academic achievement. The utility of the student (a, y, g) enrolling in college j is given by:

$$U_j(a, y, g, \epsilon_j) = \alpha V_j(a, y, g) + \epsilon_j, \tag{1}$$

where $V_j(a,y,g)$ is the systematic component of utility, ϵ_j is an idiosyncratic shock and α is a weighting parameter. The unobserved component of utility ϵ_j follows a cumulative GEV distribution:

$$exp(-\sum_{k=1}^{K}(\sum_{j\in B_k} e^{-\epsilon_j/\lambda_k})^{\lambda_k}), \tag{2}$$

where K is the number of nonoverlapping nests denoted $B_1, B_2, ..B_K$ which partition the set of alternatives J. The parameter λ_k captures the dissimilarity in unobserved utility among the alternatives in nest B_k, i.e. a high λ_k means the alternatives in the nest are less similar for unobserved reasons. If $\lambda_k = 1$ for all nests, then the nested logit reduces to the standard multinomial logit model. College options are nested in K=3 groups: presential, online education and the degenerate nest for the outside option.

The utility from graduating from college j is $u_j^c = \theta_{k,g} ln(c_j^c h_j^c)$, where $c_j^c(a,y,g)$ and $h_j^c(a,y,g)$ are the consumption and achievement of a college graduate, respectively, and $\theta_{k,g}$ is a preference parameter that might differ across the online and presential nest, as well as agent groups. The utility of a dropout is $u_j^d = \theta_{k,g} ln(c_j^d h^d)$, with the corresponding consumption c_i^d and achievement h^d.

Denote by $d_j(a,g)$ the dropout probability of agent (a,g) from college j. The systematic component $V_j(a,y,g)$ is the expected utility from enrolling, or the weighted average of utility from graduating and utility from dropping out:

$$V_j(a,y,g) = \theta_{k,g}[(1-d_j)ln(c_j^c h_j^c) + d_j ln(c_j^d h^d)]. \tag{3}$$

Students pay different prices for a college education, depending on their ability and income. For the purpose of financial aid decisions, universities and the government may take into consideration parental income (for traditional students) or own or spousal income (for nontraditional students). Denote by $t_j(a,y,g)$ the price paid per year by a student of type (a,y,g) at college j. This price is net of institutional and non-institutional financial aid.

Students also pay non-tuition costs, denoted by NC_j. The budget constraint of the student of type (a, y, g) graduating from university j is:

$$c_j(a, y, g) + 4t_j(a, y, g) + 4NC_j = 4y. \tag{4}$$

Let $\phi_j(g) \in (0, 4)$ represent the average duration, in years, spent in college j by a dropout in group g. Thus, the budget constraint of a dropout of type (a, y, g) at college j is:

$$c_j(a, y, g) + \phi_j(g)t_j(a, y, g) + \phi_j(g)NC_j = 4y. \tag{5}$$

Assuming feasibility of the budget constraints, we substitute consumption into the expression of utility, (3), and write the indirect utilities of agent (a, y, g) corresponding to enrollment in college i:

$$\begin{aligned} V_j(a, y, g) = \theta_{k,g}\Big[\ d_j ln[4y - \phi_j(g)t_j(a, y, g) - \phi_j(g)NC_j + d_j ln[h_j^d]\Big] \\ + \theta_{k,g}\Big[\Big(1 - d_j)ln[4y - 4t_j(a, y, g) - 4NC_j] + (1 - d_j)ln[h_j^c]\Big] \end{aligned} \tag{6}$$

The systematic component from the outside option is $V_0(a, y, g) = \ln(yh_0)$.

Given tuition levels, quality of colleges and institutional and non-institutional financial aid, agents choose among the options available in order to maximize their utility. We denote the conditional probabilities of choosing alternative j from the choice set J as $p_j(a, y, g; T(a, y, g); Q)$, where $T(a, y, g)$ is the vector of tuitions that apply to student (a, y, g) and Q is the vector of available qualities at all universities. With the GEV distribution, the conditional choice probability that an agent of type (a, y, g) chooses alternative j from the choice set is:

$$p_j(a, y, g) = \frac{e^{V_j/\lambda_k}(\sum_{i \in B_k} e^{V_i/\lambda_k})^{\lambda_k - 1}}{\sum_{k=1}^{K}(\sum_{i \in B_k} e^{V_i/\lambda_k})^{\lambda_k}}.$$

3.2 The Higher Education Sector

Colleges differ in quality of instruction and their objectives. The quality of college j is given by:

$$q_j = A_j(\overline{a}_j)^{\gamma_j}(I_j)^{\omega_j},$$

where $\overline{a}_j$ is the average ability of the student body in college j, I_j is the per student instructional spending, and A_j, γ_j, $\omega_j > 0$ are parameters of the quality function that may differ across universities.

As mentioned above, the per year tuition schedule at university j depends on the student type (a, y, g). We model federal and institutional financial aid as functions of student ability and income. Thus,

$$t_j(a, y, g) = T_j - FedAid_j(a, y, g) - InstAid_j(a, y, g), \tag{7}$$

where T_j is the sticker price at university j.

The public sector. The public university has three types of students within group g: in-state presential, out-of-state presential and online. The corresponding sticker prices are T_s, T_t, and $T_{p,o}$. The public university receives a subsidy s per student.

We do not explicitly model the political process that determines tuition and subsidy levels for the public university, and therefore we assume they are exogenous. However, in the policy experiments we vary them and analyze the corresponding effects. As the agents' income is net of taxes, we do not model the tax income that funds the subsidy or the student financial aid. However, in the policy experiments we model a balanced government budget that pins down the necessary increase in taxes when university subsidies or student financial aid are raised.

We model the behavior of the public university in the presential market similar to Epple et al. (2019). We assume that the public university maximizes the expected aggregate achievement of its students in the presential programs subject to a balanced budget. Given the dropout probabilities $d_p(a,g)$, the expected achievement of an agent of type (a,g) as a weighted average of her achievement if she graduates h_p^c and the corresponding achievement in case of dropout h^d. We assume students cannot switch programs.

$$Eh(q_p, a, g) = [d_p h_p^c(q_p, a) + (1 - d_p) h^d(a)],$$

where q_p is the quality of the presential public program and $h^c(q_p, a)$ and $h^d(a)$ are the achievements of a college graduate and college dropout, respectively. The achievement of a college dropout is $h^d = B_d a^\beta$ and that of a college graduate from the public presential program is $h^c(a,g) = q_p a^\beta$. The quality of the presential program is:

$$q_p = A_p(\overline{a}_p)^{\gamma_p}(I_p)^{\omega_p},$$

where $\overline{a}_p$ is the mean ability of the students in the presential program and I_p the per student spending, $A_p, \gamma_p, \omega_p > 0$.

Denote by $\delta_z(a,y,g)$ the shares of type (a,y) students from group g that are admitted to program z, which can be in-state or out-of-state. We assume the decisions of the public university are taken at the time of enrollment of the cohort, with a time horizon of four years, taking into account the expected achievement, and the expected revenues and costs.

Thus, the university chooses the expected enrollment N_p, the expected average ability of the student body $\overline{a}_p$ over the 4-year time period, instructional spending I_p per student, and the admission functions $\delta_s(a,y,g), \delta_t(a,y,g) \in [0,1]$, which are the shares of type (a,y) agents from group g that are admitted as in-state presential and respectively out-of-state presential.

The problem of the public university is:

$$\max_{\substack{\delta_s(a,y,g),\delta_t(a,y,g),\\ I_p, N_p, \overline{a}_p}} \sum_g \pi_g \sum_z \left[\int\int Eh_z(q_p,a,g)\delta_z(a,y,g)p_z(a,y,g;T,Q)f_g(a,y)dady \right]. \tag{8}$$

Using the notation for conditional probabilities introduced above, $p_z(a,y,g;T,Q)$ is the fraction of type (a,y,g) students that attend the public university if admitted.

Denote by $x_p(a,g) = [\phi_p(g)d(a,g) + 4(1 - d(a,g))]$ the expected time spent in public university by agent (a,g), where $\phi_p(g)$ is the typical time spent in college by a dropout.

Let $t_{p,z}(a,y,g)$ be the annual tuition net of financial aid paid by agent (a,y,g) in program z. The budget constraint of the university is

$$N_p s + \sum_g \pi_g \sum_z \int\int t_{p,z}\delta_z(a,y,g)p_z(a,y,g;T,Q)x_p(a,g)f_g(a,y)dady = N_p I_p + C_p(N_p), \tag{9}$$

where $N_p s$ is the total amount of subsidies received by the university. The second term on the left hand side of the equation represents total tuition revenue, where π_g is the proportion of group g in the total potential student population. On the right hand side of the budget constraint, $N_p I_p$ are the instructional costs, and $C_p(N_p)$ captures other costs that are not related to instruction ("custodial costs").

The university maximizes equation (8) subject to: budget constraint (9), the tuition schedules, the feasibility constraints $\delta_s(a,y,g), \delta_t(a,y,g) \in [0,1]$, for all student types, and the following identity constraints:

$$N_p = \sum_g \pi_g \sum_z \int\int \delta_z(a,y,g)p_z(a,y,g;T,Q)x_p(a,g)f_g(a,y)dady \tag{10}$$

and

$$\overline{a}_p = \frac{1}{N_p}\left[\sum_g \pi_g \sum_z \int\int a\delta_z(a,y,g)p_z(a,y,g;T,Q)x_p(a,g)f_g(a,y)dady\right]. \tag{11}$$

The optimization problem of the public university yields endogenous admission thresholds $a^{p,z}_{min}$ for in-state and out-of-state students, such that for the marginal student with $a = a^{p,z}_{min}$, the effective marginal cost of the student equates the marginal benefit of admission.

Setting up the Lagrangian for the public university's problem, in Appendix C we derive the admission equation for student (a, y, g) in program z (in-state or out-of-state):

$$\frac{Eh_z(\cdot)}{\lambda} + x_p(a,g)\left[t_{p,z}(a,y,g)+s\right] = x_p(a,g)\left[I_p + \nu_{1p} + \nu_{2p}\frac{N_p}{2}\right] + x_p(a,g)\frac{q_{\overline{a}_p}}{q_{I_p}}(\overline{a}_p - a). \tag{12}$$

The admission equation for out-of-state students is similar. As in Epple et al. (2017), the effective marginal cost of the student is given by the direct marginal cost of instruction and the marginal peer cost (negative for students with ability below the college average, positive otherwise). The marginal benefit of admitting the student equates the tuition paid and the per student subsidy received by the university, plus the monetary value of the student's contribution to the aggregate achievement at the public university.

Online program. The selection into the public online program is modelled through an exogenous threshold $a^{(p,o)}_{min}$, which is then calibrated to match the public market share in the online market. The tuition $T_{p,o}$ and spending per student $I_{p,o}$ are also exogenous. We allow for different peer effects and spending elasticities in the quality production function of the online program, which is:

$$q_{p,o} = A_p(\overline{a}_{p,o})^{\gamma_{p,o}}(I_{p,o})^{\omega_{p,o}}.$$

For-profit sector. For-profit colleges choose the sticker price and instructional spending per student in order to maximize expected profit. Like the public university, they make decisions over a 4-year time period. They are non-selective, admitting all students who would like to enroll. Students enrolling in the for-profit sector can receive federal financial aid and may pay a net price lower than the tuition charged by the college.

Denote by T_j and I_j the per year tuition and spending at for-profit college j. The tuition schedule for student (a, y, g) is $t_j(a, y, g)$. Let $x_j(a, g)$ denote the expected time spent in college j by agent (a, g). The choice probability of attending the for-profit college is $p_j(a, y, g; T, Q)$. The problem of a for-profit university j is:

$$\max_{T_j, I_j} \Pi_j = \sum_g \pi_g \int\int t_j(a, y, g, d) p_j(a, y, g; T, Q) x_j(a, g) f_g(a, y) da dy - N_j(T_j, I_j) I_j - C_j(N_j), \tag{13}$$

subject to identity constraints

$$N_j = \sum_g \pi_g \int\int p_j(a, y, g; T, Q) x_j(a, g) f_g(a, y) da dy, \tag{14}$$

$$\overline{a}_j = \frac{1}{N_j} \sum_g \pi_g \int\int a p_j(a, y, g; T, Q) x_j(a, g) f_g(a, y) da dy, \tag{15}$$

where N_j is the expected enrollment, $\overline{a}_j$ the expected average ability over the four year period. In the empirical exercise, we model two for-profit colleges, one offering presential instruction, with tuition $T_{r,p}$ and per student spending $I_{r,p}$ and another offering exclusively online courses, with tuition $T_{r,o}$ and per student spending $I_{r,o}$.

Not-for-profit sector. As we focus on the interaction between the public and for-profit institutions, we do not explicitly model the behavior of nonprofit colleges. In the empirical exercise we include two groups of nonprofit universities. The sticker prices and per student spending, denoted T_{e1} and I_{e1} for Group I, and T_{e2} and I_{e2} for Group II are exogenous and based on observed values. However, we model price discrimination in college tuition, which is an important feature of the nonprofit sector (see Epple et al. (2017), Epple et al. (2019)).

To this end, we estimate different institutional aid functions by ability, income and student group (traditional and nontraditional) for different groups of colleges (see Table A5). Thus, in equilibrium, students enrolled in not-for-profit institutions pay different prices, according to their type. In order to capture the selective admission at higher ranked nonprofit colleges, we introduce an exogenous admission threshold for this group of institutions (Group I). Consequently, the average ability of the student body, enrollment and resulting quality in the not-for-profit sector are endogenous, determined in equilibrium by student sorting across institutions.

Summarizing the institutional features which determine student sorting, Group I not-for-profit colleges have an explicit threshold a^e_{min}. Public institutions are selective, and admission is determined by equation (11) for presential education and a threshold $a^{(p,o)}_{min}$ for the public online program. Only the lower cost not-for-profit colleges and for-profit colleges have open enrollment, with admission being determined in equilibrium by price and financial aid functions at these institutions. Similar to Epple et al. (2017) and Fillmore (2023), however, lower cost nonprofit colleges compete with other institutions by seeking to attract high-quality applicants through institutional aid.

3.3 Equilibrium

The exogenous elements of equilibrium are: (i) the relative sizes of the two groups of potential students, π_t and π_{nt}; (ii) the joint distributions of ability and income, $f_t(a, y)$, $f_{nt}(a, y)$; (iii) the utility and achievement functions and the distribution of the preference shocks ϵ_{jk}; (iv) the sticker prices at the public university, $\{T_s, T_t, T_{p,o}\}$, for in-state presential, out-of-state presential and online programs, respectively, and the per student spending at public online program $\{I_{po}\}$; (v) the sticker prices $\{T_{e1}, T_{e2}\}$ and per student spending $\{I_{e1}, I_{e2}\}$ at not-for-profit colleges; (vi) the dropout probabilities $d_{jk}(a, g)$; (vii) the university cost and quality functions; (viii) the federal and institutional financial aid functions, $FedAid_j(a, y, g)$

and $InstAid_j(a, y, g)$; and (ix) the state subsidy s.

Definition 1. *Given (i)-(ix), the equilibrium is a vector of university qualities $\{q_j\}$, prices and per student spending at for profit colleges $\{T_j\}$, per student spending $\{I_j\}$, enrollments $\{N_j\}$, average ability of student body $\{\overline{a}_j\}$, admission functions at the public university $\{\delta_s(a, y, g), \delta_t(a, y, g)\}$, and the conditional probabilities $p_j(a, y, g)$, such that, for all $j \in J$:*

1) students make the optimal choice, taking as given the university quality and price vectors, admission thresholds at the public and the elite nonprofit school, and public policies;

2) public university chooses the optimal admission functions, given the qualities and prices of the other colleges, student choice probabilities and public policies;

3) for-profit colleges choose the optimal level of spending and tuition, given the qualities and prices of the other colleges, student choice probabilities and public policies.

In the following, we calibrate and numerically solve for the equilibrium. The algorithm used to find the equilibrium is described in Appendix B.

4 Quantitative Model Specification

We calibrate/estimate the parameters of the model in order to reproduce key features of the U.S. higher education sector and student outcomes. We model one representative public university with a presential and online program, two nonprofit and two for-profit colleges. In sections 4.1 - 4.3 we describe the independent parameters of the model, estimated or calibrated from outside sources. Table 1 provides a summary of the independent parametres of the model. In section 4.4 we describe the remaining parameters that are jointly determined and the targeted moments used in calibration. Table 2 shows the targeted statistics and Table 3 the jointly calibrated parameters.

4.1 Agents

4.1.1 Population of potential students

Relative group sizes. Our population is composed of two groups of potential students: traditional and nontraditional. We calibrate the relative sizes of the two populations (π_t, π_{nt}) using data from the American Community Survey 2000-2015 yearly samples. For traditional students, we count the number of 18-24 year olds who have attained at least ninth grade as the potential pool of undergraduates.[13] To assess the size of the nontraditional potential student population, we consider individuals aged 25-45, who do not hold a college degree and have attained at least ninth grade.[14] We find $\pi_t = 0.35$ and $\pi_{nt} = 0.65$.

Ability distributions. We fit a normal distribution to Armed Forces Qualifications Test (AFQT) data from the National Longitudinal Survey of Youth (1997).[15] Observing the AFQT scores of potential traditional and nontraditional students in the NLSY97 data, we find that nontraditional students have average AFQT scores 0.3 standard deviations lower than those of traditional students. Given that we have normalized the mean of the traditional student ability distribution to 1, this translates into a mean standardized ability of 0.93 for nontraditional students. The distribution fit is shown in Appendix Figure 1.

Income distributions. Universities and the federal government consider dependent students' parental income when determining financial aid. We therefore use the family income in households with a seventeen year old present. We use data from the 2012-2014 American Community Survey, and adjust for taxes.[16] When applying for Federal Student Aid (FAFSA), nontraditional students are considered "independent", and their relevant income

[13] Students with at least nine grades of education can potentially qualify for a GED diploma. Many universities accept GED certification in lieu of a high school diploma.

[14] We focus on ages 25-45 as the observed school enrollment in the ACS drops below five per cent of the age cohort after age 45.

[15] We have considered several other functional forms, we prefer the normal distribution because of its good fit, tractability and similarity to data used by Epple et al. (2017).

[16] Tax adjustment information uses brackets from Congressional Budget Office (2016).The Distribution of Household Income and Federal Taxes, 2013. www.cbo.gov/publication/51361

is their own (and their spouse's, if married). For nontraditional students, aged 25-45, we perform the same tax-adjustment to the (family) income they report in the ACS. We find that a three parameter log-normal distribution best fits the data (Appendix Figure 2).

Correlation of income and ability distributions. We set the correlation between income and ability at 0.3. This figure corresponds to the correlation between parental (family) income and AFQT scores in the NLSY97 for traditional students, as well as the correlation between own wages and AFQT scores for nontraditional students at the enrollment-weighted average age of nontraditional students.[17]

4.1.2 College students

Dropout probabilities. We calculate dropout probabilities using data from the Beginning PostSecondary Students 2012/2017 survey, separately for dependent and independent students, institution types, and ability categories. Values are shown in Appendix Table A8.

Non-tuition costs. To quantify non-tuition costs, we add up room and board and transportation expenses data from the College Board 2013 Annual Survey of Colleges for the school year 2012/2013. For students enrolled in exclusively online education, we adjust non-tuition costs to reflect the lower transportation costs and lower room and board costs corresponding to the higher fraction of students living with their parents.

Average enrollment duration. We quantify the average duration of enrollment for students who eventually drop out using the Beginning PostSecondary Students 2012/2017 survey, which records the status of the 2011/2012 entering cohort every year after enrollment. We then aggregate information on the fraction of students who are no longer enrolled at the initial institution. We assign dropouts the number of years completed before the drop out decision, and we calculate a weighted average based on the duration of enrollment and the year-by-year data on fraction of students dropping out. We perform this calculation separately by

[17]We find the enrollment-weighted average age of nontraditional students to be 32, based on NCES Digest of Education Statistics 2014, Table 303.45.

institution for dependent and independent students. The resulting average durations are presented in Appendix Table A9.

4.2 Subsidies and financial aid

Public sector subsidies. The per capita average state, endowment and local appropriations for public four-year colleges are extracted from IPEDS 2013.

Federal grants. The Federal Pell Grant Program is the main source of federal need-based financial aid. The amount an individual may receive under this program is calculated taking into account the cost of attendance, which includes college tuition and non-tuition costs and the "Expected Family Contribution"(EFC), a stepwise function of household assets, income, and living expenses, which is set separately for dependent and independent students. We approximate this function for the period of analysis (Appendix Table A2), using data from the NPSAS:2012, and taking into account the cap on the maximum amount of federal financial aid, which stood at 5,500 dollars in 2013.

Federal student loans. Subsidized Stafford loans are the most common type of federal loan, providing a low interest rate and a repayment grace period while students are enrolled in college. The total amount students can borrow in Stafford is capped. Students whose financing needs exceed the cap can additionally borrow at an unsubsidized Stafford rate, access other federal loan programs (such as the PLUS loans) or take out private loans. The amount borrowed is likely to differ between traditional and nontraditional students because of different parental support and eligibility rules. To obtain predicted federal student loan balances, we use the NPSAS: 2012 and regress total Federal student loan balances on parental income (or family income, for nontraditional students) and net tuition. The resulting regression coefficients are shown in Appendix Table A3.

State financial aid. We include the average amount of state financial aid based on NPSAS:2012 for different parental or own income categories for traditional and respectively nontraditional students. Figures are shown in Appendix Table A4.

Institutional financial aid. Estimates of institutional financial aid at nonprofit colleges are obtained from the NPSAS: 2012, based on family income and rank in the SAT distribution, which we take as a proxy for ability. Average values are shown in Table A5 in the Appendix. Institutional aid at public colleges is generally smaller and exhibits less variation. Using NPSAS:2012, we impute public institutional aid according to a matrix of income and ability (proxied by standardized SAT scores). Figures are presented in Appendix Table A6.

Other sources of financial aid. Following the NPSAS:2012 nomenclature, we consider "outside sources" of financial aid to be the sum of outside grants (private or employer), private commercial or alternative loans and federal Veterans' benefits and military tuition aid. Using NPSAS:2012 data, we predict the amount of outside sources as a function of parental or family income and the net cost of attendance, separately by student type (traditional/nontraditional) and institution type.[18] Figures are presented in Appendix Table A7.

4.3 Colleges

4.3.1 Tuition and instructional spending

Nonprofit sector. The sticker prices $\{T_{e1}, T_{e2}\}$ and per student spending $\{I_{e1}, I_{e2}\}$ in the nonprofit sector are exogenous in the model. We use IPEDS data for the 2013 academic year to distinguish between two groups of nonprofit institutions, high and low tuition. We use the undergraduate enrollment-weighted median tuition level (28,090 dollars) as the threshold between higher and lower priced colleges, and proceed to find the corresponding average instructional spending in each group. The corresponding values are shown in Table 1.

[18]We run these predictions separately by type of institutional control to capture the fact that some higher education providers, in particular for-profit colleges, have institutional arrangements in place to facilitate student access to private loans, and disproportionately serve students who use veteran benefits to finance their education.

Public sector. The exogenous elements in the public sector are the sticker prices at the public university, $\{T_s, T_t, T_{p,o}\}$, and the per student spending at the public online program $\{I_{p,o}\}$. We use College Board 2013 data on in-state and out-of-state sticker price at the public institution. We set online tuition at the public university at the in-state average, as we find most schools allow online students to qualify for the in-state price.[19] To evaluate instructional spending at the public online program we use information from public sector institutions reporting in IPEDS 2013 that more than 70 per cent of their students were attending exclusively online.

4.3.2 Quality production functions

We need to parametrize the quality production functions of colleges: $q_j = A_j(\overline{a}_j)^{\gamma_j}(I_j)^{\omega_j}$. The productivities A_j are estimated in the joint calibration, described in section 4.4.

Peer effect elasticities. We assume that presential institutions have the same peer effect elasticity, $\gamma_p = 0.15$, as in Epple et al. (2017). Similarly, we assume the public and for-profit online institutions have the same peer elasticity parameter, γ_o. Peer effects can operate in distance education through a number of channels, including discussion boards, social networks, study groups, and peer grading interactions. Bettinger, Liu, and Loeb (2016) analyze data from a large online university that quasi-randomly assigns students to classes based on the date of enrollment. They document homophily (same-gender and same region interactions are more common) as well as positive effects of exposure to more active online discussion with peers on the probability of passing the course, grade performance, and likelihood of enrolling in the next academic term. Huber, Lane, and Lakhani (2020) similarly find that age-based homophily has a positive effect on course completion. Studying an online business skills course offered by an elite U.S. business school, they find the presence of same-age peers

[19]This is an approximation based on the list of programs reviewed by GetEducated.com, List of Online State Universities, https://www.geteducated.com/online-universities/532-online-state-colleges-and-universities// [accessed Jan 12, 2022].

can have a significant impact on course engagement and persistence.

To assess the magnitude of the peer effect coefficient for online institutions, we use College Scorecard Data for cohorts 2004-2014 and regress the log of earnings six years after graduation on average SAT scores and instructional spending, separately for mostly presential (fraction enrolled exclusively online less than 20 percent) and mostly online institutions (fraction enrolled exclusively online greater than 70 percent). For presential institutions, the effect of the average SAT score on log earnings is 0.836, while it is 0.508 for online institutions. We use the ratio of these coefficients to adjust the peer effect elasticity for online institutions to be 60% of the peer effect at presential ones, under the assumption that the correlation between remaining unobserved factors is similar at online and presential institutions. Consequently, we set the peer effect elasticity $\gamma_o = 60\% \cdot \gamma_p = 0.09$ for the public and the for-profit online institutions. This is a crude estimate, and we present robustness checks in Appendix Tables A10 for a range of values of the peer effect coefficient at online institutions.

Spending elasticities. We set the elasticity of instructional spending parameter in the university quality function at nonprofit institutions to $\omega_e^I = \omega_e^{II} = 0.155$ as in Epple et al. (2017), and proceed to estimate elasticity parameters for other institutions, as described in the joint calibration section. We separately estimate spending elasticity parameters for the public presential institution (ω_p), for-profit presential college ($\omega_{r,p}$) and the online for profit college ($\omega_{r,o}$). We assume the spending elasticity for the online public program $\omega_{p,o}$ is equal to $\omega_{r,o}$.

4.3.3 Estimation of college cost functions

The cost function for a university with enrollment n_j and instructional costs I_j is:

$$C(n_j, I_j) = F + v_1 n_j + v_2 n_j^2 + n_j I_j,$$

where $v_1 n_j + v_2 n_j^2 + F$ is a custodial cost function, which captures the fixed costs F (e.g. maintenance of plant) and variable costs that depend on student enrollment, $v_1 n_j + v_2 n_j^2$.

To approximate the custodial cost function, we use the IPEDS Delta Cost Project dataset, which provides detailed information on categories of costs for a rich panel of universities. We include "academic support", "student services", and "institutional support" in the variable custodial cost component, and approximate fixed costs F using the expenditures for operation and maintenance of plant category, which includes items such as utilities, fire protection, property insurance, etc. These values are shown in Table A1 in the Appendix .

To estimate v_1 and v_2, the parameters of the custodial cost function, we use a balanced panel from the IPEDS data, restricted to baccalaureate granting universities.[20] We expect universities differ greatly in cost structures, and we attempt to deal with the underlying heterogeneity by estimating a fixed effects regression, capturing within-university variation in the effect of enrollment on custodial costs. In practice, we estimate

$$C_{tj} = \alpha_j + \gamma_t + c_1 k_{tj} + c_2 k_{tj}^2,$$

where C_{tj} are custodial costs per capita in period t at institution j, α_j is a university fixed effect, γ_t an academic year fixed effect, and k represents university j's market share.

In calibration, we translate these coefficients into the aggregate cost function $C(n_j, I_j)$, with $v_1 = c_1$ and $v_2 = c_2 \sum_{i=1}^{J} k^2$. As other analysts estimating such custodial cost functions, (Epple et al. (2017); Gordon and Hedlund (2017)), we find it necessary to set $c_1 = 0$ to approximate an increasing cost function. Per capita fixed costs obtained from IPEDS as expenditures for the operation and maintenance of plant category are translated from a per capita basis to be consistent with our measure of enrollment in the model (fraction of the population). Coefficients are shown in Table 1.

[20]Universities are "multi-product" firms, with research and student enrollment/graduation as notable outputs, along other functions such as public service, university hospitals, etc. In this paper, the output we focus on is student enrollment, as competition between the for-profit and public sectors targets student enrollment, and much less so other dimensions of public school activity such as research. As such, in estimating cost functions, we exclude doctoral/research universities, master's colleges, and specialized institutions such as theological seminaries, medical schools, military schools, and schools of art, music, etc. In practice, this restriction involves focusing on baccalaureate colleges, as classified under the Carnegie 2000 methodology.

4.4 Jointly determined parameters

In the following we describe the remaining parameters of the model that are jointly calibrated and the target moments used in calibration.

Utility function. We calibrate the utility weighting parameter α. We normalize to 1 the preference parameter $\theta_{k,g}$ in the presential education nest for both student groups. However, we allow different preference parameters across groups for online education ($\theta_{o,t}$ and $\theta_{o,nt}$) and calibrate them.

In order to match out-of-state enrollment in the public sector, we introduce a preference parameter for out-of state education, $\nu > 1$, common across agents. This parameter captures the willingness to pay more for out-of-state education — individuals may value the experience of going to a different state for college. In equilibrium, a fraction of agents enrolling in the public sector will choose the out-of-state option. As Epple et al. (2017) point out, the higher price tag associated with out-of-state enrollment at public universities also introduces an additional option for lower ability students not accepted at the in-state price to enroll in a public university paying the higher out-of-state price. As we do not model multiple state universities, out-of-state education is introduced as a more expensive track, in order to better match the behavior of the public sector.

Quality production functions. We normalize the productivity of presential for-profit colleges ($A_{r,p} = 1$) and calibrate the productivities of the other colleges (A_p, A_e^I, A_e^{II}, and $A_{r,o}$). We also calibrate the instructional spending elasticities at the presential program at public university ω_p, for profit presential and online colleges parameters: $\omega_{r,p}$, and $\omega_{r,o}$. We set the spending elasticity at public online program $\omega_{p,o} = \omega_{r,o}$.

Achievement functions and outside options. We calibrate the parameter β in the achievement function for college education, the achievement parameters B_t, B_{nt} of the outside option for traditional and nontraditional students, respectively, and the productivity parameter B_d in the achievement function of college graduates.

Admission thresholds. We also calibrate an admission threshold parameter a^e_{min}, which reflects the minimal ability threshold for admission to Group I nonprofit institutions, which tend to be high tuition, highly selective institutions, and a threshold for admission to public online institutions, $a^{p,o}_{min}$.

Other parameters. We additionally calibrate the dissimilarity parameters within the presential and online nests of college choices (λ_p and λ_o), to reflect differences in enrollment patterns across groups.

Summing up, there are 19 parameters to be calibrated, shown in Table 3. We determine these parameters by minimizing the distance between the target moments in the data and the simulated moments implied by the model. We minimize the following function:

$$\Phi = \arg\min_{\Phi}[M(\Phi) - M_d][M(\Phi) - M_d]',$$

where Φ is the vector of parameters, $M(\Phi)$ is the vector of simulated moments and M_d is the vector of target moments listed in Table 2.

We target the following moments in the data: enrollment rates of traditional and nontraditional students in different sectors; market shares of different sectors in total enrollment; college market shares within their respective sector (for-profit or nonprofit); levels of instructional spending in different sectors; tuition charged by for-profit colleges; the ratio of mean student ability in different sectors and the ratio of predicted achievement of college graduates relative to non-graduates, as reflected in the college graduation premium.

Our data sources for the targeted moments are presented in Table 2 and summarized below:

Enrollment data and market shares. The enrollment rate of 18-24 year olds in four-year colleges is the average reported by NCES for the 2012-2014 period. To calculate enrollment for nontraditional students, we divide total enrollment reported by age group in the NCES

Digest by the total potential nontraditional student population. We use the NCES education digest tabulations by level of institutional control to calculate market shares for 2013.

Tuition and instructional spending. We target the instructional per student spending in the presential public program (I_p), and sticker prices and per student spending at the two for profit institutions. Data on the average student spending at public presential programs and per capita instructional expenditure and average tuition by type of institutional control in the for-profit sector are collected from IPEDS 2013. We classify for-profit colleges into two groups based on the fraction of students enrolled in exclusively distance education, using data from IPEDS 2013. The online group consists of institutions where more than 70 per cent of students are classified as attending through exclusively distance learning. In the resulting online group, 91 per cent of students attend through exclusively distance learning, while in the residual presential group only 12.8 per cent of students are attending exclusively online.

Ability ratios. To proxy the ability ratio between Group I nonprofit students and public students, we turn to NPSAS:12, and take the average of composite SAT scores for U.S. citizen undergraduates enrolled in four-year bachelor's programs.

College graduation premium. Using American Community Survey 2012 data, we calculate the ratio between the wage and salary income of individuals aged 22-64, holding a bachelor's degree, and the wages and salary income of individuals whose highest attainment was "1 or more years of college credit, no degree".

5 Results

Table 3 shows the jointly determined parameters. The elasticity of spending per student is lowest at online for-profit schools $\omega_{r,o} = 0.125$, slightly higher at for-profit presential colleges and highest for public schools $\omega_p = 0.156$, very close to the calibrated value of 0.155 for nonprofit schools from Epple et al. (2017). This pattern could reflect fundamental differences in the skills production function across sectors, for example instructor training. For-profit colleges employ fewer Ph.D. holding instructors, and are more reliant on part-time and temporary staff. This suggests that increases in instructional spending may not lead to large changes in the quality of instruction at for-profit colleges compared to other institutions.

We find the estimated productivity parameters in the quality production functions to generally follow the expected pattern given by the instructional spending ranking. These productivity parameters capture other aspects of quality determination, besides peers and instructional spending, that are not included in the model, such as research activity, academic support, university industry networks, professors' teaching abilities. As these other determinants of quality are generally correlated with resources spent on instructional spending and average student body ability, we expect the productivity ranking to follow the ranking of these two dimensions. Indeed, we find that high tuition nonprofit institutions exhibits high productivity, followed by the public sector, the presential for-profit sector and the lower tuition nonprofit group. The online for-profit sector stands out, exhibiting relatively high productivity, which we understand to reflect a high degree of operational efficiency.

We find the outside option achievement parameter for nontraditional students (B_{nt}) to be higher than for traditional students (B_t), as expected given their higher accumulated labor market experience. We also find the online preference parameter to be higher for nontraditional than traditional students ($\theta_{o,nt} > \theta_{o,t}$), likely reflecting the greater flexibility sought by older students who may have family responsibilities. The dissimilarity parameter in the presential education nest (λ_p) is higher than in the online nest (λ_o), indicating less correlation in unobservables between choices of presential institutions than between online institutions.

Table 4 illustrates the model predictions about the distribution of students across sectors by ability and income. Panel A compares market share data from IPEDS 2013 with model predictions. The model does a good job of matching market shares, many of which are however directly or indirectly targeted moments. Panels B and C display model predictions about moments not targeted in estimation. In panel B, we compare market shares by levels of student ability, while in panel C we focus on student incomes.

Panel B uses data from NPSAS:2012, which allows for a breakdown by SAT score. We split the sample into six groups, based on standard deviations of the SAT score. We compare allocations between universities across these groups to allocations among standard deviations of our ability measure. Keeping in mind the differences between the two samples and the two proxies for ability,[21] the model does a good job of capturing the declining market share of for-profit colleges for higher levels of SAT/ability for dependent students. At the same time, the model captures the fact that high ability students are more likely to enroll in private nonprofit institutions. The model underperforms at the extremes of the ability distribution, particularly for low SAT/low ability students. This is likely a reflection of the higher weight that other aspects of students' backgrounds play in university admissions, particularly at nonprofit institutions, that are not captured by the model (for example, minority status).

Panel C compares model fit across sectors and student income levels. We use data on the distribution across institutional sectors by level of income from NPSAS: 2012. The model generally captures the preference of higher income traditional students for nonprofit institutions. For lower income nontraditional students, the model underpredicts enrollment at nonprofit institutions. This is again likely a reflection of the complex nature of the admissions process at nonprofit institutions.

[21] Our calibration aims to match moments for the entire U.S. population, not just the NPSAS:2012 sample. Also, while SAT scores are highly correlated with the AFQT (the basis for our measure of ability), we do not expect the two distributions to overlap in the overall population, since SAT-taking students are likely positively selected.

5.1 Policy Experiments

We use the calibrated model to perform counterfactual policy experiments. Increasing college accountability through gainful employment legislation has been a contentious policy with a potentially large impact on the for-profit sector. In section 5.1.1, we simulate the response of colleges in our model to tying access to federal aid to debt-to-earnings ratios. In section 5.1.2, we quantify the impact of changes in subsidies and tuition at public universities and in section 5.1.3 we vary the generosity of the Pell Grant cap. Together these simulations reflect a range of recent policy efforts to increase accountability and access to higher education. We compare these policies in terms of welfare impact in section 5.2.

5.1.1 Gainful Employment

We simulate the response of for-profit colleges to a gainful employment policy that would tie access to federal funding to students' debt-to-earnings ratios post-graduation. Our model delivers predictions for loan balances for each student. We forecast loan repayments under a 15-year loan repayment schedule, using a 4.15 percent interest rate.[22]

We use the individual achievement or human capital accumulated in college predicted by the model to generate graduates' market wages. Our framework captures heterogeneity in college returns through several mechanisms. First, the presence of peer effects leads to an equilibrium in which more able students enroll in better colleges, with higher spending and higher peer quality (the selection effect). Second, in our model, the quality of college and student ability enter the achievement function in a multiplicative fashion. This specification captures the fact that more able students will accumulate more skills for the same level of educational quality (the skill accumulation effect).

Let w be the price at which a unit of human capital is valued, which is random across

[22]This figure corresponds to the average of the Stafford subsidized interest rates for years 2011/2012 through 2019/2020.

graduates, reflecting labor market frictions. Thus, the wage of an agent of ability a graduating from college j is:

$$W(q_j, a) = w * h(q_j, a),$$

where $h(q_j, a) = q_j a^\beta$ is the individual achievement predicted by the model and q_j is the institutional quality of college j. We assume $\ln(w)$ is normally distributed, with mean μ and standard deviation σ. We choose μ and σ so as to match the mean and standard deviation of the distribution of wages for college graduates.

The period relevant for the calculation of college graduates' wages is, under the Department of Education proposed rules, three to four years after graduation.[23] We obtain information on earnings four years after graduation from the Baccalaureate and Beyond 2008 survey, which conducted a 2012 follow-up of the 2008 graduating cohort. We inflate the 2012 earnings to 2016 values using an index of real wage growth in order to match our period of analysis for institutional quality.[24] The resulting mean and standard deviation of graduates' wages are 44.2 and 51.9 thousand dollars, respectively.

We use the mean and standard deviation of wages for college graduates, and the mean achievement of enrolled students in the baseline model, denoted $\overline{h}$, to calculate the mean and standard deviation of w. The mean of w is given by $\overline{w} = 44.2/\bar{h}$ and standard deviation $s_w = 51.9/\overline{h}$. Next, we calculate the mean μ and standard deviation σ for $\ln(w)$ and simulate values for w to generate wages for each individual.

We then calculate the debt-to-earnings ratio for each individual, by dividing predicted loan repayment by predicted wage. Finally, we calculate the average debt-to-earnings ratios for each institution in our model.

The policy scenario we consider is the loss of federal financial aid for colleges whose

[23] "The third and fourth award years prior to the award year for which the D/E rates are calculated" (US Department of Education, Issue Paper 3: Gainful Employment, Session 2: February 14-18, 2022.)

[24] U.S. Bureau of Labor Statistics, Employed full time: Median usual weekly real earnings: Wage and salary workers: 16 years and over [LES1252881600Q], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/LES1252881600Q

graduates have a debt-to-earnings ratio in excess of twelve percent. Results are shown in Table 5. In panel A, we illustrate the debt-to-earnings ratios by type of institution. In the baseline simulation, public and nonprofit institutions have ratios below the threshold, while rates at for-profit colleges exceed twelve percent. Under the gainful employment policy, both for-profit institutions prefer to operate at the cut-off. They reach this level by lowering their tuition, from 15.3 to 11.4 in the case of the presential institution, and from 11.5 to 10.6 for the online for-profit. At the same time, presential and online for-profit colleges also lower instructional spending from 4.8 to 4.68 and from 2.2 to 1.99 thousand dollars, respectively.

Given the response of for-profit institutions is to lower tuition, their combined market share increases from 11.3 to 13.89 percent, with growth particularly strong in the nontraditional market, where they reach 31.6 percent from a baseline of 26.9.

While the policy achieves its goal of lowering debt-to-earnings ratios, given that for-profit institutions lower tuition charges, its short run impact on educational quality is negative. For-profit institutions attract lower ability students, to whom they deliver lower levels of instructional spending. The increase in overall enrollment is modest (28.3 to 28.39 percent), indicating that the cuts in tuition at for-profit colleges attract students from other institutions, notably the public college, which provides much higher levels of instructional spending. For example, for traditional students, the for-profit response leads to a reduction in the public market share, from 65.8 to 64.5 percent. Given the shift of lower ability students to the now cheaper for-profit colleges, all other institutions see a slight decrease in their debt-to-earnings ratio.

5.1.2 Subsidy changes in the public sector

In this section, we consider changes in the funding structure of public universities resulting from state subsidy cuts. Such changes have been frequent over the past decades, as illustrated in Figure 1 (d).

Subsidy cut and tuition increase in the public sector. In the first scenario, we implement a 2,000 dollar subsidy cut at public schools, coupled with a tuition increase in the same amount. The results are presented in Table 6. The cost increase at public schools leads to a decrease of 1.89 percentage points in the overall enrollment of traditional students. At the same time, the public school market share for traditional students drops from 65.8 percent to 56.5 percent. The level of instructional spending in the public sector decreases sligthly, from 11.9 to 11.7 thousand. The public university responds by enrolling a higher share of students paying the higher, out-of-state tuition (an increase from 14.7 to 16.5 percent), as well as a higher share of students attending online (who have lower net attendance costs given the lower nontuition costs).

For-profit colleges capture part of the public market share decrease. The presential for-profit institution slightly decreases tuition and instructional spending, while the online institution slightly increases prices and spending. Overall, the sector grows from 11.3 to 13.1 percent, most of the growth resulting from the presential institution, which responded the most in pricing and spending, and increased its share of the presential market from 5.1 to 6.8 percent. The magnitude of the effect of state subsidy cuts on for-profit enrollment is similar to findings by Goodman and Henriques Volz (2020), who estimate that enrollment in the for-profit sector increases about 2 percent for a 10 percent cut in state appropriations. Scaling our results, we find a 4.3 percent increase in for-profit overall enrollment for a 10 percent decrease in subsidies.

Subsidy cut and tuition cap in the public sector. In the second counterfactual scenario, illustrated in Table 5, we consider a 2,000 dollar subsidy cut at public institutions, accompanied by a tuition freeze. The public market share drops to 55.4 percent. Public schools respond by significantly decreasing the level of instructional spending, from 11.9 to 9.7 thousand, and slightly raising the fraction of students attending online, from 4.7 to 5.2 percent. For-profit colleges see an increase in market share from 11.3 to 11.9 percent, with the presential for-profit increasing its share from 5.1 to 5.5 percent while at the same time slightly raising tuition, as it is now in a better position to compete with the resource-deprived public school.

Subsidy increase and tuition decrease in the public sector. This counterfactual supplements subsidies per capita at the public institution by 2,000 dollars, allowing it to reduce tuition by an equal amount. The market share of the public institution increases from 62.7 to 69.1 percent. Out-of-state enrollment adjusts downward to 13.1 from 14.7 percent. The subsidy is financed through a 0.81% income tax, and the resulting increase in overall enrollment leads to additional tax revenue needs for Pell Grant beneficiaries, financed through a 0.08% percent direct tax on income.

5.1.3 Pell Grant increases

Doubling Pell Grants has been one of the campaign promises of the currrent administration. The fourth scenario in Table 6 considers a more modest increase in the Pell Grant cap, from 5.5 to 7.5 thousand dollars, while the fifth scenario shows the effects of a doubling of the Pell Grant maximal award, from 5.5 to 11 thousand dollars. In these scenarios, we keep the 2013 Expected Family Contribution schedule (Appendix Table A2), which implies a phasing out of Pell Grant benefits for wealthier families and individuals. For example, at a maximal cap of 7.5 (scenario IV), families with incomes above 70,000 dollars would not benefit from the Pell Grant increase. As such, the Pell Grant scenarios have a strong redistributive component, supporting college access mostly for lower income students.

Both counterfactual scenarios result in considerable increases in overall enrollment for traditional as well as nontraditional students. Under a doubling of the Pell Grant cap, enrollment of traditional students increases to as much as 36.1 percent of the cohort, while that of nontraditional students reaches 10.44 percent. For-profit colleges capture a large share of this increase. The share of traditional students enrolled in for-profit schools increases from 11.3 percent to 21.9 percent, with remarkable market share gains in the nontraditional student market, where they grow to 49.3 percent under the Pell doubling scenario. Online for-profit colleges are particularly apt at capturing the Pell Grant surplus, increasing market share by significantly reducing tuition from 11.5 to 7.8 thousand dollars and instructional spending from 1.9 to 0.8 thousand per capita.[25]

5.2 Welfare Analysis

In Table 7, we compare the aggregate utility of traditional and nontraditional agents across our policy experiments. As some of our counterfactual policies fundamentally aim to reduce societal inequalities and improve outcomes for lower income individuals, we also highlight how the average utility in the lower income group varies across experiments as a fraction of the average utility. Our analysis does not, however, take into account externalities from college attendance, which are likely to be positive (Lochner and Monge-Naranjo (2011)).

The Gainful Employment policy leads to lower overall welfare levels relative to the baseline, given the strategic response of for-profit colleges, which reduce instructional spending along with per capita tuition. However, these welfare effects do not account for any gains resulting from lower future loan default rates, which are ultimately the main goal of gainful employment policies.

Subsidy cuts coupled with tuition increases (counterfactual I) or tuition caps (counterfactual II) lead to modest welfare losses for traditional students, and modest gains for nontraditional students. The negative effect is largely driven by cuts in instructional spending at public universities, which educate the majority of traditional students. Faced with lower

[25]Such a low level of instructional spending is not uncommon for online education providers. Costs per completer for massive open online courses (MOOC) can be as low as 74 dollars per participant (Hollands and Tirthali (2014)). Columbia Southern University, an online for-profit, had a full time equivalent enrollment of 20,842 students in 2009, to whom it provided an average of 334 dollars in instructional spending, according to IPEDS data.

instructional quality and higher prices at public colleges, students reorient towards nonprofit and for-profit colleges, or choose not to enroll. As a result, the enrollment of traditional students drops 1.89 percentage points, or 6.7% of baseline. Nontraditional students see a lower relative decrease in enrollment, of about 5%, but they benefit from the response of the presential for-profit university, which decreases tuition to compete with the now more expensive public institution. The online for-profit institution similarly benefits from the pressures at the public college and increases tuition, instructional spending and enrollment. Nontraditional students also experience welfare gains from peer effect externalities, as higher ability students who would have enrolled in the public institution switch to nonprofit and for-profit institutions, which educate the majority of nontraditional students.

In counterfactual III, subsidy increases coupled with tuition cuts result in small decreases in overall welfare. The tax increase that finances this policy induces a negative effect on welfare for most groups, except lower income nontraditional students, who switch from for-profit institutions to the now cheaper public institution and experience better instructional spending and higher ability peers.

Increases in the maximal Pell cap of 2,000 dollars (counterfactual IV) are dominated by the welfare gains resulting from a policy that increases subsidies at public schools, despite the fact that the overall tax effort to sustain the Pell Grant increase is smaller than that required to increase public school subsidies. The difference between the two scenarios is, in the case of raising the Pell cap, the growth in for-profit enrollment brought by an increase in Pell Grants, which is concentrated among low income but also lower ability students. For-profit institutions respond to this inflow by reducing tuition as well as instructional spending to attract a higher share of the market, and reach an overall 12.1 percent, compared to the decrease to 9.9 percent in counterfactual III.

The Pell Grant experiment thus has the unintended consequence of leading to increased price competition and a race to the bottom in the for-profit market in terms of instructional quality. The increase in enrollment is occurring mostly in low selectivity, low instructional quality institutions. The negative impact on instructional quality translates into lower aggregate welfare in the scenario where the cap on Pell Grants is doubled. Despite much higher levels of college enrollment, the overall welfare increase is smaller than for a more modest Pell Grant cap increase. Aggregate welfare is also lowered by the higher level of direct income taxes needed to finance the doubling of Pell Grants. The redistributive effects of a doubling of Pell Grants remain, as expected, particularly strong, and the welfare gains for lower income individuals dominate an increase in the Pell cap of only two thousand dollars. In Table 8, we illustrate aggregate welfare for different categories of students under gradual Pell Grant increase scenarios, from 5.5 to 11 thousand dollars. For both traditional and nontraditional students, maximal welfare is reached for an increase to 8.5 thousand. Lower income traditional students see the highest gains under a doubling of the Pell Grant, while welfare is highest for a 10.5 increase in the case of lower income nontraditional students.

5.3 Robustness checks and validation exercise

Increases in Pell Grants may trigger crowd out responses in institutional financial aid at nonprofit and public institutions. Epple et al. (2017) estimate that about 40 percent of Pell Grant increases may be crowded out by reductions in institutional financial aid at nonprofit colleges. Turner (2017) finds that institutions capture up to 20 percent of Pell Grant aid, with much smaller crowd out levels at public institutions, of up to five percent. We re-estimate the Pell Grant counterfactual involving a doubling of the maximal cap under the assumption that 40% of the additional Pell Grant financial aid at nonprofit institutions and 5% at public institutions is crowded out by reductions in institutional financial aid. Results are presented in column VI of Table 6, and are generally similar to the magnitudes in the no crowd out scenario, however with smaller increases in overall enrollment and a larger market share at public institutions. Market shares, spending and tuition at for-profit colleges change only slightly from the no crowd-out scenario, reflecting the fact that these institutions are less responsive to the actions of the more expensive nonprofit institutions, who display the crowd out response but target a different segment of the market.

Our utility specification puts equal weight on agent's consumption and achievement. An alternative specification is to allow a different weight in the utility function for achievement, reflecting the fact that college achievement translates into labor market earnings gains after graduation, and the decision-maker may discount delayed gains. As college duration is four years in our model, we use a specification that weights achievement at $0.96 = (0.99)^4$, where the one-year discount factor is 0.99. Thus, the specification becomes $V_j(a, y, g) = \theta_{k,g}(lnc_j + 0.96lnh_j)$. We simulate the model using this alternative specification and present results in Table A11. Discounting achievement results in very similar moments, with a slight decrease in nontraditional enrollment and an increase in traditional enrollment. This is consistent with the fact that the revised specification puts a higher relative weight on current consumption, which is preferable to traditional students who enjoy the consumption afforded by the higher parental income, and less so for nontraditional students, who rely on their own (and spousal) income. The shifts in traditional vs. nontraditional enrollment do not however lead to fundamental shifts in market shares or tuition and spending at for-profit colleges.

Our model and counterfactual analyses indicate that changes in tuition and instructional spending at public universities facilitated the growth of for-profit colleges. In order to analyze the quantitative importance of this channel, we perform a counterfactual exercise in which we investigate how our model performs at predicting market shares in 2004. Thus, we simulate the model using the 2004 levels of per student subsidy and Pell grant cap, tuition, non-tuition costs and instructional spending at public colleges and nonprofit colleges. Between 2004 and 2012, the higher education market experienced significant changes in subsidies and higher education prices. Levels of these variables in 2004 and 2012 (our baseline) are summarized in Table A12.

The results of the validation exercise are presented in Figure A3 and Table A13. In Figure A3 we show the evolution of market shares by type of institution for nontraditional (panel (a)) and traditional students (panel (b)), contrasting the data and the changes predicted by the model. Our model matches the shifting patterns in nontraditional market shares away from public and nonprofit to for-profit institutions, and similar, albeit much smaller shifts in traditional enrollment market shares between these institutions.

As we can see from Table A13, the for-profit market share has grown from 4.43 percent in 2004 to 11.29 percent in 2012 (the later value is matched by our baseline model). Feeding in the model the 2004 level of public subsidies, spending and tuitions in the public and non-profit sectors yields a market share of 7.04 percent, explaining almost 62 percent of the change in market share observed in the data. The rest of the change observed in the data could be attributed to other important factors, such as changes in the income distribution or technological change in the online sector.

In column 4 of Table A12 we show our 2004 model predictions when we change only the subsidy and tuition in the public sector, keeping pricing at nonprofit institutions at 2012 levels. This allows us to quantify the relative importance of price changes at nonprofit colleges from public institution changes in tuition and subsidies. Our results point to a much larger impact of changes in public subsidies on the overall for-profit market share. Changes in subsidies and pricing in the public sector explain 52 percent of the change in for-profit market share observed in the data. This result is in line with for-profit institutions directly competing in pricing with the cheaper public colleges than with nonprofit institutions.

6 Conclusion

We set up and calibrate a quantitative model of the higher education market to study the role of for-profit institutions. The framework features heterogeneity in college quality and agents' ability, income and traditional/nontraditional status. We distinguish between presential and online education. The model matches key features of the competitive environment for public and for-profit four-year colleges: levels of enrollment for traditional and nontraditional students, levels of tuition and instructional spending, and sorting of students by ability and income into these institutions. Our estimated variable cost parameters for online for-profit institutions indicate their ability to rapidly increase enrollment in response to changing market circumstances.

Our policy experiments suggest further subsidy cuts at public schools are likely to increase the for-profit market share. We find that Pell Grant cap increases would be a boon to lower-cost for-profit colleges, which would capture a large share of the increased federal funding, enrolling more students by further lowering tuition, but also offering lower levels of instructional spending. Despite the negative effect on decreased instructional quality at for-profit institutions, our welfare analysis however suggests that raising Pell Grant caps results in higher aggregate welfare. However, we find the welfare gains from a doubling of the cap are smaller than those from more modest increases in the Pell Grant cap.

In our gainful employment legislation scenario, we find that for-profit colleges prefer to adjust their tuition downward, attempting to comply with maximal student debt-to-earnings ratios. However, they lower instructional spending in the process, leading to decreases in short term welfare. These findings suggest that gainful employment policies should be accompanied by minimal instructional quality standards.

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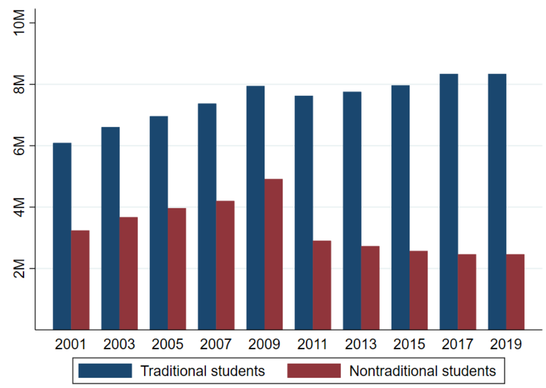
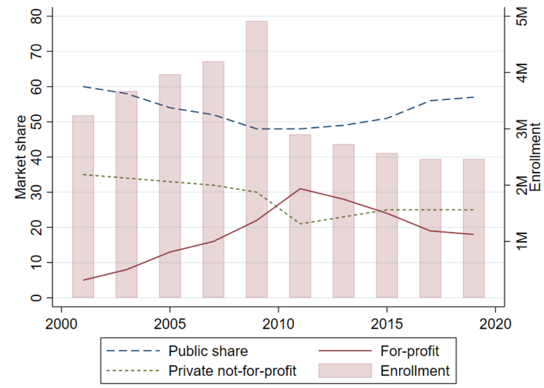
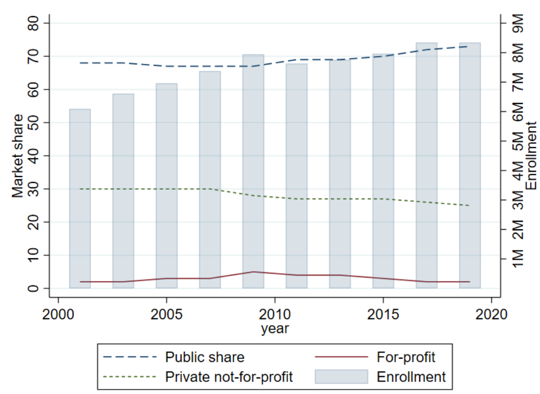
Figure 1: Trends in the Four-year College Market



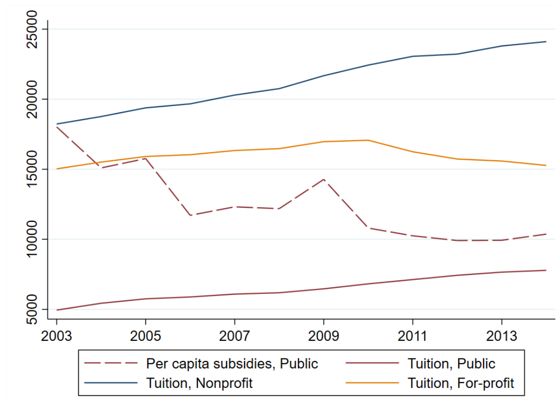
(a) Traditional and nontraditional student enrollment



(b) Market share, nontraditional students



(c) Market share, traditional students



(d) Changes in tuition and public subsidies

Notes: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS). Data is restricted to four-year degree granting institutions participating in Title IV federal financial aid programs.

Table 1: Calibration: Independent Parameters

Description	Parameter	Value	Source
Relative group sizes			
Traditional/Nontraditional	π_t; π_{nt}	$0.35; 0.65$	ACS
Ability distributions			
Traditional		$ln(a_t) \sim N(1, 0.18)$	NLSY97
Nontraditional		$ln(a_{nt}) \sim N(0.93, 0.19)$	NLSY97
Income distributions			
Traditional		$ln(y_t + 7.69) \sim N(3.95, 0.76)$	ACS
Nontraditional		$ln(y_{nt} + 10.22) \sim N(3.49, 0.71)$	ACS
Income-ability correlations	ρ	0.3	NLSY97
Tuition at public school	$T_s, T_{p,o}$ T_t	8.9 (in-state and online) 22.2 (out-of-state)	College Board[a]
Public school subsidy per capita	s	10.3	IPEDS
Tuition at nonprofit schools	$T_{e1}; T_{e2}$	$35.4; 14.57$	IPEDS
Instructional spending,			
nonprofit	$I_{e1}; I_{e2}$	$18.6; 5.78$	IPEDS
online public program[b]	$I_{p,o}$	4.7	IPEDS
Nontuition costs[c]	NC	10.25;11.25;7.25	College Board[a], NPSAS:12
Custodial cost function -public	F_p; $c_{1,p}$; $c_{2,p}$	0.4 ; 0 ; 42	IPEDS, estimated
Custodial cost function -private for-profit Group I	F_r; $c_{1,r}$; $c_{2,r}$	0.02; 0 ; 62.38	IPEDS, estimated
Custodial cost function -private for-profit Group II	F_r; $c_{1,r}$; $c_{2,r}$	0.05 ; 0; 8.44	IPEDS, estimated
Peer effect elasticity, presential	γ_p	0.15	Epple et al. (2017)
Peer effect elasticity, online[d]	γ_o	0.09	College Scorecard, estimated
Instructional spending elasticity, nonprofit	ω_e	0.155	Epple et al. (2017)
Federal grants		see Table A2	NPSAS: 12
Federal loans		see table A3	NPSAS: 12
State grants		see table A4	NPSAS: 12
Institutional financial aid		see tables A5, A6	NPSAS: 12
Other sources of aid		see table A7	NPSAS: 12

Notes: Monetary values in thousands of dollars. See text for full description of sources. a. College Board, 2014. Trends in College Pricing, Table 1A. b. 2012/17 Beginning Postsecondary Students Longitudinal Study (BPS:12/17), tabulations for undergraduates enrolled in bachelor's programs. b. Average instructional spending for public four-year institutions where 70 per cent or more of students attended exclusively through distance education. c. See text for full description of non-tuition costs. NC=10.25 for public and for-profit group I; 11.25 for nonprofit colleges; 7.25 in the case of online instruction, as we adjust the average non-tuition College Board cost to account for lower transportation costs and the higher fraction of students residing with parents (we use parental coresidence data by institution type and tuition group from NPSAS:12). d. See section 4.3.2 for estimation/calibration details.

Table 2: Moments Targeted in the Joint Calibration

Target moment	Data	Model
Enrollment, traditional students (% population)[a]	28.8	28.3
Enrollment, nontraditional students (% population)	5.4	5.5
Market shares[a]		
For-profit schools, % overall enrollment	10.7	11.3
Nonprofit Group I, % total nonprofit	50.1	50.9
Public, % traditional market	68.9	65.8
For-profit presential, % presential market[b]	5.2	5.0
For-profit, % nontraditional market	29.6	26.9
Online enrollment, % nontraditional market[c]	21.3	23.3
Nonprofit Group II, % nontraditional market[d]	73.7	72.5
Public sector, % overall enrollment	63.8	62.7
Instructional spending, public institutions[e]	10.2	11.8
Ability ratio, nonprofit Group I/public (traditional)[f]	1.1	1.2
Tuition, for-profit presential [g]	15.1	15.3
Tuition, for-profit online	11.5	11.5
Instructional spending, for-profit presential	4.9	4.8
Instructional spending, for-profit online	2.2	2.2
% Public students attending online[c]	4.7	4.7
% Public students attending out-of-state[h]	15	14.7
College graduation premium[i]	1.8	1.7

Notes: a. Enrollment market shares by type of student and institution are based on NCES Digest of Education Statistics, Tables $dt15\_302.60$ and $dt15\_303.50$, Spring 2012. Market shares for the two groups of colleges in the for-profit and not-for-profit sectors are based on IPEDS Delta Cost project data for 2012. Breakdown of nontraditional and traditional enrollment based on NPSAS:12. b. The for-profit Group I (presential) and Group II (online) shares are calculated based on fraction undergraduates attending for-profit online institutions, NPSAS:12. c. Overall online enrollment and by institution based on NCES Digest of Education, Table 311.15, Fall 2012. d. Breakdown of high tuition/low tuition nonprofit institutions based on median tuition in IPEDS 2012; enrollment share by traditional/nontraditional and low/high tuition group based on NPSAS:12. e. Instructional spending values are obtained from the IPEDS 2013. f. Using NPSAS:12 data, the abiliy ratio is proxied as the SAT composite score ratio of students enrolled at nonprofit Group I and those enrolled at public universities. g. IPEDS 2013. h. NPSAS:12 i. American Community Survey 2012, ratio between the wage and salary income of individuals aged 22-64, holding a bachelor's degree, and the wages and salary income of individuals whose highest attainment was "1 or more years of college credit, no degree".

Table 3: Calibration: Jointly Determined Parameters

Quality function public school		
Productivity	A_p	1.098
Spending elasticity	ω_p	0.156
Quality function nonprofit school		
Productivity, Group I	A_{e1}	1.272
Productivity, Group II	A_{e2}	0.996
Quality function for-profit schools		
Spending elasticity, presential	$\omega_{r,p}$	0.139
Spending elasticity, online	$\omega_{r,o}$	0.125
Productivity, online college	$A_{r,o}$	1.498
Achievement function: Individual ability elasticity	β	0.951
Achievement outside option, traditional	B_t	4.333
Achievement outside option, nontraditional	B_{nt}	5.973
Utility weighting parameter	α	3.815
Out-of-state preference parameter	ν	1.013
Admission threshold, non-profit Group I	a^e_{min}	3.269
Admission threshold, public online	$a^{p,o}_{min}$	2.722
Online preference parameter, traditional	$\theta_{o,t}$	0.912
Online preference parameter, nontraditional	$\theta_{o,nt}$	0.951
Dissimilarity parameter, presential education nest	λ_p	0.382
Dissimilarity parameter, online education nest	λ_o	0.203
Productivity parameter, college dropouts	B_d	1.244

Notes. See section 4 for the description of parameters.

Table 4: Model Fit - Market Shares by Ability and Income

	Data					Model				
	Pub	NFP	FP	Pub-O	FP-O	Pub	NFP	FP	Pub-O	FP-O
A.Enrollment										
Dependent	66.4	26.9	2.0	2.5	2.1	63.5	28.5	3.15	2.3	2.51
Independent	44.6	21.3	12.8	4.5	16.8	49.1	19.1	8.48	4.9	18.5
B. SAT distribution[a]										
Ability, dependent										
< -1	66.6	23.9	6.5	2.8	0.2	72.4	13.8	6.1	0	7.6
$[-1, 0)$	70.5	23.8	2.2	3	0.5	73.4	16.6	4.6	0.5	5
$[0, 1)$	68.3	27.9	0.9	2.6	0.3	75.3	15.6	3.6	3.8	1.7
$[1, 2)$	61.2	35.9	0.6	2.2	0.1	44.2	50.9	1.4	2.6	1
>2	40.9	57.1	0.3	1.8	0	34.7	62.5	0.7	1.5	0.6
Ability, independent										
< -1	54.2	14.6	18.4	2.4	10.4	52	6	9	0	32
$[-1, 0)$	59.2	17.8	11.9	3.6	7.4	51	9	11	0	29
$[0, 1)$	65.4	16.7	8.7	4.6	4.6	58	8	9	6	19
$[1, 2)$	55.9	23.8	11.5	5.1	3.7	45	27	7	7	14
>2	70	13.6	8.2	7.6	0.7	37	45	6	5	12
C. Income distribution										
Income, dependent										
0-30	68.4	23.9	4.6	2.4	0.8	68.1	21.0	0.6	6.4	3.9
30-50	65.4	28.9	3.3	2.2	0.2	65.4	25.0	3.1	2.9	3.6
50-70	68.8	27.2	2.2	1.7	0.1	59.5	32.4	4.9	2.01	3.2
70-100	67.9	28.7	1.2	2	0.2	52.4	39.4	5.5	1.4	2.6
>100	65.1	32	0.8	2	0.1	47.7	45.2	4.5	0.9	1.7
Income, independent										
$0 - 30$	54.5	17.8	15.9	1.9	9.9	58.3	2.6	2.5	10.7	25.9
$30 - 50$	44.9	17.8	19.8	4.4	13.1	56.7	1.1	9.4	4.2	20.7
>50	36.9	27.7	13.4	9.4	12.5	40.6	22.4	10.9	2.36	13.7

Notes: *a*. Panel B compares the distribution of standardized SAT scores by institutional control from NPSAS:2012 with the model predictions on the distribution of standardized ability. SAT ranges are: <-1: 400-801; [-1,0): 802-997; [0,1):998-1192; [1,2):1193-1388; >2: 1389-1600. Data sources: Panel A: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS), 2013. Panels B and C: U.S. Department of Education, National Center for Education Statistics, 2011-12 National Postsecondary Student Aid Study (NPSAS:12).

Table 5: Counterfactual Analysis — Gainful Employment

	Baseline	Gainful Employment
A. Simulated debt-to-earnings ratios		
For-profit, presential	12.67	12.00
For-profit, online	12.24	12.00
Public, presential	5.89	5.85
Public, online	7.04	6.83
Nonprofit, Group I	3.01	3.00
Nonprofit, Group II	6.95	6.89
B. Moments		
Enrollment, traditional students (% population)	28.3	28.39
Enrollment, nontraditional students (% population)	5.5	5.61
Market shares		
For-profit schools, % overall enrollment	11.3	13.89
Nonprofit Group I, % total nonprofit	50.9	51.32
Public, % traditional market	65.8	64.47
For-profit Group I, % presential market	5.0	7.37
For-profit, % nontraditional market	26.9	31.61
Online enrollment, % nontraditional market	23.3	23.77
Nonprofit Group II, % nontraditional market	72.5	72.64
Public sector, % overall enrollment	62.7	60.62
Instructional spending, public institutions	11.8	11.86
Ability ratio, nonprofit Group I/public (traditional)	1.2	1.24
Tuition at for-profit colleges, Group I (presential)	15.3	11.64
Tuition at for-profit colleges, Group II (online)	11.5	10.57
Instructional spending, for-profit Group I (presential)	4.8	4.68
Instructional spending, for-profit Group II (online)	2.2	1.99
% Public students attending online	4.7	4.49
% Public students attending out-of-state	14.7	14.98
College graduation premium	1.7	1.66

Notes: Gainful Employment results averaged over 50 simulations. See section 5.1 for description of the Gainful Employment policy experiment.

Table 6: Counterfactual Analyses: Subsidy and Pell Grant Cap Changes

Moment	Baseline	Counterfactuals[a]					
		I	II	III	IV	V	VI
		Subsidy cut & Tuition increase	Subsidy cut & Tuition cap	Subsidy increase & Tuition decrease	Pell Cap increase	Pell Cap doubled	Pell Cap 2x, crowd out
Enrollment, traditional	28.34	26.45	27.56	30.55	30.72	36.11	35.37
Enrollment, non-traditional	5.47	5.20	5.38	5.78	6.09	10.44	10.25
Market shares							
For-profit schools, % overall enrollment	11.29	13.06	11.93	9.90	12.12	21.87	22.65
Nonprofit Group I, % total nonprofit	50.98	46.36	49.82	55.07	49.28	46.89	52.56
Public, % traditional market	65.84	56.55	61.85	72.90	66.17	65.96	70.08
For-profit, % presential market	5.05	6.82	5.54	3.86	4.96	4.69	5.17
For-profit, % nontraditional market	26.98	29.38	27.80	24.90	29.36	49.30	50.56
Online enrollment, % nontraditional market	23.38	25.18	23.85	21.56	25.37	46.40	47.04
Nonprofit Group II, % nontraditional market	72.57	71.33	72.30	73.82	74.12	84.37	84.00
Public sector, % overall enrollment	62.70	54.65	59.25	69.06	62.59	56.58	59.22
Instructional spending, public	11.87	11.66	9.70	11.74	11.76	11.38	11.29
Ability ratio, nonprofit Group 1/ Public	1.24	1.24	1.24	1.24	1.25	1.26	1.26
Tuition at for-profit colleges, I (presential)	15.31	13.87	15.45	16.46	14.88	14.38	13.95
Tuition at for-profit colleges, II (online)	11.55	11.77	11.56	11.42	10.30	7.77	7.81
Instructional spending, for-profit I (presential)	4.88	4.28	4.89	5.35	4.72	4.52	4.34
Instructional spending, for-profit II (online)	2.21	2.30	2.21	2.12	1.90	0.77	0.77
% Public students attending online	4.76	6.83	5.24	3.38	4.50	4.32	4.12
% Public students attending out-of-state	14.69	16.48	14.49	13.10	13.20	10.25	10.00
College graduation premium	1.66	1.66	1.64	1.66	1.66	1.65	1.65
Tax financing additional subsidies (%)	-	-	-	0.81	0.18	0.61	0.68
Tax financing Pell Grant increase (%)	-	-	-	0.08	0.46	2.29	2.21

Notes: a. Counterfactual I involves a 2,000 dollar decrease in per capita subsidies at public universities coupled with an equal increase in public school tuition per capita. In Counterfactual II, a 2,000 subsidy cut at public institutions is coupled with a tuition freeze. Counterfactual III implements a 2,000 subsidy increase, along with a tuition decrease in the same amount. Counterfactual IV is a 2,000 dollar increase in the upper Pell Grant limit, from 5,500 to 7,500. Counterfactual V is a doubling of the Pell Grant cap to 11,000 dollars. Counterfactual VI considers a crowd out response at nonprofit and public institutions resulting in lower institutional financial aid in response to Pell Grant increases.

Table 7: Welfare Analysis

	All		Lower income (0-30 K)		Ratio low income/ aggregate welfare	
	Traditional	Nontraditional	Traditional	Nontraditional	Traditional	Nontraditional
Baseline	100.00	100.00	100.00	100.00	86.57	83.28
Subsidy cut, tuition increase	99.91	100.03	99.94	100.05	86.53	83.33
Subsidy cut, tuition cap	99.94	100.01	99.97	100.01	86.56	83.30
Subsidy increase, tuition decrease	99.98	99.82	100.17	99.93	86.82	83.32
Pell cap increase 7.5 K	99.88	99.74	100.04	99.82	86.72	83.27
Pell cap doubled	100.84	103.20	104.21	107.36	88.16	87.37
Pell cap doubled, crowd out	100.81	103.21	104.16	107.37	88.12	87.38
Gainful employment	99.97	99.98	99.95	99.96	86.55	83.27

Notes: Values for overall welfare are normalized to 100 for the baseline scenario. The ratio of low income to overall welfare represents the ratio of average welfare of lower income agents (0-30,000 dollars) to overall (traditional and nontraditional) average welfare. The counterfactual scenarios are illustrated in tables 5 and 6.

Table 8: Pell Grant Increase Scenarios, Aggregate Welfare Changes

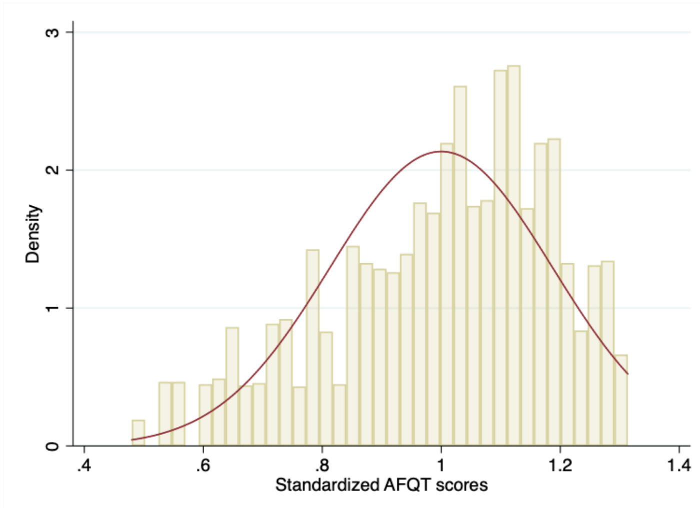
Pell Grant	All		Lower income[a]	
Cap	Traditional	Nontraditional	Traditional	Nontraditional
5.5 (baseline)	100	100	100	100
6.5	99.969	99.904	100.004	99.911
7.5	99.888	99.742	100.035	99.824
8.5	**100.644**	**103.094**	103.438	106.932
9.5	100.433	102.846	103.619	107.018
10.5	100.128	102.509	103.859	**107.134**
11	99.684	102.017	**103.926**	107.069

Notes: a. Lower income defined as 0-30 thousand dollars.

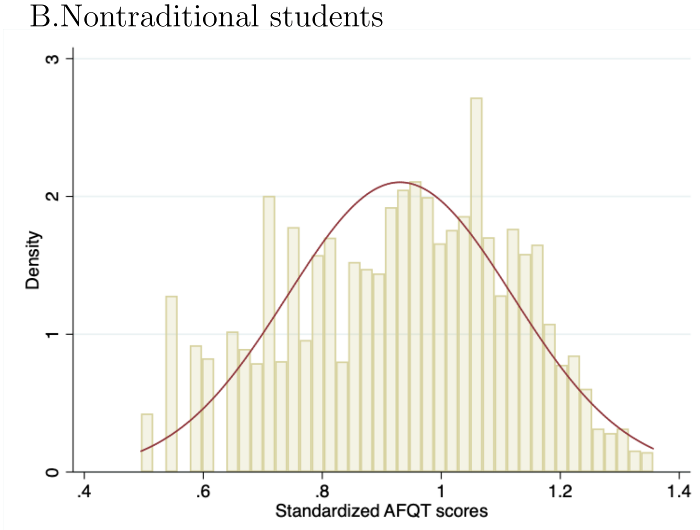
Appendix

A Additional tables and figures

A. Traditional students



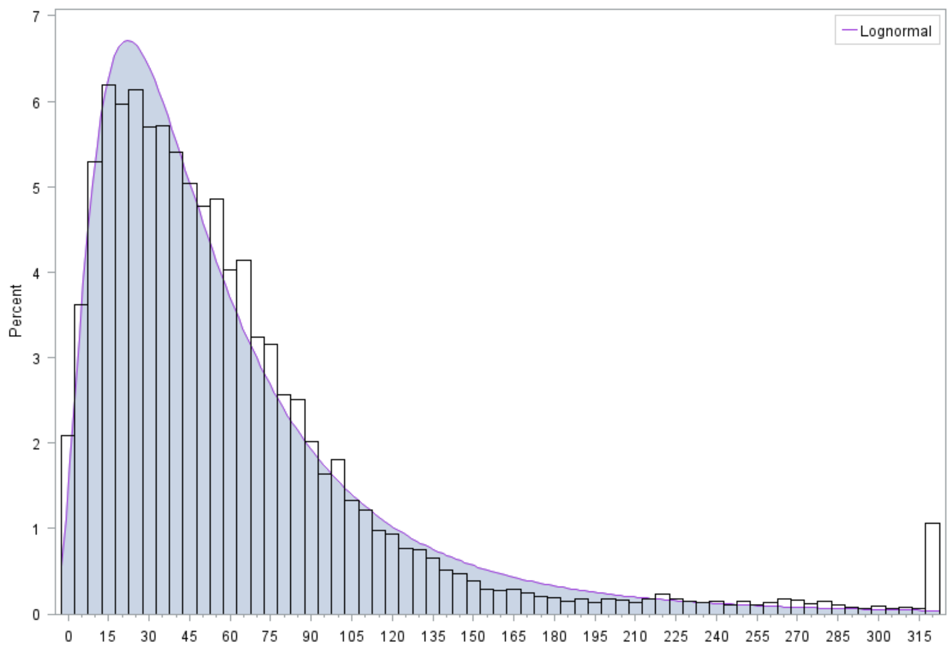
B.Nontraditional students



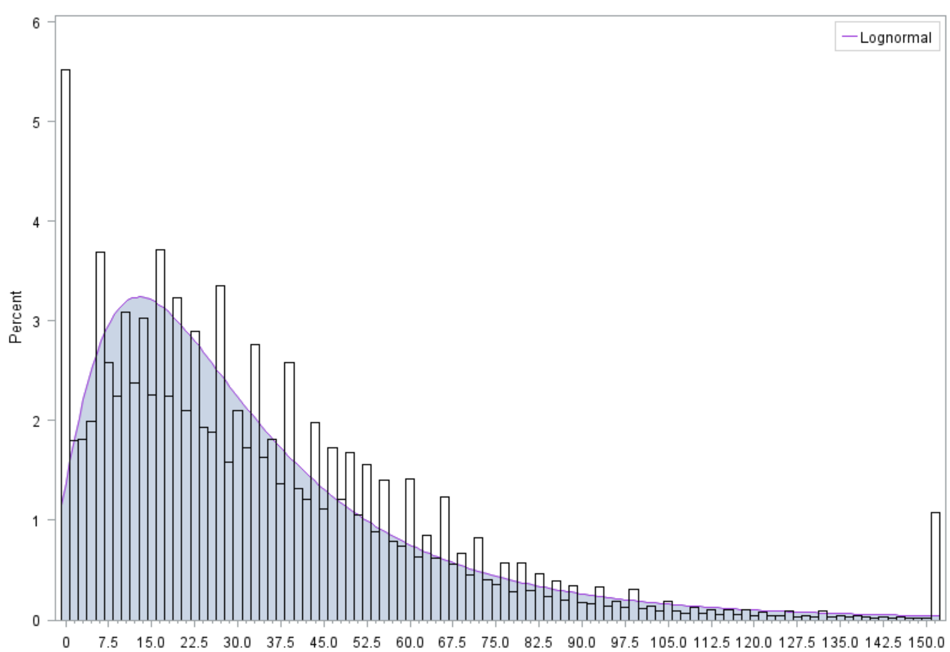
Notes: National Longitudinal Survey of Youth 1997, Armed Force Qualifications Test (AFTQ) data standardized to mean 1. Normal distribution fit. .

Figure A1: Fitted ability distribution

A. Traditional students



B. Nontraditional students



Notes: Source: American Community Survey 2012-2014 tax-adjusted data on yearly income. Three parameter lognormal fit displayed. Top one percent of incomes are capped.

Figure A2: Fitted income distribution

Table A1: Per capita custodial costs (thousands, 2015 dollars) by institutional control, selected years

	Public		Private not-for-profit		Private for-profit	
Year	Operations	Services	Operations	Services	Operations	Services
1996	1.45	4.38	2.35	8.95	1.48	6.42
1998	1.60	5.22	2.04	9.90	2.10	7.51
2002	1.75	5.17	2.09	10.90	2.34	4.69

Source: IPEDS, balanced panel of institutions 1996-2002, Carnegie Classification 31-33.

Table A2: EFC functions

Income group (top category)	EFC, Traditional	EFC, Nontraditional
15	0.244	0.875
20	0.336	2.709
25	0.471	3.143
30	1.071	3.349
35	1.537	4.220
40	2.666	5.395
45	2.927	5.884
50	4.185	5.730
55	4.814	6.428
60	6.214	7.423
70	8.238	8.347
80	10.705	10.503
>80	27.060	13.487

Source: Authors' analysis, NPSAS:2012 data. Sample restricted to U.S. citizens enrolled in bachelor's degree programs. Figures indicate thousands of dollars.

Table A3: Federal student loan functions

	Intercept	Income coefficient	Net cost coefficient
Traditional, parental income <=70k	4.052	-0.005	0.049
	(0.113)	(0.003)	(0.011)
Traditional, parental income >70	3.621	-0.005	0.015
	(0.090)	(0.000)	(0.005)
Nontraditional	4.269	-0.017	0.208
	(0.142)	(0.004)	(0.020)

Source: Authors' analysis, using NPSAS:2012 data. Sample restricted to U.S. citizens enrolled in bachelor's degree programs. Figures indicate thousands of dollars. Standard errors in parantheses.

Table A4: State financial aid functions

Traditional		Nontraditional	
Parental income	State financial aid	Own (and spousal) income	State financial aid
[0,30]	2.085	[0.10]	0.915
(30,60]	1.637	(10,20]	0.515
(60-80]	0.945	(20,30]	0.39
(80-120]	0.591	(30,50]	0.276
>120	0.434	>50	0.1

Source: Authors' tabulations, using NPSAS:2012 data. Figures indicate thousands of dollars. Sample restricted to U.S. citizens enrolled in bachelor's degree programs.

Table A5: Institutional financial aid functions, nonprofit schools

	Group I, High tuition		Group II, Lower tuition	
	Intercept	Income coefficient	Intercept	Income coefficient
(type of student/ ability group)				
Traditional, < -1	16.669	-0.034	5.593	-0.002
	(0.891)	(0.007)	(0.772)	(0.007)
Traditional, [-1,0)	16.604	-0.028	7.468	-0.002
	(0.738)	(0.005)	(0.474)	(0.004)
Traditional, [0,1)	15.781	-0.023	7.920	-0.001
	(0.738)	(0.003)	(0.561)	(0.004)
Traditional, [1,2)	18.237	-0.030	10.289	-0.015
	(1.101)	(0.006)	(1.550)	(0.008)
Traditional, > 2	22.233	-0.057	16.384	-0.045
	(3.337)	(0.018)	(4.045)	(0.022)
Nontraditional, ≤ 0	10.842	-0.080	-	-
	(1.747)	(0.151)	-	-
Nontraditional, ≤ -1	-	-	3.658	-0.041
	-	-	(0.612)	(0.021)
Nontraditional, [-1,0)	-	-	3.868	-0.046
	-	-	(0.715)	(0.012)
Nontraditional, > 0	8.743	-0.022	4.088	-0.055
	(2.297)	(0.093)	(0.842)	(0.016)

Source: Authors' analysis, using NPSAS: 12 data. Sample restricted to U.S. citizens enrolled in bachelor's degree programs. High and low tuition groups are defined as below/above average tuition. Figures indicate thousands of dollars. Standard errors in parantheses.

Table A6: Institutional financial aid functions, public four-year colleges

	SAT score, standard deviations			
	<-1	[-1,1]	(1,2]	>2
A.Traditional, by parental income:				
[0,30]	1	1.13	2.7	4.31
(30,65]	1.1	1.18	2.2	2.9
(65,106]	0.7	0.8	1.6	3.17
>106	0.4	0.77	1.56	2.48
B. Nontraditional, by own (and spousal) income:				
0,20	0.47	0.54	0.82	0.78
(20,50]	0.35	0.3	0.3	0.3
>50	0.2	0.2	0.2	0.2

Source: Authors' tabulations, using NPSAS:2012 data. Figures indicate thousands of dollars. Sample restricted to U.S. citizens enrolled in bachelor's degree programs.

Table A7: Outside sources of aid functions

	Traditional			Nontraditional		
	Intercept	Income coefficient	Net cost coefficient	Intercept	Income coefficient	Net cost coefficient
Public	1.206	0.000	-0.006	0.815	-0.002	0.135
	(0.056)	(0.001)	(0.008)	(0.081)	(0.002)	(0.032)
Nonprofit	4.075	0.005	-0.095	2.397	-0.006	0.069
	(0.265)	(0.001)	(0.014)	(0.478)	(0.005)	(0.044)
For-profit	1.484	0.023	-0.079	1.665	0.005	0.114
	(0.364)	(0.008)	(0.039)	(0.225)	(0.003)	(0.036)

Source: Authors' analysis, using NPSAS:2012 data. Figures indicate thousands of dollars. Outside sources are defined as the sum of outside grants (private or employer), private commercial or alternative loans and federal Veterans' benefits and military tuition aid. Sample restricted to U.S. citizens enrolled in bachelor's degree programs.

Table A8: Dropout functions

Traditional	Ability (s.d.)	%Dropout	Nontraditional	Ability (s.d.)	%Dropout
Public, presential	<-1	0.5820	Public, presential		
	[-1,0)	0.441		<0	0.743
	[0,1)	0.328		>0	0.612
	[1,2)	0.281			
	>2	0.154			
Not for profit group I			Not for profit group I		0.278
	<-1	0.349			
	[-1,0)	0.303			
	[0,1)	0.239			
	[1,2)	0.172			
	>2	0.092			
Not for profit group II			Not for profit group II		
	<-1	0.674		<-1	0.782
	[-1,0)	0.529		[-1,0)	0.792
	[0,1)	0.405		[0,1)	0.632
	>2	0.281		>1	0.463
For-profit, presential			For-profit, presential		0.594
	<-1	0.687			
	[-1,0)	0.651			
	[0,1)	0.5959			
	>1	0.601			
For-profit, online		0.780	For-profit, online		0.636
Public, online		0.612	Public, online[a]		0.676

Source: Baccalaureate and Beyond, 2012/2017. Figures indicate fraction who did not attain a bachelor's degree or are not still enrolled as of June 2017 by control of first four-year degree granting institution in 2011-12 and standard deviations of ability, proxied by the SAT derived composite score.

Table A9: Average Duration of Enrollment, Years

	Traditional	Nontraditional
Public, presential	1.83	2.03
Not for profit	1.86	2.08
For-profit, presential	1.61	2.18
Public, online	1.83	1.83
For-profit, online	1.90	1.93

Notes: Beginning Postsecondary Survey 2012. Table shows the average duration of enrollment among students who eventually drop out and fail to complete their bachelor's degree program.

Table A10: Sensitivity Analysis: Jointly Estimated Parameters for Different Values of Peer Effect Elasticity at Online Institutions, γ_o

		γ_o=0.09 *(baseline)*	γ_o=0.06	γ_o=0.03
Quality function public school				
Productivity	A_p	1.098	1.081	1.065
Spending elasticity	ω_p	0.156	0.152	0.159
Quality function nonprofit school				
Productivity, Group I	A_e^I	1.272	1.235	1.169
Productivity, Group II	A_e^{II}	0.996	0.984	1.005
Quality function for-profit schools				
Spending elasticity, presential	$\omega_{r,p}$	0.139	0.141	0.145
Spending elasticity, online	$\omega_{r,o}$	0.125	0.123	0.124
Productivity, online college	$A_{r,o}$	1.498	1.462	1.458
Achievement function: Individual ability elasticity	β	0.951	1.005	0.983
Achievement outside option, traditional	B_t	4.333	4.382	4.278
Achievement outside option, nontraditional	B_{nt}	5.973	5.978	5.943
Utility weighting parameter	α	3.815	3.816	3.719
Out-of-state preference parameter	ν	1.013	1.013	1.014
Admission threshold, non-profit Group I	a_{min}^e	3.269	3.293	3.074
Admission threshold, public online	$a_{min}^{p,o}$	2.722	2.733	2.692
Online preference parameter, traditional	$\theta_{o,t}$	0.912	0.916	0.914
Online preference parameter, nontraditional	$\theta_{o,nt}$	0.951	0.953	0.953
Dissimilarity parameter, presential education nest	λ_p	0.382	0.374	0.368
Dissimilarity parameter, online education nest	λ_o	0.203	0.196	0.194
Productivity parameter, college dropouts	B_d	1.244	1.147	1.140

Notes. See section 4 for the description of parameters.

Table A11: Target Moments - Robustness to Alternative Utility Specifications

	Unweighted (baseline)	Weighted
Enrollment, traditional students (% population)	28.3	28.60
Enrollment, nontraditional students (% population)	5.5	5.37
Market shares		
For-profit schools (% overall enrollment)	11.3	11.17
Group I nonprofit out of total nonprofit	50.9	50.47
Public, % traditional market	65.8	66.03
For-profit Group I, % presential market	5.0	5.16
For-profit, % nontraditional market	26.9	27.01
Online enrollment, % nontraditional market	23.3	23.88
Nonprofit Group II, % nontraditional market	72.5	73.29
Public sector, % overall enrollment	62.7	62.96
Instructional spending, public institutions	11.8	11.89
Ability ratio, nonprofit Group I/public (traditional)	1.2	1.22
Tuition at for-profit colleges, Group I (presential)	15.3	15.36
Tuition at for-profit colleges, Group II (online)	11.5	11.46
Instructional spending, for-profit Group I (presential)	4.8	4.78
Instructional spending, for-profit Group II (online)	2.2	2.23
% Public students attending online	4.7	4.96
% Public students attending out-of-state	14.7	14.92
College graduation premium	1.7	1.67

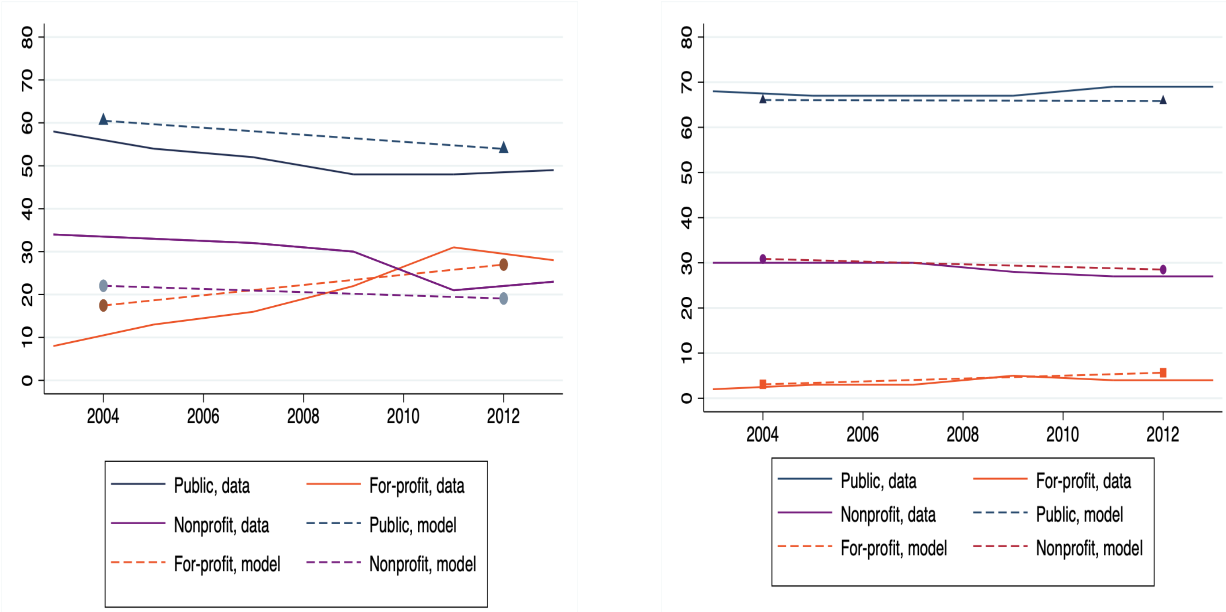
Notes: See section 5.3 for description of robustness exercise.

Table A12: Historical Changes in College Costs and Financial Aid Used in Validation Exercise

	2004	2012
Tuition, public	5.8	8.9
Subsidy per capita, public	15.1	10.3
Out of state tuition	16.6	22.2
Instructional spending, public online[a]	3.01	4.7
Pell Grant cap	5.14	5.5
Non-tuition costs		
Public and for-profit, presential	8.4	10.15
Public and for-profit, online	5.7	7.00
Nonprofit	9.6	11.25
Nonprofit I, tuition	17.6	36.9
Nonprofit I, instructional spending	21.2	29.9
Nonprofit II, tuition	6.3	17.9
Nonprofit II, instructional spending	8.3	15.2

Source for data moments: U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS). See notes for Table 2 for further detail on sources. Figures in thousands of 2013 dollars. a. Instructional spending data for public online not available in 2004, imputed as proportion of tuition following the same ratio as in 2012.

Figure A3: Evolution of market shares by student group and sector: data and model predictions



(a) Market shares, nontraditional market

(b) Market shares, traditional market

Table A13: Market Shares in 2004 and 2012: Data and Model Predictions

	2012 data (baseline)	2004 data	2004 model	2004 model (nonprofit 2012 prices)
For-profit, total	11.29	4.43	7.04	7.72
Public, total	62.69	63.89	64.52	78.53
For-profit, traditional	5.66	1.94	3.09	3.47
Public, traditional	65.84	68.11	66.05	82.10
For-profit, nontraditional	26.97	7.61	17.45	19.11
Public, nontraditional	53.94	58.13	60.50	68.98

Notes: Moment source data: U.S. Department of Education, National Center for Education Statistics,Integrated Postsecondary Education Data System (IPEDS), Spring 2004 .

B Computation of equilibrium

1. Pick starting values for the enrollment and mean ability of the student body at all institutions (six in total), instructional spending at the public presential college, and the value of Lagrange multiplier corresponding to the budget constraint of the public university;

2. Given starting values, we calculate the utilities for not enrolling in college, and expected utilities for all colleges. Given the net costs, we check whether the student affords to attend. In the case of the public university and nonprofit Group I, we check whether the student is admitted or not.

3. Given the expected utilities of the other options, for each for-profit college we calculate spending per student and tuition that maximize expected profits. We then calculate the corresponding students' expected utilities for each for-profit college.

4. Calculate the spending per student I_p , enrollment N_p and implied average ability $\overline{a}_p$ that maximizes the expected total human capital at the public university;

5. Calculate the expected utilities and the resulting choice probabilities for each option.

6. Update enrollments and the average ability at each college, spending and the budget constraint multiplier at the public university, and iterate until convergence.

C Derivation of admission equation at the public university

The Lagrange function of the university problem is:

$$L = \sum_g \pi_g \sum_z \left[\int \int Eh_z(q_p, a, g)\delta_z(a, y, g)p_z(a, y, g; T, Q)f_g(a, y)dady \right] +$$

$$\lambda \left[\sum_g \pi_g \sum_z \int \int t_{p,z}\delta_z(a, y, g)p_z(a, y, g; T, Q)x_p(a, g)f_g(a, y)dady + N_p s - N_p I_p - C_p(N_p) \right] +$$

$$\eta \left[\overline{a}_p N_p - \sum_g \pi_g \sum_z \int \int a\delta_z(a, y, g)p_z(a, y, g; T, Q)x_p(a, g)f_g(a, y)dady \right] +$$

$$\Omega \left[N_p - \sum_g \pi_g \sum_z \int \int \delta_z(a, y, g)p_z(a, y, g; T, Q)x(a, g)f_g(a, y)dady \right].$$

We compute first the derivatives with respect to I_p and $\overline{a}_p$. For simplicity, we suppress the subscript p.

$$L_I = q_I \sum_g \pi_g \sum_z \left[\int \int \frac{dEh_z}{dq} \delta_z(a,y,g) p_z f_g(a,y) da dy \right] +$$
$$\lambda q_I \sum_g \pi_g \sum_z \int \int t_z \delta_z \frac{dp_z}{dq} x(a,g) f_g(a,y) da dy - \lambda N_p -$$
$$\eta q_I \sum_g \pi_g \sum_z \int \int a \delta_z \frac{dp_z}{dq} x(a,g) f_g(a,y) da dy - \Omega q_I \left[\sum_g \pi_g \sum_z \int \int \delta_z \frac{dp_z}{dq} x(a,g) f_g(a,y) da dy \right] = 0.$$

$$L_{\overline{a}} = q_{\overline{a}} \sum_g \pi_g \sum_z \left[\int \int \frac{dEh_z}{dq} \delta_z p_z f_g(a,y) da dy \right] + \lambda q_{\overline{a}} \left[\sum_g \pi_g \sum_z \int \int t_z \delta_z \frac{dp_z}{dq} x(a,g) f_g(a,y) da dy \right] +$$
$$\eta N_p - \eta q_{\overline{a}} \sum_g \pi_g \sum_z \int \int a \delta_z \frac{dp_z}{dq} x(a,g) f_g(a,y) da dy - \Omega q_{\overline{a}} \left[\sum_g \pi_g \sum_z \int \int \delta_z \frac{dp_z}{dq} x(a,g) f_g(a,y) da dy \right] = 0.$$

From the $L_I = 0$ and $L_{\overline{a}} = 0$ we obtain:

$$\frac{q_{\overline{a}}}{q_I} = -\frac{\eta}{\lambda}. \tag{16}$$

Taking the first derivative with respect to N yields:

$$L_N = \lambda \left[s - I - C'(N) \right] + \eta \overline{a} + \Omega = 0. \tag{17}$$

Dividing by λ, we obtain:

$$s - I - C'(N) + \frac{\eta}{\lambda} \overline{a} = -\frac{\Omega}{\lambda}. \tag{18}$$

Next, we write the first variations with respects to $\delta_s(a,y,g)$ and $\delta_t(a,y,g)$, the admission functions of in-state and out-of-state students as:

$$L_{\delta_s} = \pi_g Eh_s(\cdot) p_s f_g(a,y) + \lambda \pi_g t_s p_s x(a,g) f_g(a,y) - \eta \pi_g a p_s x(a,g) f_g(a,y) - \Omega \pi_g p_s x(a,g) f_g(a,y) = 0.$$

$$L_{\delta_t} = \pi_g Eh_t(\cdot) p_t f_g(a,y) + \lambda \pi_g t_t p_t x(a,g) f_g(a,y) - \eta \pi_g a p_t x(a,g) f_g(a,y) - \Omega \pi_g p_t x(a,g) f_g(a,y) = 0.$$

Rearranging terms in L_{δ_s} and dividing by λ we obtain:

$$\pi_g p_s f_g(a,y) \left[\frac{Eh_s(\cdot)}{\lambda} + x(a,g) \left(t_s - \frac{\eta}{\lambda} a - \frac{\Omega}{\lambda} \right) \right] = 0. \tag{19}$$

Using equation (16) and (18) in (19) yields:

$$\frac{Eh_s(\cdot)}{\lambda} + x(a,g)\left(t_s + \frac{q_{\overline{a}}}{q_I}a + s - I - C_p'(N) - \frac{q_{\overline{a}}}{q_I}\overline{a}\right) = 0.$$

Per year cost function is given by:

$$C_p(N) = 4\left[F_p + \nu_{1p}(N/4) + \nu_{2p}(N/4)^2\right],$$

where $N/4$ is the average annual enrollment over the 4-year period.

$$C_p'(N) = \nu_{1p} + \nu_{2p}\frac{N}{2}.$$

Rearranging terms, we obtain the admission equation for in-state student (a, y, g):

$$\frac{Eh_s(\cdot)}{\lambda} + x(a,g)\left[t_s(a,y,g) + s\right] = x(a,g)\left[I + C_p'(N_p)\right] + x(a,g)\frac{q_{\overline{a}}}{q_I}(\overline{a} - a).$$

The admission equation for out-of-state students is obtained in a similar fashion.