# Student Loans and Social Mobility*†

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**Abstract**

Students of poor families invest much less than rich families in college education. To assess the role of financing constraints and subsidy schemes in explaining this gap, I structurally estimate an IO/finance model of college choice in the presence of financing frictions. The estimation uses novel nationally representative data on US high-school and college students. I propose a novel identification strategy that relies on bunching at federal Stafford loan limits and differences between in- and out-of-state tuition. I find that the college investment gap is mainly due to fundamental factors—heterogeneity in preparedness for college and the value-added of college—rather than financing constraints faced by lower-income students. Making public colleges tuition-free would substantially reduce student debt, but it would disproportionately benefit wealthier students, and it would entail more than $15B deadweight loss per year by distorting college choices. Expanding Pell grants, in contrast, would benefit lower-income students at a much lower cost.

**Keywords:** Student Loans, Social Mobility, Financing Frictions, Higher Education Policy, Household Finance

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# 1 Introduction

At \$1.5 trillion, the total student loan balance is now the second-largest liability, after mortgages, for American households.[1] The rise in college tuition and the shift in federal aid programs from grant- toward loan-based aid in the past few decades have made student loans a necessity for most people pursuing higher education in the US.[2] Naturally, low-income students should be the main recipients of student loans, as they cannot rely on family support to pay for college. However, in fact, students from different income backgrounds take almost similar amounts of loans on average—many just take the maximum limit of the federal Stafford loan program. The natural implication is that low-income students invest less than high-income students in college education, since they do not fill the lack of family financial support with student loans. In fact, students from low-income families pay considerably less for tuition; mostly enroll in a nearby college with lower education quality; drop out more frequently; and are less likely to enroll in college in the first place. Why don't students from low-income families take out more loans in order to invest equally in college education?

One explanation is that financing frictions make student loans an expensive source of funds to cover college costs. Limited access to cheap funds then hinders lower-income students from investing in college education. This explanation justifies a popular view: "as working families take on increasing amounts of [student] debt, higher education may actually be increasing social and economic inequality... For those [low-income] children, the idea of getting a college education and making it into the middle class is as likely as going to the moon."[3] To address this concern, many have called for tuition-free public colleges.

An alternative explanation is that students from low-income families take out fewer loans not because of financing frictions, but because of heterogeneity in fundamental factors such as college-related ability, preferences for higher education, and distance from high-quality colleges. As low-quality colleges are less expensive, naturally there is less need to take a loan.

In this paper, my goal is to identify the role of financing frictions versus fundamental factors in explaining the equal demand for student loans and the unequal investment in college education between low- and high-income students in the US. This analysis is important for several reasons. First, social mobility is intrinsically valued in modern societies and understanding sources of persistent inequality is important per se. Second, this decomposition helps us to understand the effectiveness of hotly debated policies aimed at increasing access to college. On one hand, public grants for college students boost social mobility *and* improve on social welfare, if financing constraints are quantitatively determinant for those in need (Becker and Tomes, 1986). On the other hand, if college-related ability and preferences for

[1]Source: Federal Reserve Bank of New York, `https://www.newyorkfed.org/medialibrary/interactives/householdcredit/data/pdf/hhdc_2020q1.pdf`, accessed May 13, 2020.

[2]In the academic year 2003-04, 41% of first-year college students take student loans, for whom the average loan amount is \$4,900—35% of the average tuition. Source: Beginning Postsecondary Students survey.

[3]Senator Bernie Sanders, *Our Revolution: a future to believe in*, 2016, p.343.

high-quality colleges are the main determinants of investment in college education, then policy interventions cause socially suboptimal investment choices and deadweight losses. Therefore, a model of investment in human capital with financing friction is needed to evaluate higher education policies aimed at increasing access to college for lower-income students.

I develop a dynamic IO/finance model of experimentation and investment in college education in the presence of financing frictions and imperfect competition among colleges. Using a novel dataset and identification strategy, I economically decompose the determinants of social mobility in the context of higher education studies. I structurally estimate the shadow price of financing frictions for students of different backgrounds and the value of college education with student loans in dollar terms. I measure the extent to which, given the college-related ability and unequal cash-in-pocket across students of different backgrounds, external-financing constraints cause an unequal educational attainment. I use the model to simulate three major higher education policies currently under debate: expanding federal Stafford loan limits, expanding federal need-based grants, and making public colleges tuition-free. Structural estimation allows me to measure the welfare gain for students of different income backgrounds, as well as the policies' costs for the federal government.

I use a novel dataset, the confidential version of Beginning Postsecondary Students Longitudinal Study (BPS), a panel survey from the universe of first-year US college students in 2003-04, with two follow-ups in 3 and 6 years. The unique feature of this dataset is that it contains information on college choices as well as financing structure of college costs. It also includes information on students' family background and residency, high school GPA, and SAT scores. This information allows me to estimate the value to college education and the perceived cost of student loans for students of different backgrounds. BPS also provides data on college GPA, as well as persistence and degree completion, which allows me to model experimentation of college education under financing frictions.

I supplement this dataset with Integrated Postsecondary Education Survey (IPEDS), a public database on the universe of higher education institutions in the US. I obtain measures for education quality at the college level, in- and out-of-state sticker prices, grants, and the location of colleges. This dataset allows me to estimate preferences for education quality in dollar units. In addition, I use the Education Longitudinal Survey (ELS), a representative sample of US high-school students in 2002 with 10 years of follow ups. I observe the demographics of non-college-enrollees, which allows me to estimate the value of the outside option to college enrollment across individuals of different backgrounds.

In fact, lower-income students are less likely to enroll in college; more likely to drop out; and less likely enroll in a public 4-year or a private nonprofit college rather than a public 2-year (community) college. First-year college students from the bottom income quartile families pay on average \$8,700 for tuition in 2003-04—\$5,500 (39%) less than those from the top income quartile. Moreover, at nearly 30% likelihood, students from the bottom income quartile drop out three times more frequently than those from the top income quartile.

To explain this gap in college investment, I estimate a lifetime model of investment in human capital with financing friction. There are two stages in the model. In the first stage, high-school graduates decide to enroll in a college or not. College choice takes place and the optimal student loan is raised. College enrollees update their beliefs over their college-related ability during college and decide to either drop out or finish the degree. In the second stage, individuals enter into adulthood life and earn an education premium in the labor market; enjoy a nonpecuniary benefit from college experiences; and repay student debt.

Students are heterogeneous in college-related ability, which I proxy for via a student's SAT score, high-school GPA, and parents' education. The value added of college education for a student, which is comprised of both monetary returns and nonpecuniary benefits, includes three terms. The first term depends solely on a student's college-related ability and generates variations in college enrollment, unconditionally, across students of different backgrounds and attributes. The second term is college-specific, which determines the popularity and market share of a college. Finally, the third term is the interaction between a student's ability and the observed quality of a college, which represents a complementary effect: relatively able students might value high-quality college more. This term generates a stylized enrollment pattern of able students into high-quality colleges.

Importantly, I do not assume perfect competition among colleges, in which case tuition and fees would equal the marginal cost of providing education services. Geographical barriers might give colleges a natural monopoly power over nearby students. I assume students choose from a menu of colleges with a disutility assigned to distant colleges, knowing that the education quality at the college level is not necessarily reflected in the tuition (net of grants) charged by colleges.

Students are heterogeneous in terms of cash-in-pocket, which represents variation in family support in the college-going ages; but they can take on debt to pay for college. The return rate on student loans perceived by students is possibly higher than the student's subjective time discount rate. I call this the financing friction wedge. This wedge can be justified by adverse selection and moral hazard frictions in the private loan market; administrative and application fees; impact on credit history and/or nonpecuniary costs associated with uninsurable default risk in later stages of life; debt overhang; or simply debt aversion as a behavioral phenomenon.

The financing friction wedge slows down intergenerational education mobility. To avoid paying extra returns on a student loan, a student needs to internally finance college costs, which reduces consumption and hence utility in college-going ages. Therefore, assuming that momentary utility over consumption is concave, a student with insufficient cash-in-pocket is less willing to pay the expensive tuition of a high-quality college. This friction is crucial, particularly for higher-ability and cash-poor students, who needed to lever-up in order to (optimally) invest more in college education. The challenge is to measure the quantitative relevance of this distortion.

I use the simulated minimum distance method to estimate the model. I simulate the college choice and financing structure of students and match a set of targeted simulated moments with their data counterparts to estimate the model parameters. To identify the value for education quality in dollar units, I measure the variation in college enrollment of students across state borderlines with respect to in-state tuition discounts. The education quality at the college level (observed or unobserved by econometricians) is the same for all students, yet in-state students pay lower tuition. Controlling for distance to college, the degree to which students sacrifice college quality to receive in-state discounts identifies the value of college quality per tuition dollar.

To identify the financing friction wedge, I analyze the demand for federal Stafford loans, which comprise more than 75% of total loan balances. Students usually first exploit their capacity of subsidized and unsubsidized Stafford loans;[4] they may also take private loans on top of federal loans to cover the costs of attending an expensive college. I observe the bunching at the Stafford loan limit and use the positive mass of students with a *total* loan exactly equal to the Stafford loan program limit as the identifying moment to estimate the perceived cost of taking a private loan. I then back out the return rate on internal financing—paying out of pocket as the outside option to student loans, using the idea that the return rate on all sources of funds are equal in an equilibrium. This identification strategy gives us an estimate of the value of one dollar cash in college-going time, in units of lifetime wealth.

My paper has three main results. First, the financing friction is indeed a barrier to social mobility. To show this, I run a counterfactual exercise in which I set the estimated financing friction wedges associated with student loans to zero. In such a frictionless world, students of families with below median income would take on much more debt; student loans more than double—increases by $3,600 on average. Also, students of below median income enroll in colleges with on average $600 higher tuition; this increase is one fifth of the estimated gap in tuition payment between students of the below and above median income families. Geographical mobility is boosted as well; low-income students are more likely to enroll in distant colleges. The impact on college enrollment and dropout is marginal, however, suggesting that financing constraints mainly affect college education through intensive margins. In the end, while it causes real and financial distortions, the financing friction is not the main explanatory factor of unequal investment in college. The main part of the gap in tuition and education quality is due to the *heterogeneous* value for college education, i.e., the complementary effect between students' college-related ability and the college quality, and the fact that there is positive correlation between income background and the estimated college-related ability. This result implies that fundamental factors—readiness for college

[4] Subsidized Stafford loans have an upper limit of $2,625 in 2003-04. Individuals may receive less, based on the college cost and their "expected family contribution". The limit on total (subsidized and unsubsidized) Stafford loans is $2,625 for dependent students, and $6,625 for independent, or dependent students whose parents are not eligible for PLUS loans (due to poor credit history). The interest does not accrue on subsidized loans while a student enrolls in college. Note that limits here are reported in 2003 dollars. See more details on the limits and rates in footnotes 8 and 9.

and college orientation—are first-order determinants of investment in college, including investment disparities between rich and poor students.

Second, I show that lifting federal Stafford loan maximum limits can only marginally resolve distortions due to financing constraint for an average low-income student. I simulate students' responses to the increase in Stafford loan limits implied by the Higher Education Reconciliation Act of 2005 and the Ensuring Continued Access to Student Loans Act of 2008. Although these incidents represent a major shift in the history of higher education policies in the US, their real impact is small overall. For low-income students (those from below median income families) the policy overall induces a $690 (30%) increase in student debt, while increases payment for tuition by only $120. The remainder is used to substitute for internal financing and increases early consumption, leaving college investment unchanged.

Finally, I show that making public colleges tuition-free entails social inefficiencies and has *negative* redistribution consequences, whereas expanding federal Pell grants is a much more cost-effective policy to support lower-income students. I estimate the budget cost of making public colleges tuition-free to be around $57B per year. In response to this policy, students shift from private to (distant) public colleges. In the end, however, the increase in students' surplus is about $40B—about $17B less than what the government pays as the subsidy. The policy entails a social deadweight loss because students would not internalize the social cost of enrolling in an (expensive) public college, where the social value to their enrollment might be less than its social cost. Students would mainly enroll in now-free public colleges, even though a socially optimal allocation may assign a student to a private college, simply due to geographical proximity. Although the policy would cut student debt by about 50% on average, benefits from alleviating financing constraints is considerably less than the loss associated with distorting relative prices (tuition of public vs. private colleges). Therefore, the policy *overall* entails a sizable social deadweight loss of around $17B per year.

Importantly, benefits from making public colleges tuition-free are unequally distributed among rich and poor students. Students of families in the top income quartile would receive $15B more in government subsidy than students from the bottom income quartile. The distribution of subsidy is unequal because, per estimation results, high-quality and expensive colleges are more valuable for students with more college-related ability, and these students tend to come from high-income families. Therefore, even though financing constraints would no longer be a challenge for low-income students, high-income students would keep enrolling in more expensive colleges with higher education quality, would drop out less frequently, and would be more likely to enroll in a college in the first place. This continued disparity makes students of high-income backgrounds the main recipients of the government subsidy.

On the other hand, I show that expanding Pell grants would be much more cost-effective in providing access to college education for low-income students. In 2003-04, this grant covers up to $4,050 of college costs of students from low-income families. The effective payment is mainly determined by the family income and is independent of the college choice. Hence, conditional on enrollment, this grant mimics the form of a lump-sum subsidy to a low-income student and, in contrast with making public colleges tuition-free, does not distort allocation of students into colleges. I show that increasing the maximum limit by 140% (up to $13,500) would deliver the same welfare gain as making public colleges tuition-free to students of the bottom income quartile, at only one sixth of the cost for the federal government.

This paper contributes to several strands of literature. The economic model I present builds on basic theories of investment in human capital with financing frictions (Becker and Tomes, 1986; Ljungqvist, 1993; Mookherjee and Ray, 2003). A vast literature tries to examine the empirical predictions for the case of higher education—whether financially constrained individuals invest less in college education, after controlling on an individual's ability. See, among others, Carneiro and Heckman (2002); Belley and Lochner (2007); Lovenheim (2011); Brown et al. (2012); Bulman et al. (2016). This empirical literature mainly focuses on college enrollment, unconditionally, using indirect proxies for "being financially constrained". Results are mixed and depend on sample period and identification technique. In my model, students choose from a menu of colleges with different education quality and tuition. I use micro-level data on financing structures and college choices, which enables me to directly identify financially constrained individuals and quantify the implications of financing frictions for, not only college enrollment, but also the payment for tuition and the quality of the college a student enrolls in. As I show in the counterfactual analysis, the consequence of financing frictions not only is less college enrollment, but it mainly is enrolling in cheaper and lower-quality colleges. In addition, structural estimation allows me to do policy analysis.

This paper also relates to the literature on the role of education in socioeconomic mobility. See Restuccia and Urrutia (2004); Chetty et al. (2017); Kotera and Seshadri (2017); Zimmerman (2019). In a recent study Chetty et al. (2020) document a significant degree of parental income segregation across colleges, even after controlling on proxies for academic preparedness, which per se may explain a substantial portion of the persistent intergenerational income inequality in the US. I measure the extent to which financing frictions may explain the observed stylized sorting of lower-income students into lower-tuition colleges, after controlling on measures of college preparedness (including SAT scores and high-school GPA). In addition, I quantify the costs and benefits of extensive higher education grant policies proposed to address these frictions for students of lower-income backgrounds. I show that even if the government fully subsidizes tuition in public colleges, so that financing college costs is not a concern for lower-income students, the stylized sorting of lower-income students into lower-quality and lower-tuition colleges prevails. Therefore, by making public colleges tuition-free, students of higher-income families would eventually receive much more subsidy than students of lower-income families.

A vast literature examines the impact of government subsidies for higher education. See, for example, Cellini and Goldin (2014); Turner (2014); Epple et al. (2017); Kargar and Mann (2018); Lucca et al. (2018). This literature mainly focuses on monopoly power as the friction on colleges' side, and the concern is whether colleges raise tuition in response to federal aid programs, so that students might not benefit much (Bennett, 1987). I rather focus on the implications of financing frictions on students' side, and quantify the extent to which students would switch to expensive and higher-quality colleges in response to federal aid policies. I show that the efficiency gain of relaxing financing constraints via the policy of making public colleges tuition-free is dominated by resultant discretionary costs of this policy.

A thriving literature in economics and finance documents the real impact of credit supply on firms (Chodorow-Reich, 2013; Greenstone et al., 2014; Amiti and Weinstein, 2018). In this paper, I examine the credit channel in the context of student loans and investment in human capital. In a model-based counterfactual analysis, I simulate the expansion of federal Stafford loan limits, implemented in the mid 2000s. I show that while this policy induces an increase in average loan among all low-income students by \$690 , it raises what students pay for tuition by \$120. This sensitivity—a 17-cent increase in investment size per dollar of loan—is significant in comparison to what the aforementioned literature estimates in different contexts. In a related context, Sun and Yannelis (2016) document a positive relationship between college enrollment and private credit supply shock coming from banking sector deregulation, with different timing across states, from the 1970s to 1990s. The scope of results is limited, as the private sector is not the main source of student loans in the US. In a recent study Black et al. (2020) identify the impact of federal loan expansions in the mid 2000s by considering college students with a loan equal to the maximum federal loan limit before the policy as the treatment group. The left-hand side variable is degree completion and post-college earnings. I structurally estimate the impact of expanding federal Stafford loans on not only degree completion for college enrollees, but also college enrollment and the choice of college, conditional on enrollment. As I show in the counterfactual analysis, the primary impact of lifting federal loan limits is enrolling in colleges with higher tuition, not finishing the degree condition on enrolling in college. In the end, structural estimation allows me to quantify the overall impact of financing frictions on students' welfare.

Finally, this paper relates to an extensive literature on consequences of student debt on degree completion, and post-college labor market outcome and welfare (Chatterjee and Ionescu, 2012; Beyer et al., 2015; Fos et al., 2017; Cox, 2017; Di Maggio et al., 2019). Debt-overhang and mispricing loans are two frictions that drive debt-aversion. In my model students have a perception of post-college costs associated with taking on student debt. Using a revealed preferences approach, I estimate the implication of this cost for college choice and tuition payment. I show that debt is not neutral and the net-present-value of the investment in college education is lower if it is financed via debt. This is why, if low-income students had sufficient cash-in-pocket to internally finance college costs, the payments for tuition would increase. I estimate the welfare implications of eliminating student debt via expanding federal grants. The counterfactual analysis shows that expanding Pell grants could reduce student debt and boost college enrollment for lower-income students, at a much lower cost than making public colleges tuition-free.

# 2 Data and Facts

**Data Sources.** I use the confidential version of Beginning-Postsecondary-Students survey 2004-09 (BPS:04/09), which is a student-based panel survey covering the whole population of the first-time first-year US college students in 2003-04, with two follow-ups in 2006 and 2009. This dataset reports students' demographics, SAT scores and high-school GPA, parents' education and family income in 2002; the choice of college in 2003-04, state of residency and distance to college, tuition payments, federal and private student loans, federal, state, and institutional grants; and enrollment spells and dropouts/stopouts throughout 2009.

I collect information on colleges from the Integrated Postsecondary Education Data System (IPEDS), which is a publicly available database provided by National Center for Education Statistics in order to help students to choose between colleges. This database reports annual data on tuition and fees charged for in- and -out-of-state students, admission rules, graduation rates, faculty salaries, average grants given to students, and the location of the universe of title IV higher education institutions.

I supplement these datasets with the confidential version of Education Longitudinal Study of 2002 (ELS:2002), which is a panel survey covering the whole population of $12^{\text{th}}$ grade US high-school students in 2003-04, with second and third follow-ups in 2006 and 2012. This dataset helps me to obtain the population size and attributes of the potential consumers of higher education studies. This dataset reports students' high-school GPA and SAT score for those who take the test, parents' education, and family income category.

**Selection Criteria.** I keep dependent students in the BPS:04/09 sample who enroll for the first time in college before or at age 21 and attend full-time at college to pursue a two-year- or four-year academic degree (associate or bachelor's). I drop students in vocational/technical training programs. This leaves us with a sample of 8,705 students representing 1.65 million US college students enrolled for the first-time in college in 2003-04, with two follow ups in 2006 and 2009.[5] I keep title IV higher education institutions from IPEDS who offer at least a two-year academic degree and drop postsecondary institutions with vocational/technical training programs. I drop small institutions: those with less than 15 full-time faculty/employer or those who enroll less than 50 first-year students, due to unavailable and noisy data. These criteria leave us with 2,913 colleges for which 680 is the mean number of full-time first-year enrollees. Finally, I drop high-school dropouts and track

[5]I keep young dependent students as in this research I focus on the impact of family income background on college education and the data is not reported for independent and old students. Students older than 21 make less than 20% of the entire population of students going to at least a two-year program institutions. I only keep full-time students (more than 80% of the remained sample) as in the model I abstract from working during college with part-time enrollment. Part-time enrollment besides working in the labor market in older ages in pursuit of a one-year vocational/technical training certificate should be considered as an outside option to college enrollment.

high-school students from ELS:2002 who have received a high-school degree before the age of 20.[6] This criterion leaves us with a sample of 12,805 observations representing 2.80 million high-school graduates in the US who were 12$^{\text{th}}$ graders in 2003-2004, with eight years of follow ups, from which 60% enroll full time at a two- or four-year college to pursue an undergrad degree.

In what follows I report statistics on students' attributes; enrollment patterns and college choices; colleges' characteristics; and finally, financing structure of college costs (student loans, grants, and out-of-pocket expenses). In the end, I present a suggestive evidence that shows financing constraints cause real distortions. All variables with dollar unit are reported in 2019 dollars.

**Students' Attributes.** Table 1 reports summary statistics on proxies of college-related ability for students of different backgrounds. Students from low-income families are more likely to be in a family with no college experiences; have lower SAT scores on average; and have lower high-school GPAs. This pattern indicates an unequal preparedness for college studies across students of different backgrounds. However, there is a significant variation in attributes within each income background group. Standard deviation in SAT scores for low- and high-income students are of the order of the gap in average SAT between low- and high-income students. This overlap in attributes allows me to identify the impact of college-related ability versus cash-in-pocket on investment in the college education.

**Investment in College Education.** Low-income students considerably invest less in college education. See table 2. In total, 40% of high-school graduates from the bottom income quartile families enroll in a college; pay $9,000 on average for tuition and fees conditional on enrollment; and about 50% of enrollees could attain a bachelor's degree. Students in the top income quartile, however, enroll in a college with 80% likelihood; pay around $14,500 for tuition and fees; and 80% of enrollees could attain a bachelor's degree.[7] Notably, this gap in investment is not just a left- or right-tail phenomenon. The entire distribution of tuition payments shifts to the right as family income increases. See the supplementary table 1 of the Online Appendix. Moreover, there exists substantial variation in payment for tuition, within a specif category of low- or high-income student. The variance in tuition is $6,600 and $8,800 for students of the bottom and top income quartile—of the order of the gap in mean tuition

[6]This group represents about 83% of the entire population of 10$^{\text{th}}$ grade students in the US. High-school dropouts cannot enroll in a college to pursue an undergrad degree and are not considered a potential consumer of higher education in my model.

[7]BPS follows students for six years and I cannot precisely identify dropouts from stopouts in the last year of survey study. I label a student as a college dropout if she has attained no degree from 2003 throughout 2009, and she has left the college before 2009 for at least four academic semesters. Choosing the threshold four semesters is based on the fact that about 80% of students with a stopout in the period 2003-2009 returned to college in less than 24 months. I assume those who are still enrolled in 2009 and have no degree yet (mostly due to prior stopouts) would attain the degree of the program in which they are enrolled in 2009.

across income quartiles. I argue that there exists significant heterogeneity in college-related ability, even within a specific income background category, which drives college enrollment, payment for tuition, and degree attainment. Those low-income students in the right tail of college-related ability are supposed to lever-up with student loans to pay for the expensive tuition of a high-quality college and attain a bachelor's degree—feature upward mobility in the society. Financing constraints can be a barrier.

**College Choice.** Low-income students enroll in not just lower-tuition colleges, but also in colleges with lower graduation rates, lower-paid faculty, and open admission policy. Table 3, Panel A shows that students of different backgrounds enroll into specific college types in a stylized way. About 45% of low-income students enroll in public two-year (community) or for-profit colleges and 55% attend public four-year or private nonprofit colleges, whereas 80% of high-income students enroll in private nonprofit or public four-year colleges. As table 4 shows, faculty salaries are systematically lower in public two-year and for-profit colleges; graduation rates are also lower and most of these colleges have an open admission policy, which suggests that the cohort quality is relatively lower on average. The question remains whether low-income students are less prepared for college (table 1) and put relatively less value on a distant high-quality college, or if low-income students cannot finance the expensive tuition of a high-quality college. Moreover, many low-income students attend a nearby college, which helps to save on housing costs by living with parents during college studies (see the supplementary table 2 of the Online Appendix). The concern is that colleges may exert monopoly power on low-income nearby students and provide lower-quality education, per unit of a dollar charged for tuition.

**Student Loans.** Student loans are an important source of funds to cover tuition cost. Table 5 shows statistics of total student loans for students of different income backgrounds. Students from low-income families are slightly more likely to take a student loan. However, the average size of loan, conditional on taking a loan, does not systematically vary across students of different backgrounds. Federal loan limits are a determinant factor for the demand for student loans. Around 25% of *all* students raise a total loan exactly equal to the federal subsidized and unsubsidized Stafford loan limit ($3,600 and $9,085 in 2019 dollars). This is more than 50% of students with a positive loan. Moreover, only 5-10% of all students take private loans on top of federal loans, as Stafford loans might not satisfy their financial needs. The bunching on the federal Stafford loan limits may be an indicator of a higher return rate on private loans perceived by students. A higher rate can be justified by an uninsurable default risk for students, or moral hazard and adverse selection as frictions in the private loan market.

**Grants.** Public funds and school grants are also a critical source of funds to finance college costs, especially for low-income students. Student in the bottom family income quartile received around \$5,500 in federal and state need-based grants in the academic year 2003-04. The most important source is the federal Pell grant program. Low-income students are qualified to use Pell grant to pay for tuition and room and board in any title IV higher education institution in the US. In regard to institution (school) grants, students in the top family income quartile receive a total of \$3,300 in grants from colleges, with the largest share being merit-based, as opposed to students in the bottom quartile who received \$2,200 in school grants on average with the largest share being need-based. In sum, students in the bottom income quartile received a total of \$8,400 in grants from all sources, mostly being need-based, whereas students in the top income quartile received \$4,500 in grants on average, with the largest fraction being a merit-based grant. See details in the supplementary table 3 of the Online Appendix.

## 2.1 Financing Constraint: Suggestive Evidence

I first show that the correlation between family income and investment in college education holds even after controlling on measures of college-related ability: students' SAT and high-school GPA and parents' college education. Then I propose proxies for "being financially constrained" and investigate whether financing frictions may impact investment in college education.

The empirical specification that I consider resembles a classic model in corporate finance. The investment theory in a Modigliani-Miller world implies that a firm's investment level is only explained by Tobin's Q—investment opportunities. Firm liquidity, say current cash flow, must have no explanatory power. Motivated by this idea, I consider college enrollment, degree attainment, and payment for tuition and fees as measures of investment in college education in the left-hand side of a regression model. Students' SAT scores, high-school GPA, and parents' education are proxies for the investment opportunities, and family income in a year before the student's college age is a proxy for inside cash are right-hand side variables. Regression results are reported in table 6.

The regression coefficient of family income is economically and statistically significant, especially after controlling on (need-based) grants. The coefficient in a univariate regression of $\log(tuition)$ on $\log(family\ income)$ is .233. As I show in table 1, family income correlates with factors that proxy college-related opportunities. After including students' SAT score and high-school GPA and parents' education, the coefficient shrinks to .057, which is statistically significant at 5% p-value. I also measure the impact of family income, having controlled on total grants. Need-based grants are a crucial source of funds for lower-income students. This is why after controlling on grants the point estimate increases to the significant value of .239. Logit regression models also document a positive and significant relationship between family income, and college enrollment and bachelor's degree attainment conditional on enrollment. A 20% increase in family income is associated with a 1 percentage point increase in college enrollment likelihood, and a 1.2 percentage point increase in the likelihood of attaining a bachelor's degree, conditional on enrolling in a college.

A concern is that SAT score and other proxies I include in the OLS and Logit models above are imperfect signals on college-related opportunities; and family income not only represents cash availability, but also contains *marginal* information on the college-related ability. To address this concern, I consider having a sibling in college, before or at the same time a student is enrolling in the college, as a proxy for available financial resources in the family. Results are presented in table 7. Having a sibling in college might still correlate with college-related ability of a student; but, if anything, the correlation is positive, since it indicates the family environment is college oriented. Despite this source of positive bias, the estimated regression coefficient is negative and statistically/economically significant; dependent students with a sibling in college pay about 6% less for tuition and fees.

To identify financially constrained individuals, I also target a subgroup of students whose total student loans is exactly equal to the federal Stafford loan limits. Given total grants and family contribution, such students could have paid more for tuition either by taking other types of loans, e.g., private student loans, or, say, by cutting their everyday consumption and payment for housing. I control on the level of loan to extract the discontinuity effect associated with being right at the Stafford loan boundaries. The OLS estimate reads students on the Stafford loan limits pay 8% less for tuition and fees. Subsample estimation shows that the point estimate is larger in absolute terms for lower-income students. The regression coefficient is -.15 for students of families in the bottom income quartile families and -.07 for students of the top income quartile. The supplementary table 4 of the Online Appendix reports subsample regression results.

# 3 Economic Model

In this section, I present a lifetime model of investment in human capital with financing friction. There are two stages in an adulthood life. Investment and experimentation in higher education takes place in stage one. At the beginning of stage one, a high-school graduate decides to enroll in college, or to just enter the labor market, in which case she enters the second stage of life as an unskilled worker. During college, a student updates her belief over her college-related productivity; she then may drop out, or finish the degree and enter the second stage of life as a skilled worker.

## 3.1 Fundamental Factors

**Individuals' Attributes.** An individual, named by subscript $s$ from the type set $\mathcal{S}$, draws a college-related ability $A_s$ representing fundamental factors, such as pre-college education quality, which affect the productivity of the individual in the college. Given an initial belief over $A_s$, called $A_s^{(i)}$, the individual decides whether to enroll in college or not.

The student observes a second component of the college-related ability, named $A_s^{(f)}$, while she is in college; then she decides to drop out, or finish the degree. In case she is enrolled in a two-year college, she may finish college with an associate degree or transfer to a four-year college in pursuit of a bachelor's degree. Students enrolled in four-year colleges have also the option of either drop out, quit college earlier with an associate degree, or attain a bachelor's degree.

I specify the college-related ability $A$ as a scalar composed by $A^{(i)}$ and $A^{(f)}$ in the form

$$\begin{aligned} A_s &= A_s^{(i)} + A_s^{(f)} \\ A_s^{(i)} &= \bar{A} + \Pi' D_s + \pi_1 \nu_s \\ A_s^{(f)} &= \pi_2 \rho_s \end{aligned} \tag{A}$$

Here, $\bar{A}$ is the mean ability and $D_s$ is a vector of observable attributes—specifically, high-school GPA, SAT score, parents' education and income, and whether she has a sibling with college experience. $\nu_s \sim \mathcal{N}(0, 1)$ is the unobservable (by econometricians) component of ability; $\Pi$ is a vector of coefficients with the same size as $D$. $\pi_1$ is a scalar that controls the contribution of the unobservable component to students' ability.

The individual does not observe $\rho_s$ ex-ante. $\rho_s$ is either plus or minus one with equal probabilities and is realized during college studies. $\pi_2$ is a constant that captures the extent to which a student's belief over her college opportunities updates during college. The student perfectly observes $\rho_s$ while econometricians observe a noisy signal of $\rho_s$—namely, students' college GPA.

**Colleges' Characteristics.** A student may choose a college, named by subscript $u$, from the college set $\mathcal{U}$. The education quality at college $u$ is represented by the observable and unobservable (by econometricians) components described by scalars $H_u$ and $\xi_u$, respectively. I specify $H_u$ as

$$H_u = \bar{H} + \Delta H_u = \bar{H} + \Gamma' X_u \tag{H}$$

Here $\bar{H}$ is the mean college quality and $X_u$ is a vector of observable characteristics—specifically, an indicator for two- vs. four-year program colleges, open admission policy, faculty salaries per enrollees, admission rate, and graduation rate and percentile 75th of the SAT score of students enrolled in that college in previous years as a proxy for cohort quality. $\Gamma$ is a vector of coefficients with the same size as $X_u$.

**Sticker Price.** Tuition and fees charged by college $u$ for student $s$ is denoted by $T_u - \mathcal{I}_{su}\Delta_u$. $T_u$ represents the tuition charged for out-of-state students and $\Delta_u$ represents the tuition discount for in-state students. $\mathcal{I}_{su}$ is an indicator that is equal to one if the student $s$ is the resident of the same state operating the public college $u$. $\Delta_u$ is zero for private colleges.

**Geographical Barriers.** An individual is free to apply for any college across the nation, except that she pays a nonpecuniary cost $\chi d_{su}$, where $d_{su}$ represents the log-distance between student $s$ and college $u$, and $\chi$ is a fixed parameter that depends on students' background and colleges' type. This cost captures students' imperfect information on distant colleges and the popularity of colleges for nearby residents, as well as traveling barriers and the disutility to go far from family. This geographical cost contributes to endogenous market segmentation across the country.

**The Value to Higher Education.** I specify the *mean* value to pursue higher education at college $u$ for student $s$ as

$$\omega A_s + \xi_s + \theta A_s H_u + \alpha H_u + \xi_u - \chi d_{su}$$

where $\xi_s$ and $\xi_u$ are student and college fixed effects, and $\omega$, $\theta$, $\alpha$ and $\chi$ are fixed parameters. The value to outside option—no college enrollment—is normalized to zero for each student type $s$. This mean value scales with the type of degree: bachelor's, associate, or dropout. In what follows I explain how this mean value, plus the disutility to pay for college tuition, enters into the lifetime utility-maximization problem for the college choice and the dynamic choice of degree in the college-going age.

## 3.2 Financing College Costs

**Grants.** The student $s$ possibly receives a grant $g_{su}^{inst}$ from college $u$. A student may also be qualified for the state grant $g_{su}^{state}$ by enrolling in an in-state college. Besides, a student may receive grants from private sources $g_s^{priv}$ and a federal grant $g_{su}^{federal}$ which is mostly through the Pell grant program; Pell is a need-based grant that is assigned based on the student's income background and the cost of attendance (COA) at a college; the main determinant in the academic year 2003-4 is, however, the student's income background, as the COA at almost all colleges is above the policy threshold. The total grant $g_{su} = g_s^{priv} + g_s^{federal} + g_{su}^{state} + g_{su}^{inst}$, however, depends both on a student's attributes and the college she is enrolling in. To set $g_{su}^{state}$ and $g_{su}^{inst}$ I fit a nonparametric model using the observed student-level data on state and institution grants with students' attributes and colleges' characteristics and their interactions as explanatory variables. I assume that the stochastic error term in this model is realized for a student after she is enrolled in a college, as students have imperfect knowledge on the exact amount of grants they would receive when choosing a college.

**Cash-in-pocket.** A student is endowed with initial cash-in-pocket $m$ representing family financial support and job earnings during college studies. I assume $m$ is log-normally distributed with a mean and variance depending on families' income levels. Low-income families may deliver less funds to their children for college studies. All families may provide housing to their children during college with dollar value $h$; students who go to a nearby college ($d_{su} \leq d_0$) can live with parents during college and benefit from $h$ on top of $m$.

**Student Loans.** Students may save part of the inherited endowment at the gross rate $R_0$ for the adulthood stage of life. I denote the savings by $B \geq 0$. I specify $R_0 = \beta^{-1}$, where $\beta$ denotes time-discount factor. A student with less inherited wealth may apply for a student loan, called $L$, at gross rate $R_l$ to cover college costs. I assume $R_l \geq R_0$. $R_l$ can be strictly greater than $R_0$ due to a financing friction wedge. I calibrate $R_0$ using the 10-year treasury rate. In what follows I specify $R_l$ in detail.

I consider a pecking-order model confirmed in the data: students first receive a federal subsidized loan capped by the amount $L_{su}^{sub}$; they then receive a federal unsubsidized loan up to the limit $L_{su}^{uns} = L_{su}^{tot} - L_{su}^{sub}$; finally, students can increase their leverage by taking a private loan. The limits on federal subsidized loans and total subsidized and unsubsidized loans are determined by institutional formulas

$$\begin{aligned} L_{su}^{sub} &= \min\{L^{sub}, T_u - \mathcal{I}_{su}\Delta_u + N_u - g_{su} - EFC_s\} \\ L_{su}^{tot} &= \min\{L^{tot}, T_u - \mathcal{I}_{su}\Delta_u + N_u - g_{su}\} \end{aligned}$$

where $L^{sub}$ and $L^{tot}$ are Stafford loan program limits for subsidized, and subsidized plus unsubsidized loans;[8] $N_u$ is non-tuition college costs —books and supplies, room and boarding— posted by each college; $g_{su}$ is the total grant the student $s$ is qualified for at the college $u$; finally, EFC is the "expected family contribution" derived from tax return data and other related information filed in the Free Application for Federal Student Aid (FAFSA) form, such as number of siblings in college. A larger EFC is assigned to students of higher-income backgrounds, so given a level of net tuition, high-income students are less likely to be eligible for the subsidized loan. Unlike unsubsidized Stafford loans, the interest does not accrue on a subsidized Stafford loan while the student is enrolled in the college.[9]

[8] In the academic year 2003-04, $L^{sub} = \$2,625$ and $L^{tot} = \$6,625$ for first-year independent students, or dependent students whose parents are ineligible for federal PLUS loans due to poor credit history (category 1); for other first-year dependent students (category 2) the limits are $L^{sub} = L^{tot} = \$2,625$. Most of the dependent students in the bottom family income quartile fall into category 1 and those in the top income quartile fall in category 2. Limits increase in the second year of study to $L^{sub} = \$3,500$ and $L^{tot} = \$7,500$ for category 1, and to $L^{sub} = L^{tot} = \$3,500$ for category 2; and to $L^{sub} = \$5,500$ and $L^{tot} = \$10,500$ for category 1 and $L^{sub} = L^{tot} = \$5,500$ for category 2 in the third, fourth and fifth years of study. A year of study is considered to be 29 undergrad course credits. Note that limits here are reported in 2003 dollars.

[9] The interest rate on subsidized loans originated for the academic year 2003-04 is 3.42%. Students start repaying after college and the interest does not accrue while they are in college. The interest on unsubsidized loans for the academic year 2003-04 is the same, but the interest accrues at the rate 2.82% during college.

I consider a piecewise linear specification for the perceived cost of student loan, $C(L)$

$$C(L) = R_l L = \begin{cases} f_0 + R_0 L + \eta_s L & L \le L_{su}^{sub} \\ f_0 + R_0 L + \eta_s L + \eta_u (L - L_{su}^{sub}), & L_{su}^{sub} < L \le L_{su}^{tot} \\ f_0 + R_0 L + \eta_s L + \eta_u (L - L_{su}^{sub}) + \eta_p (L - L_{su}^{tot}), & L_{su}^{tot} < L \end{cases} \quad \text{(L)}$$

$f_0$ is a fixed cost associated with having a positive loan balance. It can simply capture the cost of filing FAFSA forms; behavioral reasons associated with debt aversion; and the negative impact on the individual's credit score, which would affect the rates she may receive for other financial products in the near future (credit cards, car loans, mortgages, etc). $\eta_s < 0$ as interest does not accrue while the student is enrolled in college. I calibrate $\eta_s$ based on the subsidized loan rates and students' expected length of college study. $\eta_u$ is the margin between the rate on unsubsidized loan set by the federal government and the saving rate $R_0$. It may also include costs associated with (behavioral) debt aversion as well as (rational) debt overhang, which are more severe if the student raises too much debt. Finally, $\eta_p$ represents the (shadow) price of private loans relative to federal Stafford loans. $\eta_p$ is positive simply due to administration fees charged by banks, adverse selection and moral hazard frictions in the private loan market, individuals' exposure to uninsurable default risks, and nonpecuniary costs associated with defaulting on a student loan.

I estimate $f_0$, $\eta_u$ and $\eta_p$ via a revealed preferences approach described in the identification section. Justified by the theories that drive financing friction wedges, I assume that these parameters vary with students' income background and SAT score as the signal on ability.

## 3.3 Students' Optimization Problem

In this section I sketch out the individual's optimization problem. To simplify the illustration, I first present a simple choice model with no degree choice and experimentation and examine the role of financing friction. Then I introduce information realization during college-going age and model the choice of degree attainment.

### 3.3.1 College Choice

The individual has a log utility over consumption besides non-pecuniary benefits from higher education studies. The individual's lifetime utility is specified as

$$U = U_1 + \beta U_2 = \log(c_1(s,u)) + \beta[\log(c_2(s,u)) + v(s,u)]$$

The usual loan maturity is 10 years. Note that I calibrate the net return rate on savings $R_0 - 1$ with the 10-year treasury rate, being 3.53% in annual terms, based on data in May 2003.

where

$$
\begin{aligned}
c_1 &= m + h\mathbf{1}\{d_{su} \leq d_0\} - (T_u - \mathcal{I}_{su}\Delta_u) + g_{su} \,+\, L - B \\
c_2 &= \bar{y}(s) + \Delta y(s,u) - R_l L + R_0 B
\end{aligned}
$$

are stage 1 and stage 2 consumption and $\beta$ denotes the subjective time discount factor. Here, $y(s,u) = \bar{y}(s) + \Delta y(s,u)$ is an individual's labor income where $\bar{y}(s)$ indicates the expected mean of the labor income of a type $s$ individual, and $v(s,u)$ is the nonpecuniary benefit to college studies. Both $\Delta y(s,u)$ and $v(s,u)$ depend on students' attributes and colleges' characteristics, hence are indexed by $s$ and $u$.

I approximate the stage-2 utility by log-linearizing consumption around the base level $\bar{y}(s)$. The monetary and nonpecuniary benefit of college education then appear as additive separable terms.[10]

$$
\beta U_2 \simeq \beta \log(\bar{y}(s)) + \beta[\Delta y(s,u))/\bar{y}(s) + v(s,u)] - \beta R_l L/\bar{y}(s) + \overbrace{\beta R_0}^{=1} B/\bar{y}(s)
$$

Here $\beta[\Delta y(s,u))/\bar{y}(s) + v(s,u)]$ represents the present value of the return to the higher education studies at college $u$ for student $s$. $\Delta y$ and $v$ are determined by the technology of human capital formation and the intrinsic preferences for higher education. I specify[11]

$$
\beta[\Delta y(s,u) + v(s,u)\bar{y}(s)] = \theta A_s H_u - \chi d_{su} + \delta_s + \delta_u + \overbrace{\zeta \epsilon_{su}}^{\text{logit shock}} \tag{V}
$$

As defined before, $A_s = \bar{A} + \Pi' D_s + \pi_1 \nu_s$ is a student's college-related ability and varies with observable attributes; $H_u = \bar{H} + \Gamma' X_u$ is observable college characteristics; $\delta_s := \omega A_s + \xi_s$ is the unconditional value that student type $s$ assigns to college education; $\delta_u := \alpha H_u + \xi_u$ is the

[10]Note that to perform this approximation I am not assuming that people with college studies earn almost the same as uneducated labor force. For each individual I perform Taylor expansion over that specific individual's average income, which requires that the income gain to college studies, being equal to the monetary gain on investment in higher education minus the return on financial costs needed to undertake this investment, after controlling on an individual's attributes, is of a small order of magnitude. See the supporting evidence in the supplementary table 5 of the Online Appendix. This table reports the results of an OLS regression of post-college job earnings on degree attainment and tuition and fees as a proxy for college quality, having controlled on pre-college observed measure of ability—SAT score and parents' income and education. The regression coefficient of the dummy variable for bachelor's degree, in a regression model that controls on payment for tuition, is roughly \$7,000 without any control on measured ability and family backgrounds, and decreases to near \$5,000 after controlling on measured ability and family backgrounds. Moreover, 10 thousand dollars—around one std change in net tuition (tuition minus grant) per college study year is associated with about \$1,200 boost in post-college annual income. I use the estimated income by the model in this table to set the base income $\bar{y}(s)$ perceived by each student type $s$ in simulating her forward-looking lifetime value-maximization problem. The mean $\bar{y}(s)$ across all students is around \$36,000, much larger than variations in income associated with a change in tuition or degree attainment.

[11]In the rest of the analysis, I ignore the base term $\beta \log(\bar{y}(s))$ in the approximation of $\beta U_2$ as it shows up in all of the available choices.

mean-taste for college $u$. The term $\chi d_{su}$ represents the geographical barriers to enrolling in distant colleges. $\epsilon_{su}$ is drawn from type-I extreme value distribution and is iid across students and colleges. $\zeta$ is a fixed parameter that controls the variance of the logit shock and varies across students of different backgrounds. $\zeta$ determines the price-elasticity of demand for college education.

In the next two sections I analyze the optimal financing choice, first in a benchmark frictionless world and then in the presence of external-financing frictions.

### 3.3.2 The Frictionless Case: $R_l = R_0 = 1/\beta$

In this case a student can save/borrow at an interest rate equal to the subjective time discount factor. I show that the choice of college and financing structure are separated.

If the individual chooses college $u$, the optimal student loan is solved from:

$$\begin{aligned} \max_{L} \quad & \bar{y}_s \log(c_1) - L + constant. \\ s.t. \quad & c_1 = L + constant. \end{aligned}$$

The "constant" terms here vary with $u$ but are independent of $L$. The optimal student loan is set such that the student can perfectly smooth out her lifetime consumption

$$c_1^* = \bar{y}_s \;\Rightarrow\; L_{su}^* = \bar{y}_s - m + p_{su} \tag{1}$$

where, to simplify notations, I define

$$p_{su} := T_u - \mathcal{I}_{su}\Delta_u - g_{su} - h\mathbf{1}\{d_{su} \leq d_0\}$$

as the net effective price the student $s$ pays for college $u$.

Having solved for the optimal loan level, the college choice reduces to

$$\max_{u \in \mathcal{U}} \quad -p_{su} + A_s\theta H_u + \delta_u - \chi d_{su} + \zeta\epsilon_{su}$$

This is a standard mixed-logit demand model. Note that the initial cash-in-pocket $m$ does not show up in the college choice problem. In the frictionless case $m$ just shifts the level of student loan and leaves college choice, as well as the early consumption level, unaffected. This result resembles the Modigliani-Miller theorem.

### 3.3.3 The Case with Financing Friction: $R_l > R_0 = 1/\beta$

In case a student is endowed with sufficient cash in pocket, i.e., large $m_s$, the optimal student loan $L = 0$, and the saving is positive: $B > 0$. The optimization problem is just as in the frictionless benchmark and $B$ solves

$$c_1 = \bar{y}_s \;\Rightarrow\; B = B^* := m_s - \bar{y}_s - p_{su} \tag{2}$$

This conjecture (positive saving) is confirmed if $B^* \geq 0 \Leftrightarrow m_s - p_{su} \geq \bar{y}_s$.

Otherwise, if $m_s - p_{su} < \bar{y}_s$ (low initial endowment) the student sets $B = 0$ and may apply for a student loan that solves

$$\begin{aligned} -P_{su} := \max_{L} \quad & \bar{y}_s \log(c_1) - \beta R_l L \\ s.t. \quad & c_1 = L + m_s - p_{su} \end{aligned} \tag{F}$$

Because $\beta R_l > 1$, the optimal choice of loan is less than $L^*$—the level associated with the frictionless case ($\beta R_l = 1$). Note that the optimum value $P_{su}$ represents the *dis*utility to enroll in a college with net price $p_{su}$.

The optimal level of student loan with financing friction wedges is based on a trade-off. Taking too much debt is associated with extra external financing cost, but helps the student to smooth her lifetime consumption pattern. It is insightful to define the marginal return to early consumption $c_1$ as

$$R_c := \frac{1}{\beta}\frac{\partial\, \bar{y}_s \log(c_1)}{\partial c_1} = R_0\, \frac{\bar{y}_s}{m_s - (p_{su} - L)}$$

$R_c$ can be interpreted as the marginal cost of internal financing, i.e., paying more for college (higher $p_{su}$) by cutting on early consumption. A dollar more of student loan, however, helps an individual to finance college, at the cost of a reduction in the future consumption by the amount $d(R_l L)/dL$, keeping early consumption $c_1$ unchanged. There is no arbitrage between the two financial resources in the optimal financing plan. For students not on the loan boundaries, $R_l L$ is a smooth linear function; hence, the optimal $L$ solves a first-order condition that sets the marginal return rate to internal financing $R_c$ equal to the return rate on student loan:

$$R_c(L) = R_0 + \eta_i \;, \quad for\ i \in \{s, u, p\} \tag{3}$$

where $i \in \{s, u, p\}$ indicates the subsidized, unsubsidized, and private loan regions, i.e., $0 < L < L_{su}^{sub}$, $L_{su}^{sub} < L < L_{su}^{tot}$, and $L_{su}^{tot} < L$, respectively.

For the pool of students on the subsidized or unsubsidized loan boundaries, the cost of internal financing lies in a range that depends on the magnitude of $\eta_s$, $\eta_u$ and $\eta_p$. The global solution for the optimal loan demand achieves the best objective value associated with internal solutions solved by equation (3) and the corner solutions $L = 0$, $L = L_{su}^{sub}$, and $L = L_{su}^{tot}$.

Finally, it is insightful to show the link between external financing frictions and the price elasticity of demand for college education. In the absence of financing friction ($\beta R_1 = 1$), or in case $m_s$ is sufficiently large ($m_s \geq p_{su} + \bar{y}_s$), we have $P_{su} = -\bar{y}_s \log(\bar{y}_s) + \bar{y}_s - m_s + p_{su}$. Recall that $P_{su}$ is the solution to the optimal financing structure defined in the optimization program (F). In this case $\frac{\partial P_{su}}{\partial p_{su}} = 1$. On the other hand, if the financing friction wedge is positive ($\beta R_l = R_l/R_0 > 1$, i.e., $\eta_i, \eta_p, f_0$ is positive) and the initial money in pocket is insufficient ($m_s < p_{su} + \bar{y}_s$) then the envelope theorem and first order conditions with respect to $c_1$ and $L$ results in $\frac{\partial P_{su}}{\partial p_{su}} = 1 + \eta_i/R_0 > 1$ for $i \in \{u, p\}$ off the federal loan boundaries, and $\frac{\partial P_{su}}{\partial p_{su}} = \frac{\bar{y}_s}{\bar{L} + m_s - p_{su}} > 1$ for $\bar{L} \in \{L^{sub}, L^{tot}\}$ on the loan boundaries. Note that the price sensitivity is increasing in $p_{su}$, and decreasing in $\eta_i$, and in $m_s$ and $\bar{L}$. An additional dollar payment for tuition and fees has a trivial negative impact on the indirect utility as in any standard demand model with no financing friction. There exists an additional disutility to price due to the tightening of the liquidity constraint under financing friction for individuals with low cash-in-pocket in college-going age, which shrinks if the limit on loans is lifted and financing friction wedges decrease.

### 3.3.4 Degree Choice

Having specified the fundamental elements and external-financing costs, I now introduce experimentation and degree choice and specify the full optimization problem.

**Four-year Program Colleges.** First, consider students enrolling in a four-year college. Students have three options: attain a bachelor's degree, quit college with an associate degree, or drop out earlier. I scale the value of i) college experience and no degree—dropout; ii) associate degree; and iii) bachelor's degree with $g^d$, $g^a$, and $g^b$, respectively, with $g^b$ being normalized to 4. Denote the time—number of years needed to be in college for each degree level by $t^d$, $t^a$, and $t^g$, respectively, which I will calibrate to 2, 3, and 4 years based on median observation in data. Importantly, I do not assume that the value to a degree proportionally scales down with the time spent in college for that degree; this is meant to capture non-convexities and sheepskin effects: a year in college does not necessarily deliver one-fourth of the value of four years in college that ends with a bachelor's degree. Specifically, one may expect $g^d \ll \frac{t^d}{t^b} g^b$.

After enrolling in college, the college-related ability $A_s$ is fully realized and the student faces three degree choices delivering *mean* values

$$\begin{aligned} \textit{drop out}: V^d_{su}(A_s) &= g^d(A_s\theta H_u + \delta_s + \delta_u) - t^d\chi d_{su} \\ \textit{associate}: V^a_{su}(A_s) &= g^a(A_s\theta H_u + \delta_s + \delta_u) - t^a\chi d_{su} \\ \textit{bachelor's}: V^b_{su}(A_s) &= g^b(A_s\theta H_u + \delta_s + \delta_u) - t^b\chi d_{su} \end{aligned} \tag{D}$$

The cost of attending college scales down with the time spent in college. As in the previous section, I define the disutility to paying a net price $p_{su}$ per year of study as the solution to the maximization problem analyzed in the previous section. The optimal financing structure solves

$$
\begin{aligned}
-P^{j,k}_{su} := \max_{\{L\}} \;\; & \bar{y}_s \log(c) - \beta R_l L \\
s.t. \;\; & c = L + m_s - p_{su}
\end{aligned}
\tag{F}
$$

where $j \in \{d, a, b\}$ indicates the degree choice and $k \in \{1, 2, 3, 4\}$ stands for the class level—number of years already spent in college. One should note that $P$ depends on the number of years already spent in college, as Stafford loan limits almost double toward the end of a bachelor's degree; it also depends on the total number of years in college, as interest does not accrue on subsidized Stafford loans while the student is still enrolled in college. I indicate these dependencies with superscripts $j, k$. In a frictionless benchmark, however, $c^* = \bar{y}_s$ and $P_{su} = p_{su} + constant$ is independent of loan boundaries.

In sum, the total college cost in the first stage of life is derived as

$$
P^{j}_{su} = \sum_{k=0}^{t^j-1} \beta^k P^{j,k}_{su} + \sum_{k=t^j}^{T-1} \beta^k P^0_s, \;\; \text{for } j \in \{d, a, b\}
\tag{P}
$$

where $k$ indexes time; $t^j$ for $j \in \{d, a, b\}$ is the time length of a specific degree as calibrated above; $T$ is the length of first stage of the life, which I calibrate to $T = 4$; finally

$$
P^0_s = -\bar{y}_s \log(\bar{y}_s)
$$

explains the utility from consumption for an unenrolled individual, presuming that the individual not enrolled in college would earn a labor income as her base income in the second stage of life.

Having specified post-enrollment options, I now can recursively formulate the optimal college and degree choice for the student type $s$:

$$
\max_{u \in \mathcal{U}} \;\; \mathbb{E}_A[ \max_{j \in \{d,a,b\}} \{-P^j_{su} + V^j_{su}(A) + \lambda \mu^j_s \mid A^{(i)}_s \;] + \zeta \epsilon_{su}
\tag{U}
$$

where $\zeta\epsilon_{su}$ is the logit shock that is iid across students and colleges and $\lambda\mu^j_s$ for $j \in \{d, a, b\}$ is an additive logit random shock representing exogenous factors to choose one degree option over the others. $\mu$ is drawn from extreme value type-I distribution that is iid across students and degree choices and $\lambda$ controls the variance. A higher $\lambda$ relative to $\pi_2$ would imply that the degree choice is based on exogenous reasons rather than learning the college-related ability during college (recall the specification of the college-related ability $A = A^{(i)} + A^{(f)}$ with the update part realized in college $A^{(f)} = \pi_2\rho_s$, where $\rho_s$ is plus or minus one with equal probabilities).

**Two-Year Program Colleges.** Students who initially enroll in a two-year college have the option of finishing the program with an associate degree and enter the labor market, drop out earlier, or transfer to a four-year college. The value for dropout and associate degree is similar to what I described above for the four-year programs, and the time spent for each degree is calibrated to $t^d = 1$ and $t^a = 2$ based on the median observation in the data. As the third option: transferring to a four-year college for the last two years to attain a bachelor's degree, I assume the student chooses a four-year college as if she wanted to enroll in a full four-year program from the beginning for a bachelor's degree; the mean added value is scaled down by a factor to be estimated as a fixed parameter.

**Outside Option.** Finally, the value of the outside option—not enrolling in college—for individual $s$ is simply

$$U_{s0} = -\sum_{j=0}^{T-1} \beta^j P_s^0 + \zeta \epsilon_{s0}$$

as I normalize the mean value of a high-school degree with no further college studies to zero.

# 4 Estimation

I use the simulated minimum distance method to estimate the model. I match a set of targeted simulated moments (vector $\mathcal{M}_S$) with their data counterparts (vector $\mathcal{M}_D$) to estimate the parameters of the model (vector $\mathbf{p}$). The algorithm is straightforward. I start with an initial guess for the set of parameters $\mathbf{p}$. Given $\mathbf{p}$, I simulate the college choice and financing structure for a student in the BPS sample. I then use the survey-provided weights for each student in the sample and calculate the vector of simulated moments $\mathcal{M}_S(\mathbf{p})$ by aggregating the simulated observable outcomes. I construct the data moments via the same survey weights. Finally, I use the GMM efficient weight matrix to form the loss function. Using the survey-provided information on clusters and sampling units, I obtain the variance covariance matrix of data moments $\Omega = \mathbb{E}[\mathcal{M}'_D \mathcal{M}_D] - \mathbb{E}[\mathcal{M}'_D]\ \mathbb{E}[\mathcal{M}_D]$. I iterate on the set of parameters $\mathbf{p}$ to minimize the following loss function

$$\mathbf{p}^* = \arg\min_{\{\mathbf{p}\}}\ (\mathcal{M}_S(\mathbf{p}) - \mathcal{M}_D)'\ \ \Omega^{-1}\ (\mathcal{M}_S(\mathbf{p}) - \mathcal{M}_D)$$

I sketch out the minimization algorithm I use to obtain $\mathbf{p}^*$ in the Online Appendix.

In the next subsections I first introduce the set of identifying moments I include to estimate the model parameters. Then, I show the model fit: a selection of targeted and untargeted moments and regression slopes, and their data counterpart, followed by the parameter estimates.

## 4.1 Identification

In this section I introduce the set of targeted moments to identify parameters of the model. I first explain how I identify the fundamental parameters of the demand model: the preference for higher education and price elasticity of demand; and then I discuss the identification of financing friction wedges.

**Taste for Higher Education.** I estimate mean tastes for colleges $\{\delta_u\}_{u\in\mathcal{U}}$ by matching the market shares. Given a set of fundamental parameters $\mathbf{p}$, plus the set $\{\delta_u\}_{u\in\mathcal{U}}$, I can simulate the market share of each college from the first-year first-time students. Given $\mathbf{p}$, I iterate on $\{\delta_u\}_{u\in\mathcal{U}}$ in an inner loop using the fixed-point algorithm suggested in Berry et al. (1995) to match simulation market shares with the data.

I incorporate the set of moments suggested in Berry et al. (2004) to identify parameters governing the heterogeneous taste for higher education studies. I identify $\theta$, which controls the complementary between a student's college-related ability and the college's quality, $\Pi$: the contribution of each observable attribute to a student's college-related ability, and $\Gamma$: the contribution of each observable characteristic to the college quality, through the observed covariation of matched attributes and characteristics. A higher $\theta$ implies a stylized sorting of able students into high-quality colleges, so it creates a positive correlation between a student's observed attributes and the quality of the college she enrolls in. The elements of vectors $\Pi$ and $\Gamma$ are set to match this covariation between each single observable component of the vector of attributes and the vector of characteristics. The dispersion of students' observable attributes around the mean pattern of matched attributes and characteristics explains the extent to which unobservable attributes determine a student's college-related ability. Therefore, it identifies $\pi_1$, i.e., the variance of the unobservable component of the college-related ability.

Figure 1 shows how this procedure works in practice. In the benchmark simulation, with a positive estimate for $\theta$, students with a higher SAT score on average enroll in colleges with higher faculty salaries. Indeed, $\theta$ is set such that a linear fit to simulation results mimics the same fit to data. A counterfactual simulation with $\theta = 0$ would result in a flat fit—inconsistent with data pattern, as low- and high-SAT score students would equally value education quality. To obtain $\Pi$ and $\Gamma$, the estimation toolbox matches similar covariations observed in data as in figure 1 with various signals on college-related ability (high-school GPA, perents' education and income) on the x-axis, and various signals on education quality (cohort quality, admission policy, program length) on the y-axis.

I normalize the value to bachelor's degree $g^b = 4$. Then, I identify the value to dropout and associate degrees $g^d$ and $g^a$ by matching the share of students who drop out or attain an associate degree. Dropout is explained either through an exogenous channel: $\lambda$ as the variance of the logit shock in the dynamic degree choice model; or, it is the endogenous choice of a student driven by an update on her college-related ability. Dropouts should be unrelated to the measured ability of a students, including those realized in college: college GPA, and those that are known pre-enrolling in the college: SAT score and high-school GPA, if the exogenous shock to a degree option $\lambda$ is large. The variance of residuals in a fit of dropout on SAT score is then informative for $\lambda$. I use the college GPA as an "instrument" to identify the magnitude of the variance of the shock to ability realize in the college, $\pi_2$. If experimenting with college, i.e., the idea of going to college to learn the college-related ability is a determinant factor (large $\pi_2$), then the realized signal on ability during college (college GPA) should be informative on whether a student chooses to drop out or finish the degree, after controlling for the ex-ante signals on ability (SAT score). In summary, I identify the set of parameters governing the degree choice $(g_d, g_a, \lambda, \pi_2)$ by including as targeted moments i) the absolute share of students in each degree status; and ii) the covariation of dropout with pre- and post-college-enrollment signals on students' college-related ability.

I identify the disutility for distant colleges $\chi$ simply by matching the average distance between students' permanent address and colleges. In my specification $\chi$ depends on colleges' type and students' background. Hence, I match the mean distance moment for different student types and college categories.

So far, I explained how to identify parameters that govern the choice of college, conditional on enrolling in a college. Lastly, I explain how to identify $\{\delta_s\}_{s\in\mathcal{S}}$, i.e., the mean value for college enrollment relative to the value of the outside option: no college studies. I match the simulated rate of entry into higher education with data counterparts for students of different attributes. To obtain simulated entry rates, I first back out the unconditional enrollment probability, given a set of model parameters, for a student in the BPS sample. Using these enrollment probabilities I obtain the mass of all potential entrants (high-school graduate) on an attribute bin $s$ and calculate the simulated entry rate for each student type $s \in \mathcal{S}$. I match these simulated entry rates with data counterparts by iterating over $\{\delta_s\}_{s\in\mathcal{S}}$ in an inner loop using a fixed point algorithm similar to Berry et al. (1995). The data on college entry from the longitudinal survey of high-school graduates (ELS) is used to estimate the targeted entry likelihood for students of different attributes and backgrounds. This procedure gives us an estimate for the set $\{\delta_s\}_{s\in\mathcal{S}}$.

**Financial Resources.** I observe the financial structure in data. I explicitly observe how much grant is received (public financing) and how much student loan is raised (external financing). Using the data on tuition and fees (investment size) I can back out the out-of-pocket payment (internal financing). For students in the bottom income quartile, the average of internal financing is negative, as students receive grants not just to cover tuition and fees, but also to cover part of the non-tuition living expenses during college—including room and board. The mean and variance of internal financing is matched with data counterparts for students of different income backgrounds to identify the distribution of cash-in-pocket ($m$).

To identify $h$, the dollar value of housing received by living with parents during college, I include the following moment: the fraction of students going to a nearby college, conditional on enrolling in a college. A nearby college is considered to be within a distance of less than $d_0$. As I defined in the model section, $d_0$ is a threshold below which I assume the students can live with family during college.[12] I match this moment for students of different income backgrounds to have a flexible specification for $h$ across students.

**Price Elasticity of Demand.** The price elasticity of demand for colleges is governed by the parameter $\zeta$. A high $\zeta$ would imply that students' choice is based on idiosyncratic shocks to the value of higher education in each college, and differences in tuition and fees is not a relatively important factor to sort various options.

Identifying the price elasticity of demand is challenging as in any demand estimation model. One can just try to identify $\zeta$ by assuming that tuition and fees charged by college $u$ is uncorrelated with unobservable (by econometricians) taste for that college $\xi_u$ and estimate $\zeta^{-1}$ so that the residual that explains the heterogeneous market shares, after taking out the price term $\zeta^{-1}T_u$ and other observable characteristics, is not correlated with $T_u$. However, the critique is that a favorable college (high $\xi_u$) might also charge a higher price; in this scenario, this identification method would underestimate the price elasticity of demand.

I do not use BLP instruments to identify the price elasticity of demand. Rather, I rely on the impact of in-state tuition discounts on the relative likelihood of in- vs. out-of-state students enrolled in a college. The idea is illustrated in figure 2. The unobservable taste component $\xi_u$ is defined at the college level and experienced by all the students enrolling in that college. However, there is a variation of price at the college level for different students. Community and public colleges have on average a 50% tuition discount for in-state students. In the case of private and non-profit colleges, there is no tuition discount; but in-state students would still benefit from state grants.

Based on this idea, I target the following moment in the estimation: the covariation between enrollment likelihood of in-state students and in-state tuition discount plus state grants. One should note that the population of in-state students in a college is more that out-of-state students, naturally due to proximity and easier transportation, and not necessarily because of in-state tuition discount. This is why I target a moment that is based on a diff-in-diff notion: the variation in enrollment of in-state *relative* to out-of-state students with respect to the variation in the tuition discount across colleges. Intuitively, if students are more price sensitive, a dollar more of in-state tuition discount is associated with a higher enrollment likelihood of in- versus out-of-state students. I calculate this moment for different subcategories of college types and for students of different income percentiles to identify how

[12] I calibrate $d_0$ to 30 miles, based on the median observation reported in the data on whether a student is living with her parents or not and the distance to college from parents' home.

price elasticity varies across different demographics. The identifying assumption I need is[13]

**Assumption 1.** *There is no unobservable taste for a college put, exclusively, by in-state students.*

To show how this identification strategy works in practice, I run the following reduced form regression on the data and benchmark simulation outcome.

$$\log\left(\frac{\#\,\textit{out-of-state enrollees}}{\#\,\textit{in-state enrollees}}\right)_u = \delta_{state(u)} + (controls)_u + proximity(\textit{out- vs. in-state Pop.})_u$$
$$+\ \alpha_0(\Delta + g^{state})_u\ +\ \alpha_1(\Delta + g^{state})_u\ \mathbf{1}\{\textit{low-income}\}_u$$

The unit of observation is a college. The left-hand side variable is the log odds ratio of the out- versus in-state enrollees, and the key right-hand-side variable is the in-state tuition discount plus average state grant $\Delta_u + g_u^{state}$. To see how the coefficient of interest varies with income level, I interact the variable of interest with an indicator that shows whether the average income of the county of the main campus of the college is below the median income of all counties in the US.

One could argue that colleges that are far from state borders do not need to consider tuition discounts to attract in-state students. And being far from state borders would naturally reduce the number of out-of-state students due to geographic barriers. This is why I control on proximity to populated-with-young in-state versus out-of state towns and cities. One may also argue that there are unobservable factors that make a specific state desirable to live in and those factors affect the decision of state legislators in setting tuition discount. This is why I include state fixed effects to see how *within* state variations of in-state tuition discount across colleges affect the odds ratio of out- vs. in-state enrollees. Finally, I include a set of controls at the college level. This set includes observed characteristics that I use as proxies for education quality, total number of enrollees, and indicators on whether a college offers distance learning and weekend classes.

Regression results are presented in table 8. The point estimate indicates that $1,000 in 2019 dollars increase in the in-state tuition discount and state grants (roughly 15% of the average tuition discount across colleges), decreases the ratio of out-of-state to all (both in- and out-of-state) students in a college from the average 25% by about 1 percentage point. Results are overall robust to various specifications. Plus, the regression coefficient for simulated outcomes are similar to data counterparts.

**Financing Friction Wedges.** I focus on the bunching of students on the federal Stafford loan limits to identify financing friction wedges. The idea is illustrated in figure 3. This figure

[13] In precise terms, I need a milder assumption. For the identification method to work, there could be an unobservable taste for a college, exclusively put by in-state students; but this term may not be correlated with in-state tuition discounts.

compares the optimal loan policy for students with heterogeneous ability and cash-in-pocket in a frictionless world and in the case with external-financing frictions.

In a frictionless world, students with low cash-in-pocket ($m$) and/or high ability ($A$) would demand a larger amount of loan (denoted by $L^*$). The former group would not like to cut on their early consumption, and the latter group would lever-up to increase the investment size—pay more for tuition at a high-quality college. As there is no friction wedge there would be a zero mass of students on the Stafford loan limit (denoted by $\bar{L}$ in the graphs). The following assumption is needed for this claim.[14]

**Assumption 2.** *The distribution of students on the ability-cash space does not have a mass point.*

Introducing a friction wedge for taking private loans (positive $\eta_p$), would create an inaction region at the federal Stafford loan limit. The optimal choice of loan is denoted by $L^c$ in this case. Students with optimal frictionless loan demand $L^* < \bar{L}$ would continue taking the same amount of loan $L^c = L^*$, and take no private loans, as the distortion cost does not affect their first-best choice. However, students who demand a small amount of private loan in a frictionless world would reduce the total loan demand all the way down to the Stafford limit—would not take a private loan. A positive mass of students are then pooled to have a loan exactly equal to the Stafford limit $L^c = \bar{L}$. Students who are far above the margin might enter into the region of private loan, but they demand less compared to the frictionless case.

The positive mass of individuals taking a loan exactly equal to the federal Stafford loan limits—the thickness of red region in figure 3—will identify the interest margin on a loan on top of the specified limits. More precisely, I include the fraction of students with a *total* loan equal to the federal Stafford program subsidized loan limit $L^{sub}$ as the identifying moment for the friction wedge of taking federal unsubsidized loans ($\eta_u$). The fraction of students with a loan equal to the Stafford program limit for total (subsidized plus unsubsidized) loans $L^{tot}$ identifies the perceived cost of taking out a private loan on top of federal loans ($\eta_p$). In order to see how $\eta_u$ and $\eta_p$ varies with income status and ability, I sort students into categories based on parents' income and students' SAT scores and calculate the mass on the Stafford loan boundaries for each subcategory.

To apply this identification strategy, there should exist a positive mass of individuals taking a loan above the loan boundaries. Otherwise, any large enough $\eta_u, \eta_p$, including infinite cost, would replicate the observed pattern. There should be also a positive mass of individuals with observed loan below the limits, to identify financing costs from negative infinity. This is the standard assumption needed in any empirical research with bunching identification. These conditions hold in the data on student loans.

[14]What is actually needed for this identification strategy is a milder assumption: there should not exist a mass of students on the state-space for whom the optimal level of loan in a frictionless world is equal to or marginally above the Stafford loan limits $2,625 and $6,625 (in 2003 dollars).

Unfortunately, we cannot identify the mass of individuals without a loan, but financially constraint at the boundary of zero loan in the data. So a moment based on the same intuition as described above cannot be used to identify the fixed cost associated with taking any positive loan ($f_0$). Nevertheless, a positive fixed cost $f_0$ would decrease the fraction of people who would demand a loan. It actually forces individuals with a positive, but tiny amount of loan in a rather first-best world, to not take a loan. Plus, conditional on taking a loan, the average amount of loan goes up. This intuition guides me to include the fraction of students with a positive loan and the conditional average of loan among those who take a loan to identify the fixed cost parameter $f_0$.

Figure 4 shows how this identification strategy works in practice. This figure illustrates a one-to-one mapping between targeted moments and friction wedge parameters. I plot the cumulative distribution function (CDF) of total student loans in the data, benchmark estimation, and counterfactual simulations, in which financing friction wedges are set to zero. The benchmark estimation perfectly mimics the observed bunching of students (jumps in the CDF of total loans) at the federal Stafford loan limits. A counterfactual simulation with no friction wedge on federal Stafford loans ($\eta_u = 0$) is, however, associated with a larger fraction of student with a positive loan, and those with smaller amounts of loan would increase their demand for loan up to the federal Stafford program limit.[15] Although the CDF curve in the region of private loans—the right tail of the distribution is unaffected and is almost similar to the benchmark simulation. On the other hand, a counterfactual simulation with no friction wedge on private loans ($\eta_p = 0$) is associated with no bunching on the federal unsubsidized Stafford loan limit and, inconsistent with the data, the distribution of loans would have a much heavier right tail.

**Summary.** Table 9 lists all targeted moments included to identify corresponding real and financial parameters.

## 4.2 Model Fit

**Targeted Moments.** Table 10 reports a selected set of targeted simulated moments and data counterparts. Simulated moments fairly mimic the data pattern of college enrollment, payment for tuition and fees and bachelor's degree/dropout likelihood conditional on enrollment, proximity to college, and faculty salaries at the college that a student enrolls in, across students of different income backgrounds. As in the data, low-income students, relatively, are less likely to enroll in a college, pay less for tuition, and drop out more frequently conditional on enrollment, and mostly attend a nearby college. Faculty salaries in colleges that lower-income students attend are lower than the average level.

[15]Note that depending on PLUS loan eligibility for parents the maximum program limits on Stafford loans is either \$3,600 or \$9,085 in 2019 dollars. See details in footnote 8.

Simulation outcomes also match the pattern of financing structure observed in the data. A larger fraction of lower-income students place a positive demand for student loan, but the average amount of loan, conditional on receiving a loan, is similar for students of different backgrounds. Positive financing friction wedges in the estimated model generate bunching on the federal Stafford loan limits. As in the data, in the simulated financial structures, roughly a quarter of students take a total loan just equal to the Stafford loan program limits, and many do not take any private loan.

**Untargeted Moments.** The last tab of table 6 shows the results of the simulated regressions of college enrollment, bachelor degree attainment, and payment for tuition and fees versus family background. Simulated regression slopes are almost within the 95% confidence interval of data estimates. The last tab of table 7 reports the simulated regression coefficients in the model of tuition vs. family background for financially constrained students. As in the data estimates, students with a total student loan equal to federal Stafford loan limits pay less, relatively, for tuition and fees.

Table 3, panel B, shows simulation results for the college types that students of different backgrounds enroll in. Simulation results capture the key pattern in the data: relative to students of high-income families, low-income students are more likely to enroll in a community (public two-year) or a for-profit college, rather than a public four-year or a nonprofit private college. Per estimation results, high-income students represent a higher college-related ability ($A$) on average; also, public four-year and private colleges feature a higher education quality ($H$), relative to community colleges; the complementary term in the specification of utility for college education ($\theta AH$) with an appropriate estimate of the parameter $\theta$ then generates an enrollment pattern in the simulation model similar to the data.

## 4.3 Parameter Estimates

**Students' College-Related Ability.** Table 11 reports the variation of the estimated college-related ability $A_s$ across students of different backgrounds. See specification (A). $A_s$ includes terms that are known by students pre-enrolling in a college, named college orientation and preparedness: $\bar{A} + \Pi' D_s + \pi_1 \nu_s$, from which $D_s$ is a vector of observable attributes and $\nu_s$ is an unobservable normal iid, plus a term that is realized during the college for the student: $\pi_2 \rho_s$, where $\rho_s$ is iid and equals to plus or minus one with equal probabilities. $\Pi$ is a vector parameter, and $\pi_1$ and $\pi_2$ are scalar parameters. Panel A reports the contribution of each term to the variance of $A_s$ across population. About half of the variation of $A_s$ in the population is driven by the observable college preparedness $\Pi' D_s$; this is because of a sizable estimate of the vector parameter $\Pi$ and the variation in the vector of observable attributes $D_s$ across the population. Panel B shows that the gap in the mean observable college preparedness between students of the top and the bottom income quartile is about one in unit of the standard deviation in the whole population. This gap exists because of a positive estimate of $\Pi$ and the fact that components of $D_s$, namely SAT score, high-school GPA, and parents' college experience, positively correlate with income background (see table 1). Meanwhile, there exists significant variation in $\Pi' D_s$ within income groups. Panel C shows that a student's SAT score is the most marginally informative component of the vector of attributes $D_s$ to explaining the variations in the college preparedness $\Pi' D_s$.

**Colleges' Education Quality.** Table 12 reports the variation of the estimated observable education quality $H_u = \Gamma' X_u$ across community, for-profit, public four-year, and private nonprofit colleges. Panel A shows that the gap in education quality between community and public colleges or private nonprofit colleges is significant—about two in unit of the standard deviation across all colleges; while there is minor variation in education quality within community colleges. This gap exists due to a sizable estimate of the vector parameter $\Gamma$ and the variation in observable characteristics $X_u$ across colleges (see table 4). Panel B shows the marginal informativeness of each component of the vector of observable characteristics $X_u$ for the variations in $H_u$. The cohort quality—namely, the graduation rate and the percentile 75th of the SAT of enrollees in a college in recent years—is the most informative signal.

**College Choice.** The parameter estimate $\theta$ is positive and statistically significant with a t-stat 15.3 for the average college. To illustrate the economic significance of a positive estimate $\theta$, table 3, Panel C reports the enrollment pattern in a counterfactual experiment with $\theta = 0$. In a world with $\theta = 0$ students of lower-income backgrounds are relatively less likely to enroll in community or for-profit colleges and more likely to enroll in public four-year or nonprofit colleges. The term $\theta AH$ in the specification of the taste for college education with a positive estimate for $\theta$, together with an estimate of $A$ that positively correlates with income and an estimate of $H$ that is larger on average for public four-year and private nonprofit colleges generates the stylized sorting of students to colleges, as it is observed in the data.

**Degree Choice.** The dropout choice is determined by three elements. First, learning the college-related ability, which is controlled by the variance of the shock to ability realized in college $\rho$; see specification (A). Second, exogenous factors controlled by the variance to the logit shock to a degree choice $\lambda$; see specification (D). Third, intrinsic value to a choice of dropout, say the value to get some college experience, controlled by the scaling parameter $g^d$; see specification (D). Table 13 presents the estimated contribution of each factor to the degree choice and also to the decision to enroll in college.

In the absence of shock to ability ($\rho = 0$) the dropout ratio for students of the bottom income quartile marginally falls by half a percentage point relative to the benchmark estimation. The joint impact of no shock to ability and no exogenous shock to a degree outcome ($\rho = 0, \lambda = 0$) would have a strong effect; dropout likelihoods considerably fall to nearly zero. However, college enrollment falls as well. See Panel B. Students in the bottom income quartile, specifically, enroll in college by 10 percentage points less likelihood in the absence of any shock realization during college ($\rho = 0, \lambda = 0$). The chance to draw a positive shock post enrolling in a college creates an option value and encourages low-income students to try college, where the outcome is not necessarily attaining a college degree. See Panels C and D. While dropouts, conditional on enrolling in a college, rises in the presence of shocks, college enrollment rises as well; hence, in the end, the unconditional likelihood to attain an associate or a bachelor's degree across high-school graduates only marginally changes w.r.t. shocks realized post enrolling in college. In any case, almost the same gap in degree attainment between low- and high-income students would exist, as in the benchmark estimation. The intrinsic value to a dropout outcome ($g^d > 0$) also significantly impacts dropout ratio for all students. In a counterfactual exercise with $g^d = 0$ the dropout ratio falls by 14 percentage points overall. College enrollment falls as well (by 4 percentage points) whereas students are more likely to get an associate or a bachelor's degree. Nevertheless, more degree attainment and less dropouts are not beneficial for students here, as students are losing an intrinsic value assigned to a choice option—to drop out, viewed positively as some college experiences.

**Financing Friction Wedges.** Tables 14 and 15 report the perceived cost of taking student loans, determined by $f_0$, $\eta_u$ and $\eta_p$ (see specification L). Estimation standard errors are relatively small, confirming that model parameters are locally identified. Table 14 shows average return rate on loans for students of different backgrounds. High-income students pay higher rates, because, due to the institutional formula they are less likely to be qualified for a subsidized Stafford loan, and should take a larger portion of their loans through the unsubsidized federal Stafford program or private loans market. Table 15 shows the perceived rates on one additional dollar of federal and private loans. As calibrated by policy formula, for the academic year 2003-04 the rate on subsidized loans is about 1.9% per annum. Unsubsidized and private loans are perceived to have interest rates of around 4.3% and 10.0%, respectively. The perceived net return rate estimates are significantly above the calibrated benchmark rate ($R_0 - 1 = 1/\beta - 1 = 3.53\%$), which highlights a sizable financing friction wedge for the median student. The variation of return rates with students' income background and measured ability (SAT score) is, however, not large in magnitude; see the second and third columns. One should note that these rates are not what is offered by a bank to a low- or high-income student. A high-income or high-ability student may receive offers with lower rates from a bank, but she is less likely to default on the loan as well; hence, the student anticipates to repay the same amount on expectation. What matters in determining the cost of a loan and implying a positive wedge perceived by both low- and high-income students is, e.g., uninsurable risks or nonpecuniary costs (not priced by banks) for students associated with defaulting on a loan.

# 5 Counterfactual Analysis

## 5.1 Student Loans and Social Mobility

What if there are no external financing frictions? Through the lens of the model, this relates to a counterfactual analysis with all financing friction wedges, $f_0$, $\eta_u$ and $\eta_p$ being set to zero. Table 16, third column, shows results of this counterfactual analysis for lower-income students (whose parents' income is below median). The benchmark estimation results for both lower- and higher-income students (whose parents' income is below and above median) is reported in the first and fourth columns as points of comparison.

Financing constraints have substantial impact on financing structure of college costs. Interestingly, students would have taken much more debt in a frictionless scenario. The average student loans increases by nearly 150%—about \$3,600 per cohort per year. The change is mostly through the intensive margin: those who already have taken a loan would substantially increase their demand for a loan.

Financing constraints have real distortionary effects as well. By eliminating financing friction wedges, low-income students would pay around \$610 more for tuition. This increase is roughly a fifth of the estimated gap in tuition between low- and high-income students. Geographic mobility is boosted as well; being able to finance living costs, low-income students are more likely to enroll in a non-nearby college—more than 30 miles away from parents' home. The impact on college enrollment and dropout is, however, marginal. Financing constraints in general is binding for cash-poor *and* able individuals—for whom no-college-study is not a relevant option. Besides, enrolling in any possible college is not an expensive investment, as the least pricey colleges charge only a few hundred dollars for tuition. Therefore, financing constraints mostly impact investment in college education through intensive margins: those who go to college would switch to more expensive colleges. In the end, although frictionless access to student loans would boost investment in college education by low-income students, the impact is not sizable relative to the original gap between rich and poor students. Differences in educational attainment is mostly driven by fundamental factors—heterogeneity in college preparedness and value-added of college education.

A policy that could possibly mimic the frictionless scenario is expanding federal Stafford loan limits. Enacted by the Higher Education Reconciliation Act of 2005 and the Ensuring Continued Access to Student Loans Act of 2008, subsidized and unsubsidized loan limits are lifted by about 50%.[16] Although these incidences represent a large shift in the history of higher education policy in the US, I show they could not mitigate the financial and real

[16] For dependent first-year students whose parents are eligible for a PLUS loan (group I) the limit on subsidized and unsubsidized loans is \$2,625 in 2003-04; for dependent first-year students whose parents are not eligible for a PLUS loan (group II) the limit on subsidized and unsubsidized loans is \$2,625 and \$6,625, respectively. In 2008-09 the limit on subsidized and unsubsidized loans is lifted to \$3,500 and \$5,500 for group I, and to \$3,500 and \$9,500 for group II. Note that limits here are reported in current dollars.

distortions caused by financing frictions. I simulate students' response to the exact change in Stafford loan limits. I keep all other institutional parameters, as well as students' attributes, and colleges' characteristics and sticker prices unchanged. Table 16, second column, shows counterfactual results for lower-income students. Counterfactual analysis predicts that students would take $690 (30%) more debt—still much less than the level in the frictionless benchmark, and a significant mass of students would be constrained by new loan limits—a phenomenon confirmed by post 2008-09 student-level data. The real impact is relatively small: payments for tuition go up by $120. Per estimation results, students perceive a high cost of taking unsubsidized and private loans. Lifting the loan limits does not solve such a "debt-aversion" problem. The policy resonates more among higher-ability students. For low-income students with an SAT score above the median, the policy results in $170 more payment for tuition. Nevertheless, the predicted outcome is far below the frictionless case.

## 5.2 Tuition-free Public Colleges

In this section I evaluate extensive grant policies that aim to reduces student debt. Table 17 shows the impact of making public colleges tuition-free on students of different income backgrounds. In this counterfactual experiment, the tuition charged by public college is paid for by the government. I leave all institutional and fundamental parameters, as well as students' attributes and colleges' characteristics and tuition unchanged.

The policy increases college enrollment overall by only 2.4 percentage points. The key point is that the least pricey option in the status-quo is only a few hundred dollars, provided by many community colleges. Therefore, making public colleges tuition free does not systematically change the choice set of students on the margin of college enrollment/no college studies. Meanwhile, lower-income students would drop out at higher rates. The policy induces experimenting with college for marginal students. Moreover, tuition of colleges that students attend only marginally changes. There are two competing forces; on one hand, students would switch to more expensive public colleges, since they don't bear the cost. On the other hand, the policy induces a substantial shift from private colleges to now-free public colleges (compare the third row in Panels A and B), and public colleges in general charge less for tuition than private colleges. The search for a now-free public college increases geographic mobility; students are less likely to enroll in a nearby college. Meanwhile, the policy significantly reduces student debt, especially among higher-income students. This is simply because grants substitutes for loans in the financing structure of college costs.

Interestingly, the main recipients of the government subsidy on tuition of public college are higher-income students. Students in the top income quartile receive a tuition subsidy of around $21B, while those in the bottom quartile receive less than $6B. The reason is that students from higher-income backgrounds, relatively, are more likely to enroll in college, stay more in college (drop out less frequently), and enroll in high-quality and expensive colleges. Although making public colleges tuition-free alleviates financing constraints for low-income students, the heterogeneity in college-related ability and preferences for higher-quality colleges (fundamental factors) would maintain the unequal pattern of investment in college education across rich and poor students. Hence, higher-income students would be the main recipients of the subsidy—making public colleges tuition-free fails to achieve equity.

Moreover, making public colleges tuition-free would entail a substantial deadweight loss. While the government needs to pay $57B in total per cohort for the program, students' well-being in dollar unit increases by $40B. Making public colleges tuition-free distorts relative prices (tuition of public vs. private colleges) in the market for higher education and, therefore, results in a socially inefficient allocation of students to colleges. Students switch from a private to a relatively distant public college to save on tuition cost, even though a private college is a better fit, simply due to proximity. In the end, however, the government, instead of switching students, needs to incur the cost of tuition at the public college. Therefore, in sum, social gain is negative, and per estimation results, it is quantitatively substantial. One should note that the policy considerably reduces student debt, and by doing so alleviates external-financing friction costs incurred by students. However, the efficiency loss due to misallocation of students into colleges is dominant and the policy overall entails around $17B social deadweight loss per year.

As an alternative policy to promoting educational mobility, I analyze the impact of expanding Pell grants—a federal need-based grant provided to students of low-income backgrounds. The maximum Pell grant amount is about $5,500 (in 2019 dollars) in the academic year 2003-04; it falls to zero if a student's "Expected Family Contribution" rises;[17] or the total cost of attendance—tuition plus living cost during college—falls. The second criteria does not bind in 2003-04; hence, conditional on enrolling in any college, the grant takes the form of a lump-sum subsidy to lower-income students and, in contrast to making public colleges tuition-free, does not distort relative prices for students. I run the counterfactual analysis of increasing the Pell grant maximum amount by 140% to around $13,500 per year, leaving the grant eligibility, as well as other institutional and fundamental parameters, students' attributes, and colleges' characteristics and tuition unchanged. This grant expansion would imply the same increase in surplus for low-income students (the bottom income quartile) as making public colleges tuition-free.

Table 18 reports students' response to the policy. The policy boosts college enrollment by around 3.5 percentage points among low-income students and, as in making public colleges tuition-free, substantially reduces student debt. Importantly, the policy generates less deadweight loss in comparison to making public colleges tuition-free. Therefore, for the same benefit to students the government needs to pay less. Moreover, by construction, expanding Pell grants only benefits low-income students and, in contrast to making public colleges

[17] Expected Family Contribution is a term calculated from family tax return and data provided in the Free Application for Federal Student Aid (FAFSA) form and is mainly driven from family income and wealth.

tuition-free, the government does not need to subsidize higher education studies of rich students. In total, the program would cost about \$9B. I conclude that expanding Pell grants is much more efficient to support college education for those in need. The same benefit to low-income students as making public college tuition-free could be achieved at only one sixth of the cost for the federal government.

# 6 Conclusion

In this paper I structurally estimate a dynamic model of investment in college education to quantify the role of financing frictions in explaining the unequal investment between rich and poor students. Estimation results show that financing frictions are indeed a barrier to college education. However, fundamental factors—college preparedness and heterogeneous preferences for college education—are the main explanation for the differences in educational attainment. With frictionless access to student loans, payments for tuition of a student from a below-median-income family increases by around \$600—only one fifth of the estimated gap in tuition between students of below- and above-median-income families. Moreover, expanding federal loans could not undo the financial and real distortions caused by financing frictions. Lifting federal Stafford subsidized and unsubsidized loan limits to the extent exercised in 2006-07 and 2008-09 cannot achieve the optimal financial structure of a frictionless benchmark and has only a marginal real impact. I find that making public colleges tuition-free would mainly benefit high-income students; students from the top income quartile receive more than three times in subsidy (almost \$15B more) received by students from the bottom income quartile. Moreover, the increase in the students' surplus overall is around \$17B less than what government pays for the subsidy per year. On the other hand, I show that expanding federal Pell grants is a much more cost-effective policy to provide access to college for lower-income students. The same benefit to students in the bottom income quartile as in the tuition-free public colleges scenario could be achieved with only one sixth of the cost for the federal government.

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# A Tables and Figures

Table 1: Students' attributes by income background.

| Income background: | 1st Quartile | 2nd Quartile | 3rd Quartile | 4th Quartile |
|---|---|---|---|---|
| parents have college studies, fraction (%) | 42.6<br>(1.9) | 56.4<br>(1.6) | 68.1<br>(1.4) | 86.3<br>(0.8) |
| high-school GPA$\geq$ 3, fraction (%) | 61.8<br>(2.2) | 69.1<br>(1.7) | 76.7<br>(1.3) | 80.5<br>(1.1) |
| took SAT, fraction (%) | 84.2<br>(1.7) | 86.5<br>(1.5) | 93.5<br>(0.8) | 96.6<br>(0.7) |
| SAT score, mean | 903<br>(8) | 996<br>(7) | 1040<br>(6) | 1102<br>(5) |
| SAT score, std | 193<br>(5) | 195<br>(4) | 180<br>(4) | 188<br>(3) |
| sibling in college, fraction (%) | 47.1<br>(2.0) | 49.7<br>(1.8) | 50.1<br>(1.3) | 56.4<br>(1.1) |

*Notes.* This table reports summary statistics for attributes of US students, first time enrolled full time in college in 2003-04 below the age of 21 as dependent individuals, by parents' income rank in 2002. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, \$34,000, \$67,400, and \$116,500 in 2019 dollars, respectively, is used to categorize students. Mean and std of SAT is reported for those who took the test (91% of the sample). The average (standard deviation) for all income quartiles is 1032 (199). The range of SAT score is from 500 to 1600. Numbers in parentheses show standard errors. *Source: BPS:04/09.*

Table 2: Investment in college education by income background.

| Income background: | 1st Quartile | 2nd Quartile | 3rd Quartile | 4th Quartile |
|---|---|---|---|---|
| Enroll in college (%) | 38.4 (1.6) | 54.3 (1.4) | 68.9 (1.2) | 79.1 (1.0) |
| - Dropout (%) | 27.6 (1.9) | 23.6 (1.5) | 14.7 (1.0) | 11.3 (0.8) |
| - Associate degree (%) | 20.6 (1.7) | 14.4 (1.2) | 15.5 (1.3) | 8.1 (0.7) |
| - Bachelor's degree (%) | 51.8 (2.0) | 62.0 (1.7) | 69.8 (1.5) | 80.6 (1.1) |
| Tuition ($) | 8770 (320) | 10150 (350) | 10020 (280) | 14320 (310) |

*Notes.* Degree attainment and average tuition is reported for US college students, first time enrolled full time in college in 2003-04 below the age of 21 as dependent individuals, by parents' income rank in 2002. Enrollment likelihood is estimated for high school graduates in 2003 based on college enrollment data throughout 2007 by family income rank in 2001. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, $34,000, $67,400, and $116,500 in 2019 dollars, respectively, is used to categorize students. Degree attainment percentages and average tuition are all reported for students, conditional on enrollment. Average tuition is reported in 2019 dollars. Numbers in parentheses show data standard errors. *Source: ELS:2002 and BPS:04/09.*

Table 3: College choice by income background.

| Income background | College type | | | | Total |
|---|---|---|---|---|---|
| | community | for-profit | public 4yr | private nonprofit | |
| **Panel A: Data** | | | | | |
| 1st Quartile | 37.8% | 8.2% | 34.9% | 19.1% | 100% |
| | (1.9) | (2.2) | (1.6) | (1.3) | |
| 2nd Quartile | 30.2% | 5.3% | 41.0% | 23.4% | 100% |
| | (1.6) | (1.2) | (1.6) | (1.2) | |
| 3rd Quartile | 27.5% | 2.7% | 48.5% | 21.3% | 100% |
| | (1.6) | (0.9) | (1.4) | (1.0) | |
| 4th Quartile | 15.8% | 0.6% | 51.4% | 32.2% | 100% |
| | (1.2) | (0.2) | (1.1) | (0.9) | |
| **Panel B: Simulation (benchmark estimation)** | | | | | |
| 1st Quartile | 37.7% | 3.4% | 38.1% | 20.7% | 100% |
| 2nd Quartile | 29.9% | 3.3% | 42.2% | 24.6% | 100% |
| 3rd Quartile | 23.4% | 2.1% | 49.8% | 24.7% | 100% |
| 4th Quartile | 17.7% | 2.0% | 51.4% | 28.9% | 100% |
| **Panel C: Simulation (counterfactual: $\theta = 0$)** | | | | | |
| 1st Quartile | 31.4% | 2.6% | 46.7% | 19.4% | 100% |
| 2nd Quartile | 27.1% | 2.2% | 45.9% | 24.9% | 100% |
| 3rd Quartile | 24.1% | 2.2% | 47.6% | 26.0% | 100% |
| 4th Quartile | 21.9% | 3.1% | 46.7% | 28.3% | 100% |

*Notes.* This table shows the type of the first college a student attended: public- two-year (community), private for-profit, public four-year, or private non-for-profit, by parents' income rank. Panel A reports the data for US students, first time enrolled full time in college in 2003-04 below the age of 21 as dependent individuals by income rank in 2002. Panel B shows the simulation results of the estimated model. Panel C shows the simulation results of the estimated model, except that the parameter $\theta$ is set to zero. I reset fixed effect terms $\{\delta_s\}_{s\in\mathcal{S}}$ and $\{\delta_u\}_{u\in\mathcal{U}}$, so that given $\theta = 0$, the enrollment shares and entry rates, *unconditionally*, for colleges and students is as in the data. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, \$34,000, \$67,400, and \$116,500 in 2019 dollars, respectively, is used to categorize students. Numbers in parentheses show standard errors. *Data source: BPS:04/09.*

Table 4: Colleges' characteristics by college type.

| | community | for-profit | public 4yr | private nonprofit |
|---|---|---|---|---|
| Tuition and fees ($) | 7360 | 17920 | 16950 | 25300 |
| In-state tuition discount ($) | 4390 | — | 10600 | — |
| Institution grants ($) | 180 | 290 | 1310 | 8630 |
| Faculty salaries ($) | 2680 | 1770 | 4920 | 5850 |
| Graduation rate (%) | 27.5 | 49.1 | 57.2 | 63.0 |
| 4-year degree, fraction | 0 | 0.54 | 1 | 0.98 |
| Open admission, fraction | 0.94 | 0.41 | 0.07 | 0.06 |
| Admission rate (%) | 99.1 | 82.2 | 72.4 | 67.3 |
| Number of colleges | 936 | 335 | 571 | 1071 |
| Enrollment, share of all (%) | 29.1 | 4.4 | 43.6 | 22.9 |
| Enrollment (#1,000) | 575 | 87 | 864 | 454 |

*Notes.* This table shows averages, weighted by number of enrollees, of colleges' characteristics in the academic year 2003-04, by college type: public two-year (community), private for-profit, public four-year, and private non-for-profit. Institution grants is school grants per enrollees, not per grant recipient. Faculty salary reports total salary to faculties normalized with number of enrollees. Enrollment (last row) reports total number of first-time first-year full-time degree-seeking undergraduate US students. I scale enrollment numbers at the type by degree level using data from BPS:04/09 to approximate for dependent enrollees aged 21 or younger. Tuition and fees, in-state tuition discount, institution grants, and faculty salary are reported in 2019 dollars. *Data source: IPEDS:2003-04.*

Table 5: Distribution of student loans by income background.

| Income background | % ($loan > 0$) | percentiles of student loans ($) | | | | |
|---|---|---|---|---|---|---|
| | | 10th% | 25th% | 50th% | 75th% | 90th% |
| 1st Quartile | 40.4 | 2,055 | 3,600 | 3,600 | 7,715 | 9,485 |
| | (2.1) | (245) | (0) | (0) | (735) | (785) |
| 2nd Quartile | 48.5 | 2,400 | 3,600 | 3,600 | 4,970 | 9,085 |
| | (1.6) | (275) | (0) | (0) | (685) | (515) |
| 3rd Quartile | 43.7 | 2,895 | 3,600 | 3,600 | 4,645 | 9,085 |
| | (1.4) | (280) | (0) | (0) | (515) | (310) |
| 4th Quartile | 34.4 | 3,600 | 3,600 | 3,600 | 3,600 | 9,085 |
| | (1.0) | (70) | (0) | (0) | (185) | (370) |
| All | 41.2 | 2,770 | 3,600 | 3,600 | 4,800 | 9,085 |
| | (0.7) | (155) | (0) | (0) | (270) | (230) |

*Notes.* This table reports fraction of students with a positive loan and percentiles (excluding zeros) of the total loan: sum of federal, state, institutional, and private student loans, in the academic year 2003-04 for US students, first time enrolled full time in college in 2003-04 below the age of 21 as dependent individuals, by parents' income rank in 2002. Loan amounts are reported in 2019 dollars. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, $34,000, $67,400, and $116,500 in 2019 dollars, respectively, is used to categorize students. Numbers in parentheses show standard errors. *Source: BPS:04/09.*

Table 6: Investment in college education vs. family background and college-related ability.

| Panel A: College enrollment | | | | | |
|---|---|---|---|---|---|
| log (enrollment odds) | Data | | | | Simulation |
| | (1) | (2) | (3) | (4) | |
| log (family income) | 0.641*** (0.033) | 0.498*** (0.033) | 0.246*** (0.034) | 0.297*** (0.050) | 0.239 |
| parents' education | | ✓ | ✓ | ✓ | ✓ |
| SAT score, high-school GPA | | | ✓ | ✓ | ✓ |
| Pell grant eligibility | | | | ✓ | ✓ |
| Observations | 12,085 | 12,085 | 12,085 | 12,085 | |

| Panel B: Degree attainment | | | | | |
|---|---|---|---|---|---|
| log (bachelor's degree odds) | Data | | | | Simulation |
| | (1) | (2) | (3) | (4) | |
| log (family income) | 0.586*** (0.041) | 0.490*** (0.044) | 0.231*** (0.048) | 0.405*** (0.055) | 0.321 |
| parents' education | | ✓ | ✓ | ✓ | ✓ |
| SAT score, high-school GPA | | | ✓ | ✓ | ✓ |
| total grants | | | | ✓ | ✓ |
| Observations | 8,705 | 8,705 | 8,705 | 8,705 | |

| Panel C: Tuition and fees | | | | | |
|---|---|---|---|---|---|
| log (tuition) | Data | | | | Simulation |
| | (1) | (2) | (3) | (4) | |
| log (family income) | 0.233*** (0.024) | 0.194*** (0.026) | 0.057*** (0.022) | 0.239*** (0.021) | 0.242 |
| parents' education | | ✓ | ✓ | ✓ | ✓ |
| SAT score, high-school GPA | | | ✓ | ✓ | ✓ |
| total grants | | | | ✓ | ✓ |
| Observations | 8,705 | 8,705 | 8,705 | 8,705 | |

*Notes.* Panel A, Data tabs show the logistic regression of college enrollment throughout 2007 for high school graduates in 2003 on family income in 2001; survey population is 2.8 million. Based on federal need-based Pell grant data for college enrollees, the variable 'Pell grant eligibility' is constructed by assuming that only students with a family income below $36,100 (in 2019 dollars) are eligible for the grant. Panels B and C, Data tabs, report the logistic regression of attaining a bachelor's degree throughout 2009, and the OLS regression of tuition and fees paid in 2003-04, for first-time and first-year dependent college enrollees below the age of 21, versus parents' income in 2002; survey population is 1.7 million. Simulation tabs report the median of the slope of the same regression models on 300 simulations of the estimated model. Numbers in parentheses show standard errors. *Data source: ELS:2002 & BPS:04/09.* $^{*}p < 0.1$ $^{**}p < 0.05$ $^{***}p < 0.01$

Table 7: Tuition and fees vs. family background for financially constrained students.

| log (Tuition and fees) | Data | | | Simulation |
|---|---|---|---|---|
| | (1) | (2) | (3) | |
| log (parents' income) | 0.253*** | 0.254*** | 0.262*** | 0.291 |
| | (0.026) | (0.026) | (0.023) | |
| **1** {sibling in college} | | -0.059** | -0.033 | 0.018 |
| | | (0.027) | (0.023) | |
| **1** {total loan = Stafford limits} | | | -0.078** | -0.141 |
| | | | (0.033) | |
| log (total grants) | ✓ | ✓ | ✓ | ✓ |
| log (federal loans) | | | ✓ | ✓ |
| SAT score, high-school GPA | ✓ | ✓ | ✓ | ✓ |
| age, gender, race | ✓ | ✓ | ✓ | ✓ |
| parents' education, family size | ✓ | ✓ | ✓ | ✓ |
| # {siblings in college} = Yes | | 4,490 | 4,490 | |
| # [ total loan = Stafford limits ] | | | 1,855 | |
| Observations: | 8,705 | 8,705 | 8,705 | 8,705 |
| # Simulations: | | | | |

*Notes.* Data tabs reports OLS estimation of tuition and fees paid by US students, first time enrolled full time in college in the academic year 2003-04 below the age of 21 as dependent individuals, versus parents' income in 2002, an indicator for students with a sibling in college in or before 2003-4, and an indicator for students with total loans being equal to federal Stafford limits for subsidized loans ($3,600 or $4,800 in 2019 dollars, depending on class level) and unsubsidized loans ($9,085 or $10,285 in 2019 dollars, depending on class level, for those whose parents are denied for a federal PLUS loan due to poor credit and $3,600 or $4,800 in 2019 dollars, depending on class level, for the rest) in the academic year 2003-04. Survey population is 1.7 million. Simulation tab reports the median of the slope of the OLS regression coefficients over 300 simulations of the estimated model. Numbers in parentheses show standard errors. *Data source: BPS:04/09.* $^{*}p < 0.1$ $^{**}p < 0.05$ $^{***}p < 0.01$

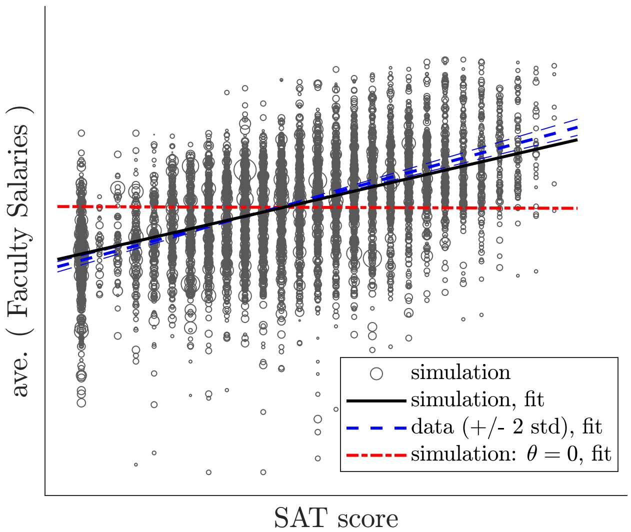


Figure 1: Faculty salaries in colleges that students of different SAT scores enroll in. Gray circles shows simulation results in the benchmark estimation for each student with a specific SAT score in the survey. Circle sizes indicate observation weights in the survey. The solid black line is a linear fit to simulation outcomes. The dashed blue lines is a linear fit to data outcome (the interval of +/-2 standard deviation of data slope estimate is plotted in blue-dashed lines as well). The dashed-dotted red line is a linear fit to a counterfactual simulation outcome with $\theta = 0$. In this counterfactual simulation I reset fixed effect terms $\{\delta_s\}_{s\in\mathcal{S}}$ and $\{\delta_u\}_{u\in\mathcal{U}}$, so that given $\theta = 0$, the enrollment shares and entry rates, *unconditionally*, for colleges and students is as in the data.

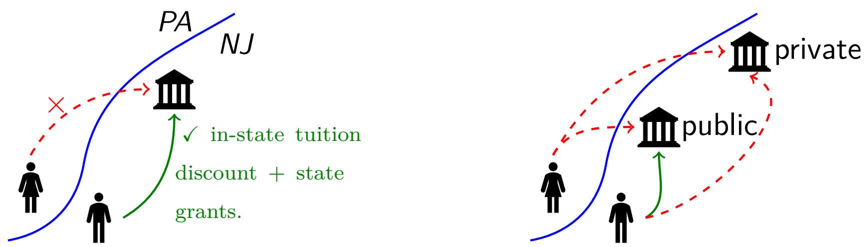


Figure 2: The variation of price at the college level, and across colleges within a state.

Table 8: Substitution of in- for out-of-state students due to in-state tuition discounts.

| log odds of out- vs. in-state enrollees | Simulation | Data | | | |
|---|---|---|---|---|---|
| | | (1) | (2) | (3) | (4) |
| in-state discount (\$1,000) | −0.070 | −0.057*** (0.006) | −0.060*** (0.006) | −0.060*** (0.006) | −0.042*** (0.008) |
| in-state discount (\$1,000) × **1**{below median income} | 0.007 | 0.001 (0.009) | 0.003 (0.009) | −0.009 (0.009) | −0.012* (0.007) |
| Proximity | | | ✓ | ✓ | ✓ |
| State FE | | | | ✓ | ✓ |
| Controls | | | | | ✓ |
| # Colleges | | 1,813 | 1,813 | 1,813 | 1,813 |
| # Enrollees | | 1,304,000 | 1,304,000 | 1,304,000 | 1,304,000 |

*Notes.* The unit of observation is a college. The left-hand-side variable is the logarithm of out-of-state divided by in-state first-time full-time enrollees. The key right-hand-side variable is in-state tuition discount plus average state grants per in-state enrollees at the college level, in unit of one thousand 2019 dollars. The variable 'proximity' measures how close a college is to in- versus out-of-state populated counties: $prox.(\neg state(u))_u - prox.(state(u))_u$, where the function $prox.(\mathcal{S})_u$ is proximity of college $u$ to people in the region set $\mathcal{S}$, defined as $prox.(\mathcal{S})_u := \sum_{c\in\mathcal{S}} N_c/(D_0 + D_{cu})$; here the sum is over all counties (indexed by $c$) in the region set $\mathcal{S}$; $N_c$ is population of county $c$; $D_{cu}$ is the distance in miles between the centroid of county $c$ and college $u$; $D_0$ represents the 'diameter' of a county—calibrated to a median value 30 *miles*. The set of controls includes the logarithm of total enrollees; whether a college offers distance learning and weekend classes; open admission indicator, admission rate, and whether SAT and high-school GPA is required in the application; graduation rate and average SAT of enrollees in recent years. College type dummies indicating community, public 4 year, for-profit and private nonprofit colleges; the logarithm of faculty salaries; and an indicator for four- vs. two-year degree colleges. Observations are weighted by total number of enrollees. To avoid noisy observations, I exclude colleges with less than 5% in- or out-of-state enrollees, and winsorize colleges with a reported state grant plus tuition discount of more than \$20,000. I also exclude colleges that flag more that 2.5% of enrolled students as unknown permanent residency. *Data source: IPEDS:2003-04.*

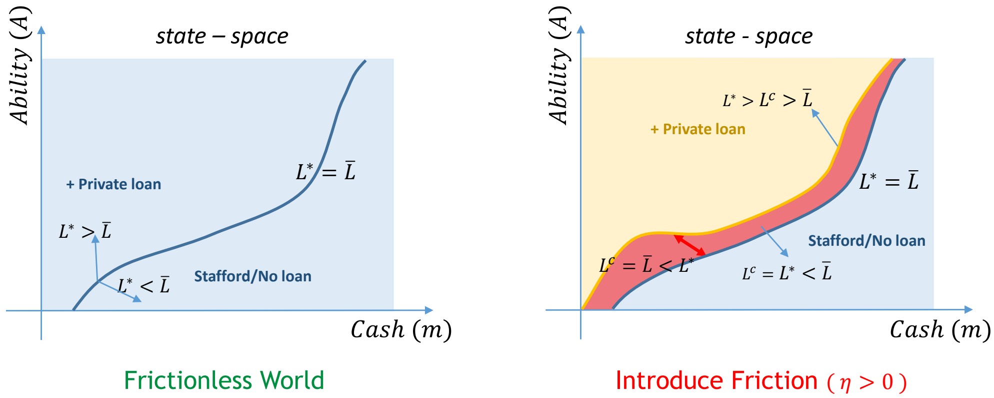


Figure 3: Graphical illustration of the optimal loan policy in a frictionless world ($L^*$) and in the case with external-financing frictions ($L^c$). $\bar{L}$ represents the federal Stafford loan limit.

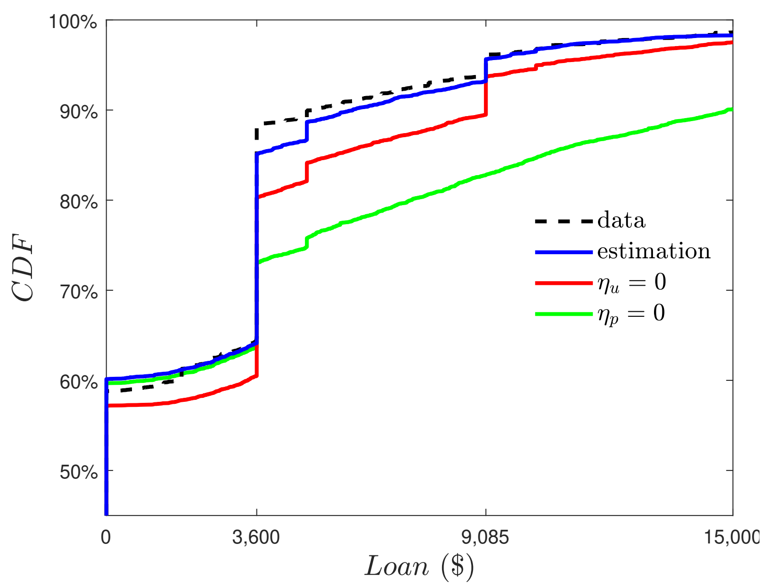


Figure 4: Cumulative distribution function (CDF) of total student loans in data, benchmark estimation, and counterfactual simulations with financing friction wedges $\eta_u = 0$ and $\eta_p = 0$. Jumps in the CDF shows bunching at federal Stafford loan limits. Note that $CDF(L)$ shows the fraction of students with a student loan amount smaller than $L$. The maximum program limit on federal subsidized and unsubsidized Stafford loans are $\$3,600$ and $\$9,085$ for students whose parents are ineligible for federal PLUS loans due to poor credit history (category 1); for students whose parents are eligible for PLUS loans (category 2) the program limits are $\$3,600$. Students from lower-income families are more likely to fall into category 1. Note that the actual limit on subsidized Stafford loan is less than the program limit for students with a large 'Expected Family Contribution'. See details in section 3.2. Limits here are reported in 2019 dollars.

Table 9: List of targeted moments incorporated to identify the model parameters.

| **Moment** | **Helps to identify...** |
|---|---|
| cov (matched attributes & characteristics) | heterogeneous taste for colleges ($\theta, \Pi, \Gamma$) |
| var (matched attributes \| characteristics) | variance of unobservable ability ($\pi_1$) |
| mean (distance from home to college) | disutility to distant colleges ($\chi$) |
| fraction (dropout & associate) | value to degree ($g^d, g^a$) |
| cov (attributes, dropout) | exog. factor to drop out ($\lambda$) |
| cov (dropout, college GPA) | shock to ability ($\pi_2$) |
| colleges' market shares | mean taste for colleges ($\{\delta_u\}_{u\in\mathcal{U}}$) |
| students' entry rate | mean taste for students ($\{\delta_s\}_{s\in\mathcal{S}}$) |
| cov (in-state college choice, tuition discount) | price elasticity ($\zeta^{-1}$) |
| mean, var (self-financing, tuition) | family financial support ($m$) |
| fraction (nearby college) | family housing support ($h$) |
| fraction (loan>0), mean (loan$\|loan > 0$) | fixed cost to take a loan ($f_0$) |
| fraction (loan=$L^{sub}$), mean (loan$\|loan > L^{sub}$) | unsubsidized loan, friction wedge ($\eta_u$) |
| fraction (loan=$L^{tot}$), mean (loan$\|loan > L^{tot}$) | private loan, friction wedge ($\eta_p$) |

Table 10: Data and simulated targeted moments.

| Parents' income: | 1st Quartile | | 2nd Quartile | | 3rd Quartile | | 4th Quartile | |
|---|---|---|---|---|---|---|---|---|
| | model | data | model | data | model | data | model | data |
| Enroll in college (%) | 38.2 | 38.4 (1.6) | 54.4 | 54.3 (1.4) | 68.9 | 68.9 (1.2) | 79.1 | 79.1 (1.0) |
| Nearby college (%) | 62.1 | 66.6 (2.1) | 54.0 | 55.9 (2.0) | 46.1 | 48.6 (1.8) | 41.1 | 35.5 (1.5) |
| log(Distance) | 4.27 | 4.19 (0.04) | 4.38 | 4.38 (0.04) | 4.48 | 4.45 (0.03) | 4.55 | 4.84 (0.03) |
| Tuition ($) | 8140 | 8770 (320) | 10490 | 10150 (350) | 11300 | 10020 (280) | 13450 | 14320 (310) |
| Tuition [SAT>med.] ($) | 11200 | 12260 (780) | 13320 | 12590 (500) | 13160 | 11820 (440) | 14870 | 16390 (460) |
| 4-year college (%) | 60.4 | 59.1 (2.0) | 68.0 | 67.0 (1.7) | 75.4 | 70.8 (1.6) | 81.5 | 83.5 (1.3) |
| Faculty salaries ($) | 3640 | 3740 (110) | 4250 | 4100 (80) | 4580 | 4480 (90) | 5070 | 5350 (90) |
| Dropout (%) | 23.5 | 27.3 (1.9) | 19.4 | 23.9 (1.6) | 15.2 | 14.5 (1.0) | 11.1 | 11.4 (0.8) |
| Bachelor's degree (%) | 57.0 | 52.0 (2.0) | 65.1 | 61.7 (1.8) | 73.2 | 69.9 (1.5) | 80.7 | 80.5 (1.1) |
| positive Loan (%) | 44.9 | 40.4 (2.0) | 44.2 | 48.5 (1.6) | 41.0 | 43.7 (1.4) | 32.7 | 34.4 (1.0) |
| mean Loan ($) | 5740 | 5440 (300) | 5280 | 5180 (180) | 5290 | 5020 (140) | 5740 | 4940 (120) |
| at Stafford limits (%) | 26.1 | 22.6 (1.6) | 31.0 | 31.0 (1.3) | 27.0 | 28.5 (1.2) | 20.6 | 24.1 (1.0) |

*Notes.* All moments in this table, except the first row 'Enroll in college', measure averages over students, conditional on college enrollment. The row: 'mean Loan', reports the average loan, conditional on receiving a loan. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, $34,000, $67,400, and $116,500 in 2019 dollars, respectively, is used to categorize students. All moments with dollar unit are reported in 2019 dollars. Numbers in parentheses show data standard errors. *Data source: BPS:04/09 and ELS:2002.*

Table 11: Students' college-related ability, point estimates.

Panel A: Variance decomposition of college-related ability $A = \Pi' D + \pi_1 \nu + \pi_2 \rho$

| | College preparedness | | Realized in College ($\pi_2 \rho$) |
|---|---|---|---|
| | Observable attributes ($\Pi' D$) | Unobservable ($\pi_1 \nu$) | |
| % of Total variance | 42.4 | 49.1 | 8.4 |

Panel B: Observable preparedness ($\Pi' D$) vs. family background

| Parents' income | Min | Median | Max | Mean | Std |
|---|---|---|---|---|---|
| 1st Quartile | 0 | 1.69 | 4.43 | 1.69 | 0.92 |
| 2nd Quartile | 0.06 | 2.19 | 4.49 | 2.1 | 1.01 |
| 3rd Quartile | 0.09 | 2.57 | 4.55 | 2.46 | 0.89 |
| 4th Quartile | 0.12 | 2.9 | 4.7 | 2.82 | 0.87 |
| All | 0 | 2.48 | 4.7 | 2.37 | 1 |

Panel C: Marginal informativeness of attributes for observable college preparedness

| Attribute ($D_j$) | $\frac{var(\sum_i \Pi_i D_i) - var(\sum_{i \neq j} \Pi_i D_i)}{var(\sum_i \Pi_i D_i)}$ |
|---|---|
| family college experience | 0.082 |
| high-school GPA | 0.194 |
| SAT score | 0.931 |
| parents' income | 0.029 |

*Notes.* Panel A shows the variance of each component of college-related ability, i.e., observable, unobservable, and the shock during college, scaled by the total variance of college-related ability across population: $100 * var(\Pi' D)/var(A)$, $100 * var(\pi_1 \nu)/var(A)$, $100 * var(\pi_2 \rho)/var(A)$, respectively. Panel B reports statistics of the observable college preparedness for each income group. The minimum possible value is set to zero, which is assigned to a student with no SAT, high-school GPA below 3, no parent with college experience, no sibling enrolled in college, and the minimum parents' income in the sample. The standard deviation across all students is normalized to 1. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, \$34,000, \$67,400, and \$116,500 in 2019 dollars, respectively, is used to categorize students. Panel C reports the marginal informativeness of components of the vector of observable attributes $D$ for the observed college preparedness $\Pi' D = \sum_i \Pi_i D_i$. The marginal informativeness of an attribute $j$ is defined as the share of variations in the observable college preparedness $\Pi' D$ that is *not* captured by the single observable attribute $D_j$, i.e., $\frac{var(\sum_i \Pi_i D_i) - var(\sum_{i \neq j} \Pi_i D_i)}{var(\sum_i \Pi_i D_i)}$. As observable attributes covary with each other the sum of marginal informativeness of all attributes is greater than one. Family college experience includes an indicates for parents' college studies and whether a sibling has enrolled or is enrolling in college.

Table 12: Colleges' education quality, point estimates.

| Panel A: Observable education quality ($H = \Gamma' X$) vs. college type | | | | | |
|---|---|---|---|---|---|
| College type | Min | Median | Max | Mean | Std |
| community | 0.21 | 0.6 | 2.1 | 0.64 | 0.24 |
| for-profit | 0.15 | 1.27 | 3.42 | 1.36 | 0.51 |
| public 4-year | 0.74 | 2.45 | 4.02 | 2.42 | 0.61 |
| private nonprofit | 0.31 | 2.55 | 4.57 | 2.59 | 0.79 |
| All | 0.15 | 2.23 | 4.57 | 1.99 | 1 |

| Panel B: Informativeness of characteristics for observable education quality | |
|---|---|
| Characteristic ($X_j$) | $\frac{var(\sum_i \Gamma_i X_i) - var(\sum_{i \neq j} \Gamma_i X_i)}{var(\sum_i \Gamma_i X_i)}$ |
| admission policy | 0.535 |
| cohort quality | 0.693 |
| degrees offered: 4- vs. 2-year | 0.235 |
| faculty salaries, per enrollees | 0.096 |

*Notes.* Panel A reports statistics of the observable education quality $H = \Gamma' X$ for all college types. The minimum possible value is set to zero, which is assigned to a college with open admission, the minimum faculty salaries per enrollees in the sample, the lowest graduation rate, and the lowest 75th percentile of SAT score of enrollees prior to 2003-04, which only offer a two-year degree. The standard deviation across all colleges is normalized to 1. Average, median, and standard deviation are calculated within each college type using the number of first-time and first-year enrollees as observation weights. Panel B reports the marginal informativeness of components of the vector of observable characteristics $X$ for the observable college quality $H = \Gamma' X = \sum_i \Gamma_i X_i$. The marginal informativeness of a characteristic $j$ is defined as the share of variations in the observed education quality $H$ that is *not* captured by the single observable characteristic $X_j$, i.e, $\frac{var(\sum_i \Gamma_i X_i) - var(\sum_{i \neq j} \Gamma_i X_i)}{var(\sum_i \Gamma_i X_i)}$. As observable characteristics covary with each other the sum of marginal informativeness of all characteristic is greater than one. Admission policy includes an indicator for colleges with open admission policy and also the admission rate (number of enrollees / number of applicants) for the rest. Cohort quality refers to the graduation rate of enrollees and the 75th percentile of SAT scores of enrollees prior to the academic year 2003-04.

Table 13: Students' degree choice, estimates in the absence of shock to ability ($\rho > 0$), exogenous shocks to degree choice ($\lambda > 0$), and intrinsic value to drop out ($g_d > 0$).

Panel A: Dropouts, *conditional* on enrollment (%)

| Parents' income | Benchmark estimation | Counterfactual | | | | |
|---|---|---|---|---|---|---|
| | | $(\rho = 0)$ | $(\lambda = 0)$ | $(\rho = 0, \lambda = 0)$ | $(g_d = 0)$ | $(\rho = 0, g_d = 0, \lambda = 0)$ |
| 1st Quartile | 23.5 | 23.1 | 2.7 | 0 | 5 | 0 |
| 2nd Quartile | 19.4 | 18.7 | 3.4 | 0.1 | 3.4 | 0 |
| 3rd Quartile | 15.2 | 14.5 | 3.8 | 0.2 | 2 | 0 |
| 4th Quartile | 11.1 | 10.3 | 3.6 | 0.8 | 1.1 | 0 |

Panel B: Enrollment rate (%)

| Parents' income | Benchmark estimation | Counterfactual | | | | |
|---|---|---|---|---|---|---|
| | | $(\rho = 0)$ | $(\lambda = 0)$ | $(\rho = 0, \lambda = 0)$ | $(g_d = 0)$ | $(\rho = 0, g_d = 0, \lambda = 0)$ |
| 1st Quartile | 38.2 | 37.7 | 28.3 | 27.7 | 33.9 | 27.7 |
| 2nd Quartile | 54.4 | 53.9 | 44.4 | 43.6 | 49.9 | 43.5 |
| 3rd Quartile | 68.9 | 68.3 | 61.6 | 60.8 | 65.1 | 60.8 |
| 4th Quartile | 79.1 | 78.7 | 74.6 | 73.9 | 76.1 | 73.6 |

Panel C: Associate degree attained (%)

| Parents' income | Benchmark estimation | Counterfactual | | | | |
|---|---|---|---|---|---|---|
| | | $(\rho = 0)$ | $(\lambda = 0)$ | $(\rho = 0, \lambda = 0)$ | $(g_d = 0)$ | $(\rho = 0, g_d = 0, \lambda = 0)$ |
| 1st Quartile | 7.5 | 7.2 | 0.5 | 0.4 | 7.9 | 0.4 |
| 2nd Quartile | 8.4 | 8.1 | 0.7 | 0.5 | 9.2 | 0.5 |
| 3rd Quartile | 8 | 7.6 | 0.6 | 0.5 | 9 | 0.5 |
| 4th Quartile | 6.5 | 6 | 1 | 0.7 | 7.4 | 0.8 |

Panel D: Bachelor's degree attained (%)

| Parents' income | Benchmark estimation | Counterfactual | | | | |
|---|---|---|---|---|---|---|
| | | $(\rho = 0)$ | $(\lambda = 0)$ | $(\rho = 0, \lambda = 0)$ | $(g_d = 0)$ | $(\rho = 0, g_d = 0, \lambda = 0)$ |
| 1st Quartile | 21.8 | 21.7 | 27 | 27.3 | 24.3 | 27.3 |
| 2nd Quartile | 35.5 | 35.7 | 42.2 | 43 | 39 | 43 |
| 3rd Quartile | 50.4 | 50.8 | 58.6 | 60.2 | 54.8 | 60.2 |
| 4th Quartile | 63.9 | 64.5 | 70.9 | 72.6 | 67.9 | 72.7 |

*Notes.* Panel A shows dropout ratio for college enrollees. Panels B shows the fraction of high-school graduates who enroll in college. Panels C and D report the fraction of high-school graduates who attain an associate or a bachelor's degree. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, \$34,000, \$67,400, and \$116,500 in 2019 dollars, respectively, is used to categorize students.

Table 14: The perceived cost of student loans; average return rate estimates.

| Income background: | 1st Quartile | 2nd Quartile | 3rd Quartile | 4th Quartile |
|---|---|---|---|---|
| Federal Subsidized | 2.11 (.24) | 2.11 (.12) | 2.13 (.07) | 2.10 (.12) |
| Subsidized & Unsubsidized | 3.68 (.12) | 3.80 (.08) | 4.57 (.12) | 5.19 (.19) |
| Federal and Private Loans | 6.13 (.17) | 7.31 (.11) | 7.80 (.14) | 8.77 (.20) |

*Notes.* This table presents the perceived net average return rate on student loans in percentage units per annum $(\frac{C(L)}{L} - 1) * 100$ in the academic year 2003-04, across students of different backgrounds taking only federal subsidized loans (first row), subsidized and unsubsidized loans (second row), and both federal and private loans (third row). The fixed cost $f_0$ is included in the calculation of perceived average rates; see specification (L). Recall that the 10-year treasury rate is 3.53%. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, \$34,000, \$67,400, and \$116,500 in 2019 dollars, respectively, is used to categorize students. Numbers in parentheses show estimation standard errors.

Table 15: The perceived cost of student loans; marginal return rate estimates.

| | median ($r$) | $\Delta r/\Delta income$ | $\Delta r/\Delta SAT$ |
|---|---|---|---|
| Federal Subsidized | 1.89 | -0.03 | -0.14 |
| Federal Unsubsidized | 4.26 (.12) | 0.09 (.12) | 0.07 (.11) |
| Private Loans | 10.04 (.20) | 1.12 (.21) | -0.19 (.20) |

*Notes.* This table presents the perceived net marginal return rate on federal subsidized loans, unsubsidized loans, and private loans in percentage units per annum $r = (\frac{\partial C(L)}{\partial L} - 1) * 100$ in the academic year 2003-04. See the specification (L); recall that the 10-year treasury rate is set to 3.53%. In the second and third columns, variation of $r$ with respect to family income and students' SAT is reported. $\Delta income := p75(parents'\ income) - p25(parents'\ income)$ and $\Delta SAT := p75(SAT) - p25(SAT)$. Numbers in parentheses show estimation standard errors.

Table 16: Counterfactual analysis; no financing friction and lifting federal Stafford loan limits from pre 2006-07 to post 2008-09 values.

| Parents' income: | Low income | | | High income |
|---|---|---|---|---|
| | Estimation | Lift Loan limits | No Friction | Estimation |
| Enroll in college (%) | 46.3 | 46.4 | 47.0 | 74.0 |
| Nearby college (%) | 57.4 | 57.0 | 55.5 | 43.5 |
| Tuition ($) | 9520 | 9640 | 10130 | 12450 |
| Tuition [SAT>median] ($) | 12690 | 12860 | 13520 | 14150 |
| Bachelor's degree (%) | 61.8 | 61.7 | 61.3 | 77.2 |
| positive Loan (%) | 44.5 | 44.8 | 46.4 | 36.6 |
| mean Loan ($) | 5470 | 6970 | 12970 | 5500 |
| at Stafford limits (%) | 29.0 | 23.8 | 6.9 | 23.6 |

*Notes.* The first and the fourth columns reports the results of the benchmark estimation, for students whose parents' income is below median: 'low income', and above median: 'high income'. The second column shows the counterfactual results of lifting federal Stafford loan limits from the pre 2006-07 to post 2008-09 values, for low-income students. Specifically, for dependent first-year students whose parents are eligible for a PLUS loan (group I) the limit on subsidized and unsubsidized loans is $2,625 in 2003-04; for dependent first-year students whose parents are not eligible for a PLUS loan (group II) the limit on subsidized and unsubsidized loans is $2,625 and $6,625, respectively. In 2008-09 the limit on subsidized and unsubsidized loans is lifted to $3,500 and $5,500, respectively, for group I, and to $3,500 and $9,500 for group II. The third column shows the counterfactual results of setting financing friction wedges, $f_0$, $\eta_u$ and $\eta_p$ to zero, for low-income students. All variables in this table, except the first row 'Enroll in college', measure averages over students of different income backgrounds, *conditional* on enrolling in college. The row 'mean Loan' reports the average loan, conditional on receiving a loan. The median estimate of parents' income for high-school graduates, $67,400 in 2019 dollars, is used as the criteria to assign students into low- and high-income category. All variables with dollar unit are reported in 2019 dollars.

Table 17: Policy analysis; making public colleges tuition-free.

| Parents' income: | 1st Quartile | 2nd Quartile | 3rd Quartile | 4th Quartile | All |
|---|---|---|---|---|---|
| | | Panel A: Pre-Policy | | | |
| Enroll in college (%) | 38.2 | 54.4 | 68.9 | 79.1 | 60.2 |
| Nearby college (%) | 62.1 | 54.0 | 46.1 | 41.1 | 48.8 |
| Enroll in priv. college (%) | 31.6 | 34.3 | 31.6 | 35.0 | 33.4 |
| Tuition ($) | 8140 | 10490 | 11300 | 13450 | 11320 |
| Faculty salaries ($) | 3640 | 4250 | 4580 | 5070 | 4520 |
| Dropout (%) | 23.5 | 19.4 | 15.2 | 11.1 | 16.1 |
| positive Loan (%) | 44.9 | 44.2 | 41.0 | 32.7 | 39.6 |
| mean Loan ($) | 5740 | 5280 | 5290 | 5740 | 5490 |
| | | Panel B: Post-Policy | | | |
| Enroll in college (%) | 40.4 | 57.2 | 71.4 | 81.1 | 62.5 |
| Nearby college (%) | 53.5 | 43.5 | 37.0 | 33.1 | 39.9 |
| Enroll in priv. college (%) | 10.8 | 10.2 | 8.0 | 10.8 | 9.8 |
| Tuition ($) | 7900 | 10060 | 11200 | 12650 | 10880 |
| Faculty salaries ($) | 3740 | 4220 | 4570 | 5020 | 4500 |
| Dropout (%) | 24.6 | 20.6 | 16.2 | 12.0 | 17.2 |
| positive Loan (%) | 33.6 | 29.3 | 24.5 | 17.8 | 24.9 |
| mean Loan ($) | 4450 | 4200 | 3990 | 4430 | 4250 |
| | | Panel C: Post- vs. Pre-Policy | | | |
| Δ [ Enrollment ] (%) | 2.2 | 2.8 | 2.5 | 2.0 | 2.4 |
| Δ [ Tuition ] (%) | -3.0 | -4.1 | -0.9 | -6.0 | -3.9 |
| Δ [ Student Loans ] (%) | -42.0 | -47.3 | -54.9 | -58.0 | -51.4 |
| Δ [ Student Surplus ] ($B) | 4.4 | 7.9 | 12.6 | 15.5 | 40.3 |
| Δ [ Government Subsidy ] ($B) | 6.4 | 11.8 | 17.5 | 21.2 | 56.9 |

*Notes.* In this policy experiment, the government pays for the tuition of students in public colleges; all other institutional and fundamental variables, as well as students' attributes and colleges' characteristics and tuition, are unchanged. In panels A and B, all variables, except 'Enroll in college', measure averages over students of different income backgrounds, *conditional* on enrolling in college; the row: 'mean Loan', reports the average loan, conditional on receiving a loan. Panel C reports percentage change in enrollment ratio, and average tuition and student loans for all college enrollees; Δ [Student Surplus] shows change in students' utility in dollar units (lifetime wealth equivalent value) and Δ [Government Subsidy] reports what the government needs to pay for the policy. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, $34,000, $67,400, and $116,500 in 2019 dollars, respectively, is used to categorize students. All variables with dollar unit are reported in 2019 dollars.

Table 18: Policy analysis; expanding federal Pell grants.

| Parents' income: | 1st Quartile | 2nd Quartile | 3rd Quartile | 4th Quartile | All |
|---|---|---|---|---|---|
| **Panel A: Pre-Policy** | | | | | |
| Enroll in college (%) | 38.2 | 54.4 | 68.9 | 79.1 | 60.2 |
| Nearby college (%) | 62.1 | 54.0 | 46.1 | 41.1 | 48.8 |
| Enroll in priv. college (%) | 31.6 | 34.3 | 31.6 | 35.0 | 33.4 |
| Tuition ($) | 8140 | 10490 | 11300 | 13450 | 11320 |
| Faculty salaries ($) | 3640 | 4250 | 4580 | 5070 | 4520 |
| Dropout (%) | 23.5 | 19.4 | 15.2 | 11.1 | 16.1 |
| positive Loan (%) | 44.9 | 44.2 | 41.0 | 32.7 | 39.6 |
| mean Loan ($) | 5740 | 5280 | 5290 | 5740 | 5490 |
| **Panel B: Post-Policy** | | | | | |
| Enroll in college (%) | 41.8 | 55.8 | 68.9 | 79.1 | 61.4 |
| Nearby college (%) | 59.6 | 53.5 | 46.1 | 41.1 | 48.5 |
| Enroll in priv. college (%) | 33.6 | 35.1 | 31.7 | 35.0 | 33.8 |
| Tuition ($) | 8370 | 10600 | 11320 | 13450 | 11340 |
| Faculty salaries ($) | 3590 | 4220 | 4580 | 5070 | 4490 |
| Dropout (%) | 24.8 | 19.8 | 15.2 | 11.1 | 16.6 |
| positive Loan (%) | 29.4 | 37.7 | 40.7 | 32.7 | 35.5 |
| mean Loan ($) | 5350 | 5160 | 5270 | 5740 | 5400 |
| **Panel C: Post- vs. Pre-Policy** | | | | | |
| Δ [ Enrollment ] (%) | 3.6 | 1.4 | 0.0 | 0.0 | 1.2 |
| Δ [ Tuition ] (%) | 2.8 | 1.0 | 0.1 | 0.0 | 0.1 |
| Δ [ Student Loans ] (%) | -39.0 | -16.5 | -1.1 | 0.0 | -11.9 |
| Δ [ Student Surplus ] ($B) | 4.4 | 3.5 | 0.4 | 0.0 | 8.2 |
| Δ [ Government Subsidy ] ($B) | 5.0 | 3.7 | 0.4 | 0.0 | 9.1 |

*Notes.* In this policy experiment, federal Pell grant amount for all recipients of Pell grants is increased by 140%, and grant eligibility is left unchanged (the maximum grant amount is increased from $5,500 to $13,500, in 2019 dollar). All other institutional and fundamental variables, as well as students' attributes and colleges' characteristics and tuition, are unchanged. In panels A and B, all variables, except 'Enroll in college', measure averages over students of different income backgrounds, *conditional* on enrolling in college; the row: 'mean Loan', reports the average loan, conditional on receiving a loan. Panel C reports percentage change in enrollment ratio, average tuition, and student loans, for all college enrollees; Δ [Student Surplus] shows change in students' utility in dollar unit (lifetime wealth equivalent value) and Δ [Government Subsidy] reports what the government needs to pay for the policy. Percentiles 25th, 50th, and 75th estimates of parents' income for high-school graduates, $34,000, $67,400, and $116,500 in 2019 dollars, respectively, is used to categorize students. All variables with dollar unit are reported in 2019 dollars.