Over-optimism About Graduation and College Financial Aid*

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Abstract

Many student debtors who once enrolled in a bachelor's program have not completed their college degree. We establish empirically that college students and their parents are overly optimistic about the probability of college graduation when making college enrollment decisions. We incorporate such over-optimism into an overlapping generations model, which also includes family transfers, federal student loans, and a private student loan market. We discipline these model attributes using panel data from the U.S. Bureau of Labor Statistics and the U.S. Department of Education, and then examine the effects of eliminating over-optimism and of expanding federal student loan limits. We find that eliminating over-optimism, despite correcting beliefs, lowers welfare due to equilibrium adjustments of income taxes, family transfers, and skill (which depends on parent education). Expanding federal student loan limits reduces welfare for low-skill students from poor families, a result driven by the presence of over-optimism.

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1 Introduction

Outstanding student loan balances in the United States are large, amounting to 7.6 percent of gross domestic product in 2019.[1] Yet a sizable fraction of student debtors did not complete the education program the loan was used to pay for. Previous structural studies examining college financial aid policy in the presence of dropout risk have assumed that consumers' beliefs about dropout risk are accurate. We provide new empirical evidence that both students and their parents are overly optimistic about the likelihood of college graduation.[2] We then build a general-equilibrium model, in which consumers solve a life cycle problem featuring college as a risky investment that can be financed with federal and private student loans, endogenous family transfers, grants, and labor earnings. A novel model ingredient is that consumers exhibit overly optimistic beliefs about their college graduation likelihood, both when they enroll in college and when they choose how much to transfer to their own child later in life. Such over-optimism leads to a higher college enrollment rate and higher inter-vivos transfers than would occur with accurate beliefs. We use this framework to study the economic effects of two separate policies: eliminating over-optimism and expanding federal student loan limits.[3] We find that, despite correcting mistaken beliefs, eliminating over-optimism lowers welfare for young adults because it lowers family transfers, raises income taxes, and lowers average skill via intergenerational effects. Expanding federal student loan limits affects students from low-income families the most.[4] In this group, those with low skill see welfare losses, while those with high skill see welfare gains. Without overly optimistic beliefs, all skill levels would benefit from such a policy change.

Our main empirical findings are drawn from two nationally representative panel surveys: the 1997 National Longitudinal Survey of Youth (NLSY97) and the High School Longitudinal Study of 2009 (HSLS:09). In the public-use NLSY97, we observe expectations about the sample member's probability of earning a bachelor's degree (BA) by age 30, solicited from both the sample member and their parents. For those who later enroll in a BA program, we construct the realized rate of BA completion by age 30. We show that over-optimism about college graduation, computed as

[1] Student loans are now the largest category of consumer credit after mortgages. Source: Federal Reserve Board G19, Bureau of Economic Analysis, and authors' calculations.

[2] Sources: 1997 National Longitudinal Survey of Youth and High School Longitudinal Study of 2009. Authors' calculations.

[3] An example of a policy eliminating over-optimism is mandating that high schools and universities educate potential college students and their parents about college dropout risk.

[4] The substitutability between federal and private student loans is very relevant for this policy experiment. In our model economy, we incorporate private student loans as an imperfect substitute for federal student loans. In particular, acquiring private student loan requires an additional search cost, which captures costs due to predatory lending, hidden fees, and potential challenges in acquiring a co-signer. This search cost is disciplined by the student portfolio of college enrollees in the HSLS:09, which indicates that students borrow from the federal student loan program before borrowing from the private student market. Authors' calculations.

the difference between expected and realized probabilities of BA completion, is widespread. On average, college students believe there is a 90 percent chance they will earn a BA by age 30, yet only 70 percent go on to earn their degree. This over-optimism is especially severe among those with low skill (where skill is measured with high school GPA), a pattern which continues to hold even when we account for gender and parental education. Moreover, parents of college students exhibit similar patterns of over-optimism. In the restricted-use HSLS:09, we observe uptake of federal financial aid and private student loans. By using the HSLS:09 to track a cohort of college enrollees until several years after college enrollment, we show that the amount of student debt owed by college dropouts (federal or private) is economically significant at the individual level and in the aggregate.

Our model is calibrated to match moments related to overly optimistic beliefs, college enrollment and graduation, student loans, and family transfers.[5] With the fully parameterized model, we perform two policy experiments. First, we study a policy that that eliminates over-optimism (an "information intervention") by setting the expected probabilities of college graduation equal to the true probabilities of graduation. Second, in the baseline model economy with over-optimism, we expand the federal student limit so that federal loans can be used to pay for all four years of college. This change represents a significant expansion: under current U.S. policy and in the model's baseline economy, the federal student loan limit is enough to pay for 37.5 percent of average annual college costs.[6] Furthermore, we provide new empirical evidence motivating this policy experiment, by establishing that a significant share of recent college students fully utilize their federal student loan limits under current policy.[7]

In the first policy experiment, we find that the information intervention reduces welfare for the average 18-year-old, despite correcting mistaken beliefs: in the later periods of the transition, losses reach 0.9 percent of lifetime consumption. Welfare declines after the information intervention for three main reasons, highlighting the complex role of over-optimism in the economy. First, family transfers decrease because, with the correct beliefs, parent have less incentive to provide inter-vivos transfers to pay for their child's college education. Furthermore, eliminating over-optimism leads to lower enrollment in college as young adults now realize they are less likely to graduate, resulting in fewer college graduates in the new equilibrium. Consequently, the economy will be poorer in income and wealth as time goes on, which compounds the decrease in family transfers

[5] We can document that college students are overly-optimistic on either side of the enrollment decision, but the data is not sufficient to establish learning dynamics while enrolled in college. To be conservative, in our model college students learn the truth about graduation likelihood during the first academic year. Relaxing this assumption would make the magnitude of effects we document increase without changing the qualitative properties of those effects.

[6] Source: CRS (2019) and NCES (2019), authors' calculations.

[7] Source: HSLS:09 and CRS (2019), authors' calculations. For a broader discussion of borrowing constraints and post-secondary education, see Lochner and Monge-Naranjo (2016).

as parents now have fewer resources to give to their children. Second, once we take general equilibrium effects into account, income taxes rise because lower college enrollment leads to fewer college graduates and a contraction in the income tax base. Third and finally, fewer college graduates in the economy reduces the mass of high-skill adults in the next generation, because the parameterized model exhibits a positive correlation between parental education and a child's skill endowment.

In the second policy experiment, we find that expanding federal student loan limits leads to heterogeneous welfare changes, especially among students from poor families. In that group, those with low skill see losses ranging from 1.3 to 2.6 percent of lifetime consumption, while those with high skill see gains ranging from 1.7 to 5.4 percent of lifetime consumption. Low-skill young adults are hurt by the limit expansion because access to more federal loans greatly increases their ability to finance college and thus worsens the extent of their over-enrollment. Consumers with high skill, on the other hand, experience welfare gains. We are able to uncover this heterogeneity in welfare effects because we incorporate over-optimism into the model environment: in supporting analysis, we show that in a model economy without over-optimism such an expansion in federal student loan limits benefits all levels of skill.

This study is not the first to examine college enrollment and college financial aid policies. Indeed, previous related work—which includes Caucutt and Kumar (2003), Ionescu (2009), Lochner and Monge-Naranjo (2011), Chatterjee and Ionescu (2012), Krueger and Ludwig (2016), Ionescu and Simpson (2016), Luo and Mongey (2019), Abbott, Gallipoli, Meghir, and Violante (2019), and Caucutt and Lochner (2020)—also examines the role of federal and private loans, public grants, and family transfers. A key assumption maintained in these studies is that student expectations about academic outcomes are consistent with realized outcomes; in those studies, more financial aid raises welfare. We build on that literature and, motivated by our empirical findings, incorporate over-optimism about college graduation likelihood. We demonstrate that, with over-optimism, more financial aid reduces welfare for some consumers.

Our study also contributes to the consumer credit literature on over-borrowing. Related work includes Nakajima (2012, 2017), which examine the impact of increased access to unsecured credit (e.g., credit cards) and bankruptcy policy reforms when consumers have time inconsistent preferences. Another example is Exler, Livshits, MacGee, and Tertilt (2021), which analyzes policies aimed at correcting for over-borrowing in the unsecured credit market due to over-optimism about earnings. One of the key takeaways from these studies is that quantity restrictions, even in the presence of over-borrowing, lead to welfare losses. We contribute to this literature in two ways. First, we focus on student loans rather than unsecured credit, and find that expanding federal borrowing limits (reducing quantity restrictions) leads to welfare losses for low-skill students from poor families. Second, we address a challenge for the consumer credit literature by incorporating empirical discipline for the bias present in our model: in particular, we leverage data on expectations about graduation likelihood and realized educational outcomes to pin down the extent of over-optimism.

The role of private student loans as a source of college financing has been emphasized in previous work. As argued by Lochner and Monge-Naranjo (2011), including private student loans in studies of college financial aid policy is important because the private market provides an outside option to the government financial aid program. However, while the current literature has routinely incorporated key features of the federal student aid program, there is less consensus about modeling the private student loan market. For example, Lochner and Monge-Naranjo (2011) assume that lenders price repayment risk based on student skill, making low-skill students less likely to have access to private student loans than their high-skill peers. Ionescu and Simpson (2016) assume that private lenders price the student loan based on the inherent credit risk of the borrower. Abbott, Gallipoli, Meghir, and Violante (2019) assume that students from low-income families do not have access to private student loans. We build on the aforementioned studies by using the HSLS:09 and the 2019 Survey of Consumer Finances (SCF) to document key attributes of the U.S. private student loan market, which are then reflected in our model framework.

Our empirical evidence on over-optimism about college graduation likelihood complements previous work by Stinebrickner and Stinebrickner (2012). That study examines a small panel survey of students at a single U.S college in the early 2000s, and finds that students are overly optimistic about their academic performance in college. Using this information, the authors then infer the extent of over-optimism about college graduation likelihood and find it to be sizable. We use reported expectations about educational attainment in the NLSY97, a nationally representative public survey, to provide new evidence that over-optimism about educational attainment is widespread among both students and their parents. Echoing the findings of Stinebrickner and Stinebrickner (2012), our results indicate that college students with low skill tend to be more overly optimistic than their high-skill peers.

Our findings documenting student debt among dropouts complements the work of Chatterjee and Ionescu (2012), which uses the SCF to show that outstanding balances held by college dropouts are significant. We build on this result in two ways. First, we use the HSLS:09 to document significant balances among dropouts by tracking a single cohort of college students for several years after enrollment. This allows us to avoid measuring balances in a cross-sectional sample like that of the SCF, with the potentially large heterogeneity in federal policy regimes at loan issuance, time in repayment, labor market experience, and other factors that such a sample implies. Second, our HSLS:09 findings on student debt balances are drawn from student records submitted by post-secondary institutions, likely a more reliable source than self-reported balances recorded in the

SCF.

This paper proceeds as follows. Section 2 overviews our empirical findings. Section 3 lays out the model, Section 4 describes the model parameterization, and Section 5 analyzes properties of the model equilibrium. Section 6 reports the results of our main policy experiments. Section 7 concludes.

2 Data

The two main data sets we draw on are the 1997 National Longitudinal Survey of Youth and the High School Longitudinal Study of 2009, supplemented with the 2019 Survey of Consumer Finances. All of these surveys are collected within the United States.

The NLSY97 is a nationally representative panel following young adults born between 1980 and 1984 from 1997 until 2019. It is collected by the U.S. Bureau of Labor Statistics (NSLY, 1997). The NSLY97 provides information on expected probabilities of college graduation for college students and their parents, as well as realized education outcomes, which we use to document over-optimism about college graduation likelihood.

The HSLS:09 is a nationally representative panel that follows a sample of 9th-grade students from 2009 until 2016, although some information from post-secondary transcripts and student records is collected after 2016 (HSLS, 2009). It is conducted by the National Center for Education Statistics (NCES), which is a subsidiary of the U.S. Department of Education. This is our preferred data set to document patterns of student loan usage because the HSLS:09, unlike the NLSY97, follows a cohort which interacted with the most recent iteration of U.S. financial aid policy (e.g., borrowing limits). In particular, we use the HSLS:09 to document student loan uptake and balances by college dropout status. We also document the composition of student debt portfolios by loan type (i.e., federal or private), and private loan uptake patterns by high school GPA and family income.[8]

The 2019 SCF is a nationally representative cross-sectional survey of families that is conducted every three years. It is sponsored by the Federal Reserve Board of Governors and the U.S. Department of the Treasury (SCF, 2019). The SCF reports interest rates for federal and private student loans. Together with findings on private student loans from the HSLS:09, we use interest rates by loan type from the SCF to discipline model attributes of the private student loan market.

[8]We also use the HSLS:09 as a source of supporting evidence for the NLSY97 over-optimism findings, by capitalizing on HSLS:09 questions about educational attainment expectations which were asked to students and their parents when students were in the spring of their third year of high school. These findings are presented in Supplementary Appendix C. In the HSLS:09, there is no age limit condition on the outcome being asked about, and the response is categorical (e.g., "Bachelors") rather than a continuous probability. That is why our main results on over-optimism are established with the NLSY97.

2.1 Over-optimism about college graduation likelihood

The NLSY97 asks sample members about their expected probability of earning a BA by age 30 twice, in 1997 and in 2001. The survey also asks parents the same question about their child once, in 1997.[9] This question can be paraphrased as: "What is the percent chance that [you/your child] will have a four-year college degree by the time [you/they] turn 30?" The response is a percent value between 0 and 100. The NLSY97 also reports the high school GPA, college enrollment, and educational attainment of sample members over the course of the panel. We assign each sample member to a skill quantile using the distribution of high school GPA among high school graduates. We also flag those who had enrolled in a BA program, as well as those who had earned a BA, by age 30.

Using this information, Panel A of Table 1 compares education outcomes with sample member expectations about educational attainment by skill quantile. The sample is restricted to those who enrolled in a BA program sometime before turning 30.[10] To construct expectations about college graduation likelihood as close as possible to the college enrollment decision, for the sample member beliefs we use the most recent valid response to this question collected while the respondent was enrolled in high school. To measure the average outcome within a skill quantile, the column "% earned" reports the frequency of BA attainment by age 30; the next column, "E(prob)", reports average expected probability of earning a BA by age 30. The last column reports the percentage point difference between average expected probabilities and the realized probability, which represents the extent of over-optimism for the skill quantile. Panel A indicates that, within each skill quantile, the expected probability of earning a BA by age 30 is much higher than the realized rate of attaining that outcome. This is especially true for those with the lowest skill, whose over-optimism is about 50 percentage points, compared to those with the highest skill, whose over-optimism is about 15 percentage points.

Panel A documents over-optimism while the respondent is in high school, conditional on their eventually enrolling in a BA. Does the over-optimism documented in Panel A persist until the point of the college enrollment decision? We are argue that it does, and offer supporting evidence by examining a group of respondents for whom we can measure over-optimism on both sides of the college enrollment decision. Specifically, we restrict attention to students who answer the 1997 question while still in high school, and also answer the 2001 question while enrolled in a BA program. Results are shown in Panel B of Table 1.[11] Sample members maintain overly optimistic

[9]In the 2001 questionnaire, respondents were divided into 4 groups for the beliefs questions. Only groups 1 and 3 were asked about educational attainment expectations.

[10]The tabulation is done for the sample of students who enroll in a BA program to focus on over-optimism about college *graduation*, rather than about college enrollment.

[11]We do not break down the statistics for Panel B by skill quantile because of the small sample size. The sample size

Table 1: Over-optimism about BA attainment by age 30

Panel A	Skill	Obs	% earned	E(prob)	Over-optimism
	1	222	31.98	81.78	49.80
	2	395	55.95	87.42	31.47
	3	587	78.19	93.56	15.36
	Obs	1,204			
Panel B		**E(prob)**		**Over-optimism**	
	% earned	**HS**	**BA**	**HS**	**BA**
	69.62	92.07	93.14	22.45	23.52
	Obs	316			
Panel C	**Skill**	**Obs**	**% earned**	**E(prob)**	**Over-optimism**
	1	166	31.33	80.93	49.61
	2	297	54.88	84.79	29.91
	3	429	78.79	93.03	14.24
	Obs	892			

Notes: Table 1, Panel A shows the graduation rate and students' expected probability of graduation by skill quantile, for students who enroll in a BA program by age 30; Panel B compares the realized graduation rate with the expected probability of graduation reported in high school ("HS", in 1997) and while enrolled in college ("BA", in 2001), for the sample of respondents enrolled in high school in 1997 and were enrolled in a bachelor's degree program in 2001 and answered the education expectations question in both years; Panel C compares outcomes with parent expectations by student skill quantile, for the sample of students whose parents were asked the expected education question while their child was in high school. Skill quantiles are assigned using the distribution of high school GPA among high school graduates. Source: NLSY97.

beliefs about graduation likelihood after they enroll in college. If these individuals were changing their expectations right before college enrollment to be closer to the realized probability, then one could safely presume that the expected probability after enrolling would be closer to the realized probability of graduating, which is about 70 percent. This is not the case in the data: the expected probability of graduating from a BA slightly increases after college enrollment.

Panel C reports the same statistics as Panel A, but uses parent expectations to compute the last two columns. Because this panel conditions on observing parent expected probabilities for their child earning a BA, the sample differs from Panel A. Consequently, the college completion rates by skill quantile change slightly. Panel C indicates that parents, like their children, are overly optimistic about their child's prospects for earning a BA, and to a similar extent as their child.[12]

Our findings from the NLSY97 indicate that over-optimism about the likelihood of earning a bach-

is small for several reasons: a small proportion of respondents meet the education timing criteria and the design of the round 5 questionnaire only asks the relevant question for 2 of the 4 sub-groups among the surveyed.

[12]For a comparison within families of student and parent expectations, see Table 14 and the associated discussion in Supplementary Appendix A. Parents and children report very similar likelihoods of college attainment: the median difference in expected probabilities of the parent and the child is zero within families, not just on average as shown in Panel C of Table 1.

elor's degree is widespread among those who enroll in college, especially among those with low skill. This over-optimism appears to be stable around the college enrollment decision, and parents exhibit a similar degree of over-optimism and with similar patterns across child skill quantiles. In Table 15 of Supplementary Appendix A.1, we show how over-optimism for each skill quantile varies by gender and parental education, and find that low-skill students continue to exhibit higher over-optimism within each gender and parental education grouping. We also show supporting evidence for our over-optimism findings in the NLSY97 from an additional dataset, the HSLS:09, in Table 26 of Supplementary Appendix C.1. However, our main findings from the HSLS:09 relate to student loans, and in the next section we use that data set to document how uptake of student loans varies by college persistence status.

2.2 Student loan uptake and balances

The HSLS:09 contains information about the focal ninth-grade high school student (e.g., their total high school GPA and their expected educational attainment) as well as about their family (e.g., family income and parental education). For the vast majority of sample members, high school graduation occurs in the spring of 2013. The HSLS:09 also contains information on student loan balances, if any, collected from student records submitted by post-secondary institution in the 2016-2017 academic year.[13] We use the HSLS:09 to demonstrate that there is sizable student loan uptake among those who enroll in a BA program but do not persist toward graduation. Note that all tabulations of HSLS:09 data, both here and in the Supplementary Appendix, use survey weights. The specific weights used for each tabulation are noted in the table footnote.

We restrict our sample to students who have graduated from high school by the summer of 2013 and enrolled in a BA program in the fall of 2013. Among this group, we additionally restrict attention to individuals for whom we observe family (parent) income, state of residence, parental educational attainment, the student's race and ethnicity, and the student's high school GPA. We also require that the student reports their educational attainment expectations in the spring of their junior year of high school.[14] In Table 2, we report loan statistics by persistence status; by "persisting", we mean maintaining enrollment in their program from the first year (the 2013-2014 academic year) until the fourth year (the 2016-2017 academic year). Someone who does not persist leaves college for at least one academic year after enrolling. Unlike the NLSY97, the short panel dimension of the HSLS:09 prevents us from using more long-term measures of college completion, so we largely avoid using terms like "dropout" in our discussion of the HSLS:09 findings.

[13]See Supplementary Appendix C for further explanation of the HSLS:09 structure.

[14]This allows us to use a consistent sample for both the student debt findings and a comparison of over-optimism in the HSLS:09 with findings in the NLSY97.

Table 2 shows that over 30 percent of the enrolled population fail to persist towards college completion. Students who do not persist owe almost one in four dollars of the sample's student debt balances (either federal or private), and are more likely to have student debt than those who persist. Conditional on having student debt, the average and median student loan balance is economically significant several years after enrollment, regardless of persistence status. This is true despite non-persisters usually using that money to finance fewer years of tuition, compared to students who persist toward degree completion.[15] In the next section, we focus particularly on private loans using information from the HSLS:09 and the 2019 SCF, interpreted using several additional sources.

Table 2: Student loans by persistence status

Persistence status	% of enrollees	% of SL $	% with SL	Average $	Median $
Did not persist	32	24	74	17,051	13,250
Persisted	68	76	65	24,175	19,500
Obs	2,670				

Notes: Table 2 divides the pool of 2013 BA enrollees into students who persisted in college and those who did not persist. Persistence status is assigned based on whether their student record indicates that they were enrolled for each academic year between 2013-14 and 2016-17. Within each persistence outcome group, the table reports the group's share of the total population, the dollars owed by the group as a share of aggregated student debt, the percent of the group with a positive student debt balance, and the average and median student loan balance owed by debtors in the group by the end of their third year in 2016 dollars. Percentages are rounded to the nearest percentage point. Sample: students who enrolled in a BA in the fall of 2013. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to the nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights.

2.3 Private student loans

We are interested in federal student loan policy, so the private student loan market warrants further examination as it is the source of a potential substitute for federal loans. We begin with information from the HSLS:09 reported in Table 3, which summarizes sources of student loans three academic years after enrollment among 2013 college enrollees. Results are broken down separately for each persistence status. The columns of Table 3 report, first, the percent of the group that has either federal or private student loans; second, the percent that has only federal; third, the percent with only private; and fourth, the percent with debt from both kinds of student loans. This table has two main takeaways, which hold for both persistence statuses: first, that more than 1 in 5 students takes out a private student loan during college, indicating that it is quite common to use this source of financing; and, second, that there is a "pecking order" for loan types, where students tend to

[15] Patterns of grant aid are similar, as shown in the Table 27 of Supplementary Appendix C.2.

take out a federal loan and then sometimes turn to private loans. For intuition about the second takeaway, note that if students often took out private loans without first using federal loans, then the share of student debtors with only private loans would be more similar to the share with only federal loans. However, Table 3 shows that this is not the case in the data: for both persistence groups the share with only private student loans is almost 0, while the share with only federal loans is quite large.

Table 3: Student debt portfolio composition

Persistence status	**Either**	**Federal only**	**Private only**	**Both**
Did not persist	74	48	2	23
Persisted	65	44	1	19
Obs	2,670			

Notes: Table 3 reports, by persistence status, the percent of all college enrollees who owe money for either, only federal, only private, or both types of student loans three years after enrollment. Percentages are rounded to the nearest percentage point. Sample: students who enrolled in a BA in the fall of 2013. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to the nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights.

The HSLS:09 also sheds light on access to private student loans by key student characteristics. Table 4 reports uptake rates for private loans, computed as the percentage of each quantile of the joint distribution of family income and skill which has taken out a private student loan three years after they began college. Family income and skill quantiles are assigned using the distribution of each variable among high school graduates. Since access is a necessary condition for uptake, this table illustrates that college students from the poorest families and students in the lowest skill group have access to private student loans, like their richer and higher-skill peers.

To examine what is driving the findings of Table 4, we turn to industry reports and guides for potential private loan borrowers. Based on these sources, it seems that with most private lenders having a cosigner is a sufficient condition for access to private student loans at good terms, yet the presence of a qualifying cosigner is almost ubiquitous and not highly correlated with skill or family income. Indeed, it is quite rare to take out a private student loan without a cosigner: for the five largest private student lenders, 90 percent of undergraduate student loans issued since 2010 have had a cosigner (Amir et al., 2021).[16] Most adults qualify as co-signers for private student loans: for loan approval, the minimum credit score requirements range from none to 680, and even

[16]For students without a co-signer, it is much more difficult to get any private student loan in the freshman and sophomore years of college. However, in the junior and senior years of college, students with a credit score and a steady income can get a private student loan. For an example of a private student loan that does not require a cosigner, see Funding U., Inc. (2022).

co-signers without a credit score could still qualify with some lenders if their income is steady and meets a low threshold level (Holhoski et al., 2022).

Table 4: Private loan uptake

		High school GPA		
	Q	**1**	**2**	**3**
Household income	**1**	23	19	14
	2	27	31	26
	3	28	21	18
Obs	2,670			

Notes: Table 4 reports the percent of each cell that has a positive private student loan balance three years after enrollment. Percentages are rounded to the nearest percentage point. Rows are student family income quantiles using parents' income during high school in the distribution of high school graduates; columns are high school GPA quantiles assigned using the distribution of high school GPA among high school graduates. Sample: students who enrolled in a BA in the fall of 2013. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Weights are PETS-SR student records longitudinal weights.

The HSLS:09 does not report specifics of the private loan contracts signed by these college students, such as the loan's interest rate. Therefore, we turn to the 2019 SCF to compare interest rates on private and federal student loans. For a given family, the SCF records information on up to 6 student loans; each loan is associated with a separate set of variables which record responses to various questions about that loan, such as the interest rate or the type of loan (federal or private). We separate student loans into federal or private loans and report the mean, median, and standard deviation of interest rates within each group in Table 5, both overall and by the borrower outcome groupings of income, education, and delinquency status. These three statistics are very similar across the two loan types (column 2).[17] Columns 3 to 6 of Table 5 break down interest rates by income quantile, while the remaining four columns break down interest rates by graduate (that is, education outcome) status for all families and for families who are delinquent.[18] Along all of these margins, the difference between federal and private student loans in the mean or median interest rate is small. Even the standard deviation of the distribution of interest rates is quite similar across loan types. These findings indicate that private and federal student loans do not differ in their interest rates, and that the interest rates on private loans exhibit similar relationships to debtor attributes as the interest rates on federal loans (which are set by statute).

[17] The observed low standard deviation of private loan interest rates (comparable to federal interest rates) is likely because, as discussed above, most private student loans have a cosigner and having a cosigner leads to more favorable terms regardless of other student attributes (Holhoski et al., 2022).

[18] Graduate families (for whom the graduate status is "Yes") have completed at least one of the programs their education loans were taken out to pay for. Delinquent families have at least one education loan for which they are late making payments. See Table 34 in Supplementary Appendix D for mapping to SCF codebook variables.

Table 5: Student loan interest rates

Loan type	All families	All families Income quantile 1	2	3	All families Graduate status Yes	No	Delinquent families Graduate status Yes	No
Federal								
Mean	5.97	5.95	6.08	6.26	5.92	6.29	6.02	6.88
Median	5.50	5.50	5.32	5.96	5.50	5.60	6.00	6.00
SD	3.19	3.19	3.25	3.55	3.26	3.27	2.58	3.63
Obs	3,841	592	1,647	1,602	2,658	675	202	194
Private								
Mean	5.85	5.65	5.95	6.78	5.86	6.07	6.18	6.90
Median	5.84	6.00	4.85	6.38	5.84	5.40	6.70	6.00
SD	2.62	1.48	3.24	2.91	2.50	3.18	2.35	2.88
Obs	779	85	253	441	554	144	52	30

Notes: Table 5 reports interest rates for federal and private student loans for all families (column 2), by income quantile within all families (columns 3-5), by educational attainment within all families (columns 6 and 7), and by educational attainment within delinquent families (columns 8 and 9). Graduate families (for whom the graduate status is "Yes") have completed at least one of the programs their education loans were taken out to pay for. Delinquent families have at least one education loan for which they are late making payments. Source: 2019 SCF.

In the next section, we build a model framework that incorporates our empirical findings on over-optimism, college persistence, financial aid, and the private student loan market.

3 Model

Our model economy builds on Krueger and Ludwig (2016), Chatterjee and Ionescu (2012), and Luo and Mongey (2019). Motivated by our findings in Section 2, we enrich the general equilibrium life cycle model with college choice of Krueger and Ludwig (2016) by incorporating over-optimism about graduation likelihood. We also incorporate endogenous and exogenous college dropout, as in Chatterjee and Ionescu (2012), as well as key features of the U.S. market for student loans. The features of the federal student loan program are largely based on Luo and Mongey (2019) and the features of the private student loan market are based on empirical patterns we documented in Section 2.

3.1 Overview of the model environment

Time is discrete and runs forever; each period lasts one year. Although we compute transition paths for our analyses, we omit time subscripts here for the purpose of exposition. Let j denote the age of consumers; consumers start making decisions when they turn 18 at $j = 1$. At the beginning of $j = 1$, with an exogenous probability q, 18-year-old consumers may choose whether to go to college; otherwise, college is not an option, and they join the workforce without a college degree. This model feature captures reasons for which consumers may not go to college, such as personal or family reasons, that are not otherwise incorporated in our model.[19] The 18-year-old's college entrance decision will be based on their skill, e, idiosyncratic productivity, η, and initial net assets, a. Skill is an endowment that is drawn once from a conditional distribution which depends on parental education. The skill endowment determines several things: the consumer's expectations about their persistence probability in each year of college at the time of enrollment, the true probability of persisting given enrollment, deterministic earnings productivity, and grants for college from the government and private sources. The idiosyncratic productivity component of earnings follows a lag-1 auto-regressive, or AR(1), process that depends on completed schooling. Net assets are determined at the start of adulthood by a one-time inter-vivos transfer from the consumer's parent. After $j = 1$, assets are affected by the borrowing, repayment, and savings decisions of the consumer, as well as their own choice of transfers to their child.

When making the college entrance decision, consumers have potentially mistake beliefs about the probability of college graduation. At the time of enrollment, consumers with skill e believe they will continue their education in each year of college with probability $\hat{p}(e)$. The true annual probability of continuing a college education is given by the function $p_g(j, e)$. Consumers are overly optimistic as long as $\hat{p}(e) > p_g(j, e)$ for all e and j, with higher $\hat{p}(e) - p_g(j, e)$ implying higher over-optimism. Note that, if $\hat{p}(e) = p_g(j, e)$, consumers have the correct beliefs about the probability of persistence (and therefore about graduation likelihood). Our empirical findings in Section 2.1 indicate that college enrollees are overly-optimistic, and to a greater extent for those of lower skill. Our first policy experiment will be to eliminate over-optimism in the baseline parameterized model by setting $\hat{p}(e) = p_g(j, e)$.

In the model consumers learn their true probability of persisting in college immediately after enrollment. This assumption allows over-optimism to have the least affect on behavior.[20] After the first year of college, consumers may choose to leave college (endogenous dropout) or may be forced to leave college with an annual probability of $p_d(j, e) = 1 - p_g(j, e)$ (exogenous dropout). Exogenous dropout represents college students who leave due to a lack of academic ability.[21]

[19] See Table 31 in Supplementary Appendix C.3 for suggestive empirical evidence. An alternative modeling approach is to assume stochastic utility costs to go to college as in Abbott, Gallipoli, Meghir, and Violante (2019). Our approach can be interpreted as a nested version of stochastic utility costs, where with probability $1 - q$, the utility cost of college is large enough, so that those consumers will not go to college.

[20] In practice this assumption does not matter quantitatively: in Supplementary Appendix K we consider a sensitivity analysis where students never learn about their true graduation likelihood, and we find that the main welfare estimates barely change.

[21] This model attribute is also supported by the findings of Stinebrickner and Stinebrickner (2012); in that paper, the authors argue that it is heterogeneity in ability, rather than heterogeneity in effort, that drives the college dropout

In the model economy, college lasts 4 years. The benefits of graduating from college are higher labor earnings, a higher probability of having high-skill children, and higher Social Security transfers. Consumers must graduate from college to enjoy these benefits.[22] College students work part time, $\ell_{pt} < 1$, and therefore forego additional earnings from full time work; they also incur a college effort cost net of college consumption value, λ. The annual pecuniary cost of college (tuition and fees) is denoted by κ, and may be financed with any of the following sources: student loans borrowed from the federal student loan program, student loans borrowed from the private loan market, inter-vivos transfers from parents, grants from public and private sources, and earnings from part-time work.

The federal student loan program is characterized by a cumulative student loan limit $\bar{A}$ and a student loan interest rate $r_{SL} = r + \tau_{SL}$, where r is the risk-free savings interest rate and τ_{SL} is the add-on to the risk-free savings interest rate set by the government. For our second policy experiment, an expansion in federal student loan limits, we increase $\bar{A}$. Federal student loans are assessed interest starting from the year after the age of college graduation ($j > 4$). The assumption about interest accrual implies that there is an interest-free grace period for federal student loans for the duration of the college years (that is, student loans are subsidized).[23] Student loan payments are required to begin after the age of college graduation, and per-payment amounts are set so that, if there is no delinquency, the loan balance is paid off in T_{SL} years.

Consumers enrolled in college may also borrow from the private student loan market. We model the private loan market based on findings from our empirical analysis in Section 2. First, to capture the pecking order from federal to private student loans (Table 3), we introduce a psychic cost for acquiring private student loans, ξ^{pr}. This captures costs resulting from predatory lending, hidden fees, and the mental anguish of acquiring a co-signer, and makes private student loans an imperfect substitute for federal student loans. Second, we do not explicitly exclude any consumer from access to the private student loan market based on their type, which is consistent with private loan uptake observed in every cell of the joint distribution of family income and student skill (Table 4). Third,

decision. For example, even for students in the same major who put in the same hours of study, they find significant differences in academic performance.

[22] In Supplementary Appendix B.1, we show that, relative to having only a high school degree, the marginal effect of some college (college dropouts or those with an associate's degree) on age profiles of earnings is approximately zero.

[23] The federal student loan program modeled here abstracts from unsubsidized loans and other institutional features of the federal student loan program such as loan fees and the Expected Family Contribution (EFC). In Supplementary Appendix III, we show that our main findings do not change if we incorporate a higher add-on for the student loan interest rate as a sensitivity analysis for the lack of unsubsidized loans and loan fees in our model economy. We do not view the lack of EFC as a concern for our findings because the borrowing limits we currently use represent upper bounds on yearly loan amounts, and introducing heterogeneity in borrowing limits resulting from EFCs would simply constrain some agents more and leave others unchanged, relative to our model baseline. For this reason we view our policy experiment results as lower bounds relative to a framework that directly modeled with EFCs.

we incorporate a student loan issuance cost that is common to both private and federal student loans, τ_{is}, to capture the fact that the mean and median of private student loan interest rates are roughly the same as federal student loan interest rates (Table 5). Fourth and finally, to capture the lack of dispersion in private student loan interest rates by key characteristics (Table 5), we assume that risk-neutral competitive lenders cannot price-discriminate by family income or student skill (or any other characteristics). This means that private lenders pool each cohort of students for the purpose of pricing their loans, which leads to a single interest rate for private student loans, r^{pr}_{SL}.[24]

After the age of college graduation, consumers with a positive student loan balance (federal, private, or both) may be either college graduates or dropouts. At this point in the life cycle, consumers must begin to make decisions about whether to make their required loan payments: in particular, they may choose to repay only federal loans, only private loans, both types of loans, or neither type of loan.[25] Upon paying off their student loans, consumers may save and solve a standard consumption-savings problem.[26] Consumers who do not make payments on their student loans are considered delinquent, and their disposable income above $\bar{y}$ is garnished at the rate τ_g. Delinquent debtors also incur a penalty fee equal to a fraction ϕ_D of the missed payment for the particular year and loan on which they are delinquent; this penalty fee captures a collection fee. The penalty fee and the missed payment are added to the outstanding balance for the next period.[27] Besides these pecuniary costs, delinquent consumers also incur a stigma cost indexed to the type of loan, where ξ_D and ξ^{pr}_D denote the stigma costs for federal and private loans, respectively.

All consumers have a child at the fertile age, j_f. This child will grow up and leave the household at adulthood, which occurs j_a years after birth. At the beginning of the period when the child leaves the household, as in Krueger and Ludwig (2016) and Abbott, Gallipoli, Meghir, and Violante

[24]We have one market for private student loans because most loans are co-signed. We could incorporate another market for student loans that are not co-signed with worse terms. This would make private student loans even more of an imperfect substitute for federal student loans, in which case the welfare implications from the federal loan limit expansion policy experiment will be larger. Therefore, our model specification likely makes the magnitude of welfare changes we find lower bounds.

[25]It is important to note that it is not possible to default on either a federal or a private student loan and have the outstanding debt written off. This is consistent with the U.S. federal student loan system, as well as with private student loan policies. In both cases, student loans may eventually be classified as defaulted loans, but are almost never discharged.

[26]We assume that student loans must be paid off for consumers to save because this reduces the state space necessary to represent asset positions (assets, federal student loans, and private student loans) from three to two elements. This assumption is consistent with optimizing behavior by the consumer in an environment in which consumers cannot be delinquent, because in that case the optimal strategy would be to pay off all loans and not save as long as the interest rates on loans are higher than the savings interest rate. The interest rates are ordered in this way in our framework. This incentive is somewhat offset in our framework because of the delinquency choice we incorporate, but it is not a quantitatively significant concern.

[27]These delinquency rules reflect the current U.S. system, where private lenders are allowed to garnish student loans as long as they acquire a court order. See Yannelis (2020) for more institutional details on federal student loan delinquency and penalties.

(2019), each parent make an inter-vivos transfer to their child after observing the child's skill, e_c. This transfer is motivated by parental altruism, where the parent has (potentially mistaken) beliefs about the likelihood of their child persisting successfully towards college completion that are built into the altruism term included in their objective function. The parameterized model will feature parents who are overly optimistic about their child's graduation likelihood, reflecting our findings in Section 2.1.

Consumers retire at age j_r. At this point, they stop working and receive Social Security transfers. Consumers survive each period with probability ψ_j, and live for a maximum of J periods.

The government, in addition to running the federal student loan program, providing grants for college education, and providing Social Security, also incurs an exogenous government consumption requirement expressed as a fixed fraction g of gross domestic product (GDP). Government expenditures are financed with tax revenue generated from progressive income taxes as well as consumption taxes at a flat rate. Only the income tax rate adjusts to balance the government's budget constraint in every period.

Lastly, output is produced by a final goods firm, which operates a Cobb-Douglas production technology in which the inputs are capital and efficiency units of labor.

3.2 Primitives of the consumer life cycle problem

This section describes the various primitives of the consumer's life cycle problem in more detail. Subsequently, we provide and explain the value functions that consumers solve at each stage of their life.

College dropout and continuation probabilities Dropping out of college can occur due to an exogenous shock or by choice. As mentioned above, $p_d(j, e)$ denotes the true annual exogenous probability of dropping out of college, which is determined by two objects which both depend on skill:

$$p_d(j, e) = (1 - p(e))\rho_d(e)^{j-1} \tag{1}$$

where $1 - p(e)$ is the common probability of not continuing in college in any year of enrollment, and $\rho_d(e)$ is the persistence of the probability of dropping out of college conditional on college year. To illustrate, if $1 - p(e)$ is high, the student is more likely to drop out of college. If $\rho_d(e)$ is low, then the college dropout probability is less persistent with each year of college, and hence, the student is less likely to drop out of college the longer they continue their education. The probability of continuing in each year of college, $p_g(j, e)$, is equal to $1 - p_d(j, e)$.

Student loan payments As mentioned above, consumers (graduates or dropouts) are expected to make payments starting at age $j = 5$. Both federal and private loans are expected to be paid off in T_{SL} years. Equation (2) specifies the full payment function $\rho_R(a, j)$ for federal student loans.

$$\rho_R(j,a) = \begin{cases} -\frac{r_{SL}}{1-(1+r_{SL})^{-(T_{SL}+5-j)}}a & \text{if } a < 0 \text{ and } 4 < j \leq T_{SL}+4 \\ -(1+r_{SL})a & \text{if } a < 0 \text{ and } j > T_{SL}+4 \\ 0 & \text{otherwise } (a > 0) \end{cases} \tag{2}$$

If there is an outstanding balance (i.e., $a < 0$) and if j is still within the standard repayment period so that $4 < j \leq T_{SL} + 4$, the loan is amortized with an interest rate of r_{SL} (first case in equation (2)). If there is an outstanding loan balance and the standard repayment period has expired ($j > T_{SL} + 4$), then the outstanding principal plus interest is due (second case in equation (2)). If $a > 0$, then there is no student loan debt, and hence, no payment.

Instead of repayment, consumers may choose delinquency. Loans in delinquency are not discharged. Instead the consumer's disposable income income above $\bar{y}$ is garnished at the rate τ_g. This leads to a partial payment function in delinquency given by

$$\rho_D(j,a,y) = \min[\tau_g \max[y - T(y) - \bar{y}, 0], \rho_R(j,a)] \tag{3}$$

where the garnishment amount is bounded above at the full payment amount $\rho_R(j, a)$.

College students can also borrow from the private student loan market. We use x to denote the outstanding private student loan balance. The payment structure for private student loans is the same as the payment structure for federal student loans. When consumers borrow on the private market ($x > 0$), they are expected to pay off the private loan T_{SL} years after the age of college graduation. The loan is amortized with an interest rate r_{SL}^{pr}. Unlike the federal student loan interest rate, which is set by the government, the interest rate for private student loans is determined by market forces in a pooling equilibrium (see equation (25) in Supplementary Appendix F). If private loans are not fully paid off within T_{SL} years, all loans and interest become due every year until the balance is fully repaid. The full payment function for private student loans is given by

$$\rho_R^{pr}(j,x) = \begin{cases} \frac{r_{SL}^{pr}}{1-(1+r_{SL}^{pr})^{-(T_{SL}+5-j)}}x & \text{if } x > 0 \text{ and } 4 < j \leq T_{SL}+4 \\ (1+r_{SL}^{pr})x & \text{if } x > 0 \text{ and } j > T_{SL}+4 \\ 0 & \text{otherwise } (x = 0) \end{cases} \tag{4}$$

If consumers are delinquent on private loans, their disposable income above a threshold $\bar{y}$ is garnished at the rate τ_g. Similar to the federal loan partial payment function, the partial payment for private loans is capped at the full payment amount $\rho_R^{pr}(j,x)$, and is given by

$$\rho_D^{pr}(j,x,y) = \min[\tau_g \max[y - T(y) - \bar{y}, 0], \rho_R^{pr}(j,x)] \tag{5}$$

Preferences A consumer's utility depends on total household consumption, c, the consumer's age, j (which determines whether or not they have a child), and their schooling status, $s \in \{h, \ell\}$. It is given by

$$U(c,j,s) = \frac{\left(\frac{c}{1+\zeta\,\mathbb{I}_{j\in\{j_f,..,j_f+j_a-1\}}}\right)^{1-\sigma}}{1-\sigma} - \lambda 1_{s=h \text{ and } j\in\{1,2,3,4\}} \tag{6}$$

where h refers to a high-education consumer who is either enrolled in college or is a college graduate, and ℓ refers to a low-education consumer who did not go to college or who dropped out of college. Together with j, s indicates whether or not a consumer is in college. Utility exhibits constant relative risk aversion over per-capita household consumption, with a relative risk aversion given by σ. When the child lives with the parent, $j \in \{j_f, .., j_f + j_a - 1\}$, the child will be included in total household consumption with an adult equivalence parameter ζ. Note that college students, for whom $s = h$ and $j \in \{1, 2, 3, 4\}$, are subject to an effort cost net of college consumption value, represented by λ.

Income Income depends on age, education, skill, AR(1) earnings productivity, and net assets, summarized by the tuple (j, s, e, η, a). Positive net assets are indicated by $a > 0$ and these savings earn an interest rate r (recall that federal student loan balances are indicated by $a < 0$). The remaining elements of the tuple determine the income function y, which is given by

$$y_{j,s,e,\eta,a} = \begin{cases} s = h & \begin{cases} w\epsilon_{j,\ell,e}\eta\ell_{pt} & \text{if } j = 1 \\ w\epsilon_{j,\ell,e}\eta\ell_{pt} + r\max(a,0) & \text{if } 1 < j \leq 4 \\ w\epsilon_{j,h,e}\eta + r\left[\max(a,0) + Tr_j\right] & \text{if } 4 < j < j_r \\ ss_{h,e} + r\max(a,0) & \text{if } j \geq j_r \end{cases} \\ s = l & \begin{cases} w\epsilon_{j,\ell,e}\eta & \text{if } j = 1 \\ w\epsilon_{j,\ell,e}\eta + r\left[\max(a,0) + Tr_j\right] & \text{if } 1 < j < j_r \\ ss_{\ell,e} + r\max(a,0) & \text{if } j \geq j_r \end{cases} \end{cases} \tag{7}$$

where w is the wage rate and $\epsilon_{j,s,e}$ is a deterministic life cycle productivity component that depends on age, education level, and skill. Tr_j is accidental bequests, which depends on age; accidental bequests are a consequence of the assets of the deceased being greater than zero.

When consumers first enter the labor market at age 18 ($j = 1$), their only source of income is labor earnings. If they choose to go to college ($s = h$), they work part time ($\ell_{pt} < 1$) and receive $w\epsilon_{j,\ell,e}\eta$ in labor earnings per unit of labor supply. Note that, because this consumer is still in college, their life cycle productivity component is indexed to $s = \ell$, and their AR(1) productivity component are drawn from the distribution for $s = \ell$. If a working-age consumer does not go to college or drops out of college ($s = \ell$), thereafter they work full time and receive $w\epsilon_{j,\ell,e}\eta$ in labor earnings (labor supply is inelastic and equal to one for all those not enrolled). If a working-age consumer is a college graduate, they also work full time thereafter and their labor earnings is given by $w\epsilon_{j,h,e}\eta$. In this case, the deterministic life cycle component, $\epsilon_{j,h,e}$, and the AR(1) productivity component, η, are drawn from the distribution for $s = h$. When consumers retire at age j_r, they receive Social Security $ss_{s,e}$. The level of Social Security transfer a consumer receives depends on both their education and skill (see equation (26) in Supplementary Appendix F for the payment function).

After the first year of adulthood, when $j > 1$, consumer income includes any interest from positive net assets and accidental bequests, $r[\max[a, 0] + Tr_j]$, in addition to labor earnings or Social Security. When consumers are 18, at $j = 1$, they receive an inter-vivos transfer from their parents. Interest income on the inter-vivos transfer accrues to the parents, not the transfer recipient.

3.3 Consumer problems before college graduation age (j ≤ 4)

Given their type, (e, η, a), which reports skill, e, idiosyncratic AR(1) productivity, η, and net assets, a, an 18-year-old ($j = 1$) has a value function given by

$$\begin{aligned}\hat{W}(e,\eta,a) =& q\Big[\max_{\hat{d}_s\in\{0,1\}}(1-\hat{d}_s)V(1,\ell,e,\eta,a,x=0)+\hat{d}_s\hat{V}(1,h,e,\eta,a,x=0)\Big] \\ &+ (1-q)V(1,\ell,e,\eta,a,x=0)\end{aligned} \tag{8}$$

With probability q, the consumer may make a discrete college entrance decision by choosing $\hat{d}_s \in \{0, 1\}$, where $V(1, \ell, e, \eta, b, x = 0)$ is the value of not going to college, and $\hat{V}(1, h, e, \eta, a, x = 0)$ is the over-optimistic value of going to college. The first element in value functions V and $\hat{V}$ denotes age (everyone starts from age 1 when making college entrance decisions), and the second element represents college choices (ℓ denotes high school or some college while h denotes a college student or a college graduate). The last element, x, represents the balance of private student loans and is set to 0, to reflect that no one has taken out any private student loans at age 18. With exogenous probability $1 - q$, the consumer does not have the option to enroll, and proceeds through life as a low-education worker with $s = \ell$.

The value of not going to college or dropping out for $j \leq 4$ is given by

$$V(j,\ell,e,\eta,a,x) = \max_{c\geq 0,a'} U(c,j,\ell) + \beta\psi_j E_{\eta'|\ell,\eta} V(j+1,\ell,e,\eta',a',x) \tag{9}$$

$$s.t.$$

$$(1+\tau_c)c + a' = y_{j,e,\ell,\eta,a} + a + Tr_j - T(y_{j,e,\ell,\eta,a})$$

$$a' \begin{cases} a' = a & \text{if } \ a < 0 \\ \geq 0 & \text{otherwise} \end{cases}$$

where β is the discount factor, τ_c is the consumption tax rate, and $T(y_{j,\ell,e,\eta,a})$ is the income tax function which will be defined in Subsection 3.5. As in Krueger and Ludwig (2016), the AR(1) productivity process depends on completed schooling. Therefore, this consumer draws their next period AR(1) productivity from the expectation operator that depends on ℓ, in addition to the current shock, η. For consumers who drop out of college and therefore solve (9), the stock of any student debt is frozen at a until $j > 4$, at which point they begin repaying their loan. For consumers who never enroll in college, net assets are always weakly positive because student loans are the only form of borrowing in our model environment, and are available only while enrolled in college.

At the time of the college enrollment decision, consumers compute the expected value of college using their expected probability of continuing in each year of college, $\hat{p}(e)$, whereas the true probability of continuing is $p_g(j,e)$. Our empirical evidence presented in Section 2 indicates that consumers are overly optimistic in their beliefs at the enrollment stage, so we refer to the value functions based on their beliefs as "overly optimistic". The overly-optimistic value of college for $j = 1, 2, 3$ is given by

$$\hat{V}(j,h,e,\eta,a,x) = \max_{\hat{c}\geq 0,\hat{a}',\hat{x}'} U(c,j,h) - \xi 1_{a\geq 0 \text{ and } x=0 \text{ and } (\hat{a}'<0 \text{ or } \hat{x}'>0)} - \xi^{pr} 1_{x=0 \text{ and } \hat{x}'>0} \tag{10}$$

$$+ \beta\psi_j E_{\eta'|\ell,\eta}\Big[\hat{p}(e)\max[\hat{V}(j+1,h,e,\eta',\hat{a}',\hat{x}'), V(j+1,\ell,e,\eta',\hat{a}',\hat{x}')] + (1-\hat{p}(e))V(j+1,\ell,e,\eta',\hat{a}',\hat{x}')\Big]$$

$$s.t.$$

$$(1+\tau_c)\hat{c} + \hat{a}' + (1-\theta(e)-\theta^{pr}(e))\kappa = y_{j,h,e,\eta,a} + a + Tr_j - T(y_{j,h,e,\eta,a}) + (\hat{x}'-x)$$

$$\hat{a}' \geq -\bar{A}\left(\tfrac{j}{4}\right)[(1-\theta(e)-\theta^{pr}(e))\kappa + \bar{c}]$$

$$\hat{a}' \leq a \ \text{ if } \ a \leq 0$$

$$\hat{x}' - x \in \Big[0, [(1-\theta(e)-\theta^{pr}(e))\kappa + \bar{c}] - [\max(-\hat{a}',0) - \max(-a,0)]\Big]$$

where ξ is the psychic cost of acquiring any student loan and ξ^{pr} is the additional costs associated with acquiring any private student loans.[28] Parameters $\theta(e)$ and $\theta^{pr}(e)$ are the share of tuition and fees that are paid for by public and private grants, respectively, and are a function of skill; $\bar{c}$ is the amount that can be borrowed for room and board expenses while in college. These consumers may also choose to drop out after the first year of college, which is captured by the expression $\max[\hat{V}(j+1, h, e, \eta', \hat{a}', \hat{x}'), V(j+1, \ell, e, \eta', \hat{a}', \hat{x}')]$. College students can borrow from federal student loans up to a limit equal to $\bar{A}\left(\frac{j}{4}\right)[(1-\theta(e)-\theta^{pr}(e))\kappa+\bar{c}]$, where $\bar{A}$ represents the number of years worth of net tuition and fees, plus room and board expenses, that the federal student loan limit can cover.[29] Students can also borrow additional funds from the private student loan market. The last constraint, which is the limit constraint for private student loans, requires that the flow amount borrowed from private student loans in a given year must not exceed tuition plus room and board costs net of any other financial aid (public and private grants and federal loans).

The overly-optimistic value for the final year of college, when $j = 4$, is presented in equation (23) in Supplementary Appendix E. When constructing this value, the post-college continuation value conditional on graduation is based on $E_{\eta'|h,\eta}$ rather than $E_{\eta'|\ell,\eta}$. Furthermore, there will be no endogenous dropout decision in the continuation value at this age, because in the next period the consumer will have graduated from college. The rest of the value function for the final year of college remains unchanged from previous years.

Note that when consumers make the college entrance decision in equation (8), they are overly optimistic and will use the inflated value of college from (10) to compute their expected value. However, we assume that consumers learn their true dropout probabilities in the first year of college so that, while enrolled, the consumer's realized consumption-savings and dropout decisions are

[28] Psychic costs of getting any student loan can be thought of as mental anguish from completing paperwork, which may be excessively complicated as noted by Dynarski and Scott-Clayton (2008) and Dynarski, Libassi, Michelmore, and Owen (2021). Costs particular to private loans capture predatory lending and hidden fees; this parameter allows for a pecking order for borrowing first from federal student loans and then private student loans as noted in Table 3.

[29] For example, if $\bar{A}$ is equal to four, then the student loan limit is equal to four years of net tuition and fees, plus room and board. The multiplier $\frac{j}{4}$ is an adjustment for the fact that the total student loan limit increases with each year of college.

based on the following value function for $j = 1, 2, 3$

$$
\begin{aligned}
&V(j,h,e,\eta,a,x) = \max_{c\geq 0,a',x'} U(c,j,h) \; - \xi 1_{a\geq 0 \text{ and } x=0 \text{ and } (a'<0 \text{ or } x'>0)} - \xi^{pr} 1_{x=0 \text{ and } x'>0} \qquad (11)\\
&+ \beta\psi_j E_{\eta'|\ell,\eta}\Bigg[p_g(j,e)\max[V(j+1,h,e,\eta',a',x'), V(j+1,\ell,e,\eta',a',x')]\\
&+ (1-p_g(j,e))V(j+1,\ell,e,\eta',a',x')\Bigg]\\
&s.t.\\
&(1+\tau_c)c + a' + (1-\theta(e)-\theta^{pr}(e))\kappa = y_{j,h,e,\eta,a} + a + Tr_j - T(y_{j,h,e,\eta,a}) + (x'-x)\\
&a' \geq -\bar{A}\left(\tfrac{j}{4}\right)[(1-\theta(e)-\theta^{pr}(e))\kappa + \bar{c}]\\
&a' \leq a \;\; \text{if} \;\; a \leq 0\\
&x' - x \in \Bigg[0, [(1-\theta(e)-\theta^{pr}(e))\kappa + \bar{c}] - [\max(-a',0) - \max(-a,0)]\Bigg]
\end{aligned}
$$

The only difference between this value function and the overly-optimistic value function given by (10) is that, in (11), consumers use the true probabilities of continuing in each year of college, $p_g(j,e)$, rather than the over-optimistic probability, $\hat{p}(e)$, when computing their value of being enrolled in college. Again, in the final year of college ($j = 4$), the consumer's value of college will be computed using equation (23) in Supplementary Appendix E, with the exception that the consumer will use the true probability of graduation rather than the over-optimistic probability of graduation.

3.4 Consumer problems after college graduation age (j > 4)

Consumers begin student loan repayment the year after college graduation age, regardless of whether or not they complete college.[30]

For all $j > 4$, consumers choose between repayment of both student loans, delinquency on only federal student loans, delinquency on only private student loans, or delinquency on both federal and private student loans. The idiosyncratic state of a consumer while $j > 4$ and $j \neq j_f + j_a$ is given by the tuple (j, s, e, η, a, x). Their value function is given by

$$
\begin{aligned}
&V(j,s,e,\eta,a,x) = \max_{d_f\in\{0,1\},d_x\in\{0,1\}} (1-d_f)(1-d_x)V^R(j,s,e,\eta,a,x) + \qquad (12)\\
&d_f(1-d_x)V^{D_f}(j,s,e,\eta,a,x) + (1-d_f)d_xV^{D_x}(j,s,e,\eta,a,x) + d_fd_xV^D(j,s,e,\eta,a,x)
\end{aligned}
$$

[30]In the United States, federal student loans typically have a six month grace period after graduation in which repayment does not need to be made. Since our model period is one year, we assume that repayment starts at $j = 5$, right after graduation. For simplicity, we assume that payments begin in the same age for dropouts.

where $d_f \in \{0,1\}$ and $d_x \in \{0,1\}$ denote the federal and private student loan delinquency decisions, respectively. $V^R(j,s,e,\eta,a,x)$ denotes the value of repayment on both loans, $V^{D_f}(j,s,e,\eta,a,x)$ denotes the value of delinquency on only federal loans, $V^{D_x}(j,s,e,\eta,a,x)$ denotes the value of delinquency on only private loans, and $V^D(j,s,e,\eta,a,x)$ denotes the value of delinquency on both types loans.

The value of repayment for $j > 4$ and $j \neq j_f + j_a$ is given by

$$V^R(j,s,e,\eta,a,x) = \max_{c \geq 0, a'} U(c,j,s) + \beta\psi_j E_{\eta'|s,\eta} V(j+1,s,e,\eta',a',x') \tag{13}$$

$$s.t.$$

$$(1+\tau_c)c + a' = y_{j,s,e,\eta,a} + a + 1_{\{a<0\}} r_{SL} a + Tr_j - T(y_{j,s,e,\eta,a}) - \rho_R^{pr}(j,x)$$

$$a' \begin{cases} = (1+r_{SL})a + \rho_R(j,a) & \text{if } a < 0 \\ \geq 0 & \text{if } a \geq 0 \text{ and } x = 0 \\ = 0 & \text{otherwise } (a \geq 0 \text{ and } x > 0) \end{cases}$$

$$x' = x(1+r_{SL}^{pr}) - \rho_R^{pr}(j,x)$$

A consumer who chooses repayment must make a payment equal to $\rho_R(j,a)$ on their federal student loans. If this consumer has outstanding federal loans (i.e., $a < 0$), then $a' = a(1+r_{SL}) + \rho_R(j,a)$. Consumers with private student loans must make a payment equal to $\rho_R^{pr}(j,v,x)$. As in Ionescu and Simpson (2016), we assume consumers cannot choose to pay down their federal or private loans faster than the required payment amount. If the consumer has paid off their student loans so that $a \geq 0$ and $x = 0$, then they may save by choosing $a' > 0$.

Alternatively, consumers can choose delinquency on either type of loan or on both loans. If a consumer chooses delinquency on only federal loans, their value function for $j > 4$ and $j \neq j_f + j_a$ is given by

$$V^{D_f}(j,s,e,\eta,a,x) = U(c,j,s) - \xi_D + \beta\psi_j E_{\eta'|s,\eta} V(j+1,s,e,\eta',a',x') \tag{14}$$

$$s.t.$$

$$(1+\tau_c)c = y_{j,s,e,\eta,a} + Tr_j - T(y_{j,s,e,\eta,a}) - \rho_D(j,a,y_{j,s,e,\eta,a}) - \rho_R^{pr}(j,x)$$

$$a' = (1+r_{SL})a + \rho_D(j,a,y_{j,s,e,\eta,a}) - \phi_D[\rho_R(j,a) - \rho_D(j,a,y_{j,s,e,\eta,a})]$$

$$x' = x(1+r_{SL}^{pr}) - \rho_R^{pr}(j,,x)$$

where ξ_D is the stigma cost of choosing delinquency on federal loans. In the case of non-repayment of federal loans, consumers do not make a consumption-savings decision. Instead, they have their wage garnished to make a partial payment of $\rho_D(j, a, y_{j,s,e,\eta,a})$. Therefore, they consume whatever remains from their disposable income, plus accidental bequests, after making the partial payment on federal loans and full payment on private loans. As mentioned in Section 3.2, ϕ_D is the fraction of missed payment (difference between full payment and partial payment) that is charged as a collection fee. The outstanding principal plus interest is then augmented by the missed payment plus the collection fee (net of any partial payment). Similarly, if a consumer chooses delinquency on only private loans, their value function for $j > 4$ and $j \neq j_f + j_a$ is given by

$$
\begin{aligned}
&V^{D_x}(j, s, e, \eta, a, x) = U(c, j, s) - \xi_D^{pr} + \beta\psi_j E_{\eta'|s,\eta} V(j+1, s, e, \eta', a', x') \qquad (15)\\
&s.t.\\
&(1+\tau_c)c + a' = y_{j,s,e,\eta,a} + a + 1_{\{a<0\}} r_{SL} a + Tr_j - T(y_{j,s,e,\eta,a}) - \rho_D^{pr}(j, x, y_{j,s,e,\eta,a})\\
&a' = 1_{a<0}(1+r_{SL})a + \rho_R(j, a)\\
&x' = (1+r_{SL}^{pr})x - \rho_D^{pr}(j, x, y_{j,s,e,\eta,a}) + \phi_D[\rho_R^{pr}(j, x) - \rho_D^{pr}(j, x, y_{j,s,e,\eta,a})]
\end{aligned}
$$

where ξ_D^{pr} is the stigma cost of choosing delinquency on private loans. As in the case of delinquency on only federal loans, here the consumer does not make a consumption-savings decision. Instead, they pay the fixed amount of federal student loans repayment $\rho_R(j, a)$, and they are subject to wage garnishment due to delinquency on private loans. The garnishment amount is denoted by $\rho_D^{pr}(j, x, y_{j,s,e,\eta,a})$ as described in Section 3.2. Similar to the case of delinquency on federal loans, the consumer faces a collection fee, which is equal to a fraction ϕ_D multiplied by the difference between full payment and partial payment on private loans.

Lastly, the value of choosing delinquency on both types of loans is given by

$$
\begin{aligned}
&V^D(j, s, e, \eta, a, x) = U(c, j, s) - \xi_D - \xi_D^{pr} + \beta\psi_j E_{\eta'|s,\eta} V(j+1, s, e, \eta', a', x') \qquad (16)\\
&s.t.\\
&(1+\tau_c)c = y_{j,s,e,\eta,a} + Tr_j - T(y_{j,s,e,\eta,a}) - \rho_D(j, a, y_{j,s,e,\eta,a}) - \rho_D^{pr}(j, x, y_{j,s,e,\eta,a})\\
&a' = (1+r_{SL})a + \rho_D(j, a, y_{j,s,e,\eta,a}) - \phi_D[\rho_R(j, a) - \rho_D(j, a, y_{j,s,e,\eta,a})]\\
&x' = (1+r_{SL}^{pr})x - \rho_D^{pr}(j, x, y_{j,s,e,\eta,a}) + \phi_D[\rho_R^{pr}(j, x) - \rho_D^{pr}(j, e, x, y_{j,s,e,\eta,a})]
\end{aligned}
$$

A consumer who chooses this outcome is subject to stigma cost, wage garnishment, and a collection fee (analogous to the previous two cases) both from the federal student loan program and the private lender; their consumption for the current period and outstanding loan balances for the next period follow from the same set of delinquency rules described above.

We assume that parents are altruistic towards their children. Parents make a one-time familial inter-vivos transfer when their child leaves the household at parent age $j = j_f + j_a$, after observing their child's skill e_c. The child becomes an independent decision maker starting in the period in which they receive the transfer. The parent's value function is given by

$$V(j,s,e,\eta,a,x) = \sum_{e_c} \pi(e_c|s)\big[\max_{d_f\in\{0,1\},d_x\in\{0,1\}}(1-d_f)(1-d_x)V^R(j,s,e,\eta,a,x,e_c)+ \tag{17}$$
$$d_f(1-d_x)V^{D_f}(j,s,e,\eta,a,x,e_c)+(1-d_f)d_xV^{D_x}(j,s,e,\eta,a,x,e_c)+d_fd_xV^D(j,s,e,\eta,a,x,e_c)\big],$$

where $\pi(e_c|s)$ is the conditional distribution over child skill given parent schooling level. The value of repayment for $j = j_f + j_a$ is given by

$$V^R(j,s,e,\eta,a,x,e_c) = \max_{c\geq 0,a',b} U(c,j,s) + \beta\psi_j E_{\eta'|s,\eta}V(j+1,s,e,\eta',a',x') + \beta_c E_{\eta'|\ell}\hat{W}(e_c,\eta',b) \tag{18}$$

$$s.t.$$
$$(1+\tau_c)c + a' + b = y_{j,s,e,\eta,a} + a + 1_{\{a<0\}}r_{SL}a + Tr_j - T(y_{j,s,e,\eta,a}) - \rho_R^{pr}(j,x)$$
$$a'\begin{cases} = (1+r_{SL})a + \rho_R(j,a) & \text{if } a<0 \\ \geq 0 & \text{if } a\geq 0 \text{ and } x=0 \\ = 0 & \text{otherwise } (a\geq 0 \text{ and } x>0)\end{cases}$$
$$x' = x(1+r_{SL}^{pr}) - \rho_R^{pr}(j,x)$$
$$b\begin{cases} = 0 & \text{if } a<0 \text{ or } x>0 \\ \geq 0 & \text{otherwise } (a\geq 0 \text{ and } x=0)\end{cases}$$

where b is the familial inter-vivos transfer, $\hat{W}(e_c,\eta',b)$ is the child's value function, and β_c disciplines the intensity of parental altruism towards the child. Note that because the parent uses $\hat{W}(e_c,\eta',b)$ for their child's lifetime utility, the parent continuation value for their child incorporates potentially mistaken beliefs, which we document as being overly optimistic in the data in Section 2. The child's AR(1) productivity η' is drawn from the stationary distribution for a consumer without a college degree. If the parent has any federal or private student loans, they will not make a familial inter-vivos transfer to their child ($b=0$), which is consistent with the assumption that consumers cannot save until they have paid off their student loans.[31]

When $j = j_f + j_a$ and the consumer chooses delinquency, we assume those consumers cannot make a familial inter-vivos transfer in order to be consistent with our assumption that consumers cannot

[31] In the initial stationary equilibrium, this situation is rare: only 0.2 percent of consumers at age $j = j_f + j_a$ have any unpaid student debt.

save until they have paid off their student loans. Therefore, the value functions for delinquency are largely the same as in equations (14)-(16), with the difference that the parent has a term reflecting altruistic utility towards their child, represented by the addition of $\beta_c E_{\eta'|l} \hat{W}(e_c, \eta', b = 0)$ to the objective function.

3.5 The government budget constraint and production firm problem

The government collects consumption and income taxes. The income tax function follows Heathcote, Storesletten, and Violante (2017), and is given by

$$T(y) = y - \gamma y^{1-\tau_p} \tag{19}$$

where τ_p governs the tax progressivity of income taxes and γ is used to balance the government budget constraint in every period (see equation (28) in Supplementary Appendix F). The government uses its tax revenue to finance government consumption, Social Security transfers, college grants, and the federal student loan program.

The production function is Cobb-Douglas given by

$$K^{\alpha}(ZL)^{1-\alpha} \tag{20}$$

where K is aggregate capital stock, Z is aggregate labor productivity, L is total efficiency units of labor, and α is the capital share. This production function assumes that an efficiency unit of labor from a college graduate is perfectly substitutable with an efficiency unit of labor from a worker without a college degree.[32] The capital stock depreciates at rate δ. The representative firm rents capital at an interest rate $r + \delta$ and hires workers at the wage rate w. The firm's profit maximization problem leads to standard conditions given by

$$r = \alpha K^{\alpha-1}(ZL)^{1-\alpha} - \delta \tag{21}$$

$$w = (1-\alpha)K^{\alpha}L^{-\alpha}Z^{1-\alpha} \tag{22}$$

The definition of the equilibrium is given in Supplementary Appendix F.

[32]Because the wage rate has small general equilibrium effects in our policy analyses, this assumption will not affect our results.

4 Model Parameterization

The parameters of this model are divided into those estimated externally, shown in Tables 6 and 7, and those calibrated inside the model, shown in Table 8.

The externally estimated parameters presented in Table 6 relate to education. Panel A reports parameters governing the federal student loan program. First, we set the aggregate federal student limit, $\bar{A}$, to the current cumulative borrowing limit for four years of college, normalized by the average annual net tuition and fees plus room and board.[33] The parameter value for $\bar{A}$, 1.49, therefore represents the number of years of college tuition and fees, plus room and board, that 4 years of annual limits are able to finance. The yearly limits we use to construct this parameter are for dependent students, who represent the vast majority of federal student loan borrowers.[34] We set the add-on for federal the student loan interest rate, τ_{SL}, to the announced value of 0.021 from FSA (2021), and the maximum number of years that one can be in repayment for a student loan, T_{SL}, to 10 based on CRS (2019).[35] The garnishment rate conditional on delinquency for both federal and private student loans, τ_g, is set to 15 percent as reported in Yannelis (2020).[36] The student loan penalty rate, ϕ_D, which is common to both federal and private loans, is set to 0.185 following Luo and Mongey (2019). This penalty rate represents collection costs for the loan provider.

Panel B of Table 6 reports the estimated proportional tuition subsidies (grants and scholarships) from public and privates sources, as well as the working time available during college. To estimate shares of college tuition subsidized by the government, $\theta(e)$, and shares of college tuition subsidized by private beneficiaries, $\theta^{pr}(e)$, we combine estimates from HSLS:09 with estimates from Krueger and Ludwig (2016). First, we compute shares of tuition subsidized via grants, from either government or private sources, by skill quantile in the HSLS:09. However, we cannot distinguish whether the subsidy was received from the government or a private source in the HSLS:09, so we additionally incorporate estimates from Krueger and Ludwig (2016) showing that government subsidies pay for 38.8 percent of total tuition and private subsidies pay for 16.6 percent of total tuition. This implies the government's share of total tuition subsidies is 70 percent and private beneficiaries' share of total tuition subsidies is 30 percent. To assign values to $\theta(e)$, we multiply the total share of tuition subsidized by the government or private entities by 0.7; to assign values

[33] This limit has been in place since July 1, 2012. In the federal student loan program, there are yearly limits and lifetime limits on borrowing. Yearly limits depend on one's academic year (freshman, sophomore, etc.). We use the cumulative limit over the first four years because college in our model lasts four years.

[34] See Table 31 in Supplementary Appendix C.3.

[35] In the U.S., those with student loans may choose between a standard repayment plan of 10 years and an income based repayment plan, which may have a repayment time frame ranging from 10 to 25 years.

[36] We set the garnishment rate for private loans equal to the garnishment rate for federal loans. This is consistent with the U.S. system where garnishment is allowed for delinquent private loans as long as the loan provider obtains a court order.

Table 6: Externally estimated parameters related to education

Parameter	Description	Data Target	Value
Panel A: Federal student loan program			
$\bar{A}$	Limit	Ave. 2016-2018, CRS (2019) and NCES (2019)	1.493
τ_{SL}	Interest rate add-on	FSA (2021)	0.021
T_{SL}	Maximum years to repay	CRS (2019)	10
τ_g	Federal SL garnishment rate	Yannelis (2020)	0.150
ϕ_D	Student loan penalty rate	Luo and Mongey (2019)	0.185
Panel B: Tuition subsidies and college working hours			
$\theta(e_1)$	Public tuition subsidy given e	HSLS:09, Table 27, and Krueger and Ludwig (2016)	0.286
$\theta(e_2)$			0.332
$\theta(e_3)$			0.360
$\theta^{pr}(e_1)$	Private tuition subsidy given e		0.122
$\theta^{pr}(e_2)$			0.142
$\theta^{pr}(e_3)$			0.154
ℓ_{pt}	Part-time working hours while in college	HSLS:09, Table 30	0.319
Panel C: Child skill distribution given parent schooling			
$\pi(e_{c,1}\|s=\ell)$	Parent does not have BA	HSLS:09, Table 30	0.424
$\pi(e_{c,2}\|s=\ell)$			0.343
$\pi(e_{c,3}\|s=\ell)$			0.233
$\pi(e_{c,1}\|s=h)$	Parent has BA		0.185
$\pi(e_{c,2}\|s=h)$			0.322
$\pi(e_{c,3}\|s=h)$			0.493

Notes: Panel A reports the policy parameters of the federal student loan program. Panel B reports the proportional tuition subsidy rates from public and private sources (i.e., grants and scholarships), and time spent working while in college. Panel C reports the conditional probability of drawing child skill e_c (high school GPA) given parental education s. Data sources are provided in the second column. Panels B and C use moments from the HSLS:09; see table notes in the the referenced tables above for survey weights used. HSLS:09 data source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Referenced tables with numbers above 12 are in the Supplementary Appendix.

to $\theta^{pr}(e)$, we multiply it by 0.3. The generosity of grants from both sources is increasing in the student skill quantile, e. Working hours while in college, ℓ_{pt}, is set to the average time spent working for students in their third year of a BA expressed as a fraction of full-time work (40 hours per week).

Panel C of Table 6 reports parameter values for $\pi(e_c|s)$, which is the conditional distribution of child skill given parental education. Note that, in the HSLS:09, parents with a college education are more likely to have children with higher skill (high school GPA), but nevertheless a significant fraction of children with highly educated parents are in the lowest skill bin, and a significant fraction of children with low-education families are in the highest skill bin.

Next, we turn to Table 7, which presents externally estimated parameters that are not related to education. Panel A reports parameters governing demographics. The first four rows in this panel contain the lengths of different phases of life. First, the fertility period, j_f, is set to 13, which implies consumers have a child when they turn 30; second, the number of years before the child moves out, j_a, is set to 18, which implies that consumers move out and make the college entrance decision when they turn 18; third, the retirement age, j_r, is set such that consumers retire at 65; and, fourth, the maximum life span J is set such that consumers live for at most 100 years. As in Krueger and Ludwig (2016), we set conditional survival probabilities ψ_j for $j = 1, ..., j_f + j_a - 1$ to one. This avoids there being children without parents in the model, which is a reasonable abstraction: young working-age consumers have high survival probabilities. For $j \geq j_f + j_a$ (that is, starting at age 48), we use estimates from the Social Security Administration life tables. Specific values for ψ_j are not reported in Table 7 because there is one value for each age j.

Panel B of Table 7 reports parameters which govern preferences and technologies in the model. The relative risk aversion parameter, σ, is set to 2 based on the findings of Chetty (2006). The capital share parameter, α, is set to 0.36, which is implied by a labor share of 0.64 as computed in Kydland and Prescott (1982).[37] The depreciation rate of capital, δ, is set to 0.076, as in Krueger and Ludwig (2016). To discipline the life cycle productivities $\epsilon_{j,s,e}$, which depend on age, j, education, s, and skill endowment, e, we impose functional form assumptions and then implement a modification of the estimation in Abbott, Gallipoli, Meghir, and Violante (2019). Our estimation procedure uses data from the Panel Study of Income Dynamics (PSID) and the NLSY97; it is described in detail in Supplementary Appendix B, with results summarized in Table 23.

Table 7: Externally estimated parameters not related to education

Parameter	**Description**	**Data Target**	**Value**
Panel A: Demographics			
j_f	Child bearing age	30 years	13
j_a	Years for child to move out	18 years	18
j_r	Retirement age	65 years	48
J	Maximum life span	100 years	83
ψ_j	Survival probability	SSA (2020)	-
Panel B: Preferences & technology			
σ	Risk aversion	Standard value, see Table 1 Panel D of Chetty (2006)	2
α	Capital share	Kydland and Prescott (1982)	0.360
δ	Depreciation rate	Krueger and Ludwig (2016)	0.076
$\epsilon_{j,s,e}$	Earnings life cycle profile	PSID and NLSY97, Table 23	See Table 23
Panel C: Government			
τ_c	Consumption tax rate	Krueger and Ludwig (2016)	0.050
τ_p	Income tax progressivity	Heathcote et al. (2017)	0.181
g	Government consumption	Ave. share of GDP 2016-2018, BEA (2022a) and BEA (2022b)	0.141

Notes: This table contains parameters set outside of the model which are not related to education. Panel A reports parameters that govern model demographics; Panel B reports those which govern preferences and technologies; Panel C reports government policy parameters that are set exogenously. Referenced tables with numbers above 12 are in the Supplementary Appendix.

Panel C, the last panel of of Table 7, contains values for parameters related to government policy.

[37] There is a lively and ongoing debate about time trends in the labor share—see for example the discussion in Grossman and Oberfield (2021). Our results are not sensitive to values of this parameter within the range of estimates in the literature.

The consumption tax rate τ_c is set to 5 percent as in Krueger and Ludwig (2016); the progressivity of the income tax function, τ_p, is set to 0.181 as in Heathcote, Storesletten, and Violante (2017); and, lastly, government consumption as a share of GDP, g, is set to 0.141 using estimates from the Bureau of Economic Analysis (BEA).

The remaining parameters, reported in Table 8, are internally calibrated to bring the model equilibrium as close as possible to target moments of the U.S. economy. Although parameters and moments are grouped in Table 8 using the most significant one-to-one relationship between each parameter and target moment, and are discussed accordingly, the parameters are calibrated jointly and each parameter can affect all targets moments. The first column of that table contains the parameter symbol; the second column, the parameter description; and the third column, the parameter value. Columns 4 through 6 contain the target moment's data source, the moment in the data, and the moment in the model, respectively.

Panel A of Table 8 presents parameters governed by moments from the HSLS:09. The first two objects are $p(e)$, which determines the true persistence probability, and the persistence of the true dropout probability, $\rho_d(e)$. Note that both of these objects depend on the student's skill endowment, e. These objects are governed by persistence rates to the fourth academic year (Y4), given enrollment in a 4-year degree (Y1), and persistence to the fourth academic year given persistence to the second academic year (Y2). The last two rows in Panel A contain the credit market frictions, ξ_L and ξ_L^{pr}, which determine loan search costs or debt aversion, and the particular cost of taking out a private loan, respectively. These parameters allow private loans to have an uptake cost which differs from that of federal student loans. For example, navigating the private student loan market could be more challenging than taking out a federal loan: private lenders may offer complex contracts with adverse terms hidden in the fine print, while federal loans are more standardized. It may also be more difficult to *find* a private lender, compared to federal loans borrowing from the government. Consistent with these examples, the calibrated parameter values for ξ_L and ξ_L^{pr} indicate that private loans must have a higher cost of uptake in order for the model to match the private loan uptake rate compared to the overall student loan uptake rate (federal or private). This pattern is the "pecking order" result discussed in Section 2.

Panel B of Table 8 reports parameters which are governed by moments from the NLSY97. These include the college effort cost net of the consumption value of college, λ, which is determined by observed college enrollment rates before age 25, as well as the college attendance probability, q, which represents unmodeled taste shocks or heterogeneous factors that lead some students to not attend college and is chosen to target the enrollment rate of the top skill quantile.[38] The parameter β_c, which governs the degree of parental altruism towards children, is set so that the model matches

[38]See Table 31 in Supplementary Appendix C.3 for suggestive evidence about the presence of such shocks.

Table 8: Internally calibrated parameters

Parameters			Moments		
Parameter	**Parameter Description**	**Value**	**Target Source**	**Data**	**Model**
Panel A: Moments from the HSLS:09					
$p(e_1)$	Persistence probability parameter given e	0.577	Enrolled year 4 if enrolled year 1, Table 30	*0.388*	*0.388*
$p(e_2)$		0.743		*0.563*	*0.563*
$p(e_3)$		0.913		*0.787*	*0.787*
$\rho_d(e_1)$	Dropout probability persistence given e	0.546	Enrolled year 4 if enrolled year 2, Table 30	*0.672*	*0.672*
$\rho_d(e_2)$		0.621		*0.757*	*0.757*
$\rho_d(e_3)$		0.878		*0.862*	*0.862*
ξ_L	Loan search and debt aversion cost	0.000	Uptake of student loans if persisted, Table 3	*0.650*	*0.610*
ξ_L^{pr}	Private loan uptake cost	4.002	Uptake of private loans if persisted, Table 3	*0.200*	*0.199*
Panel B: Moments from the NLSY97					
λ	College effort cost net of consumption value	0.000	Enrolled in BA by age 25, Table 16	*0.478*	*0.470*
q	College attendance probability	0.770	Enrolled in BA by age 25 if highest skill, Table 13	*0.770*	*0.770*
β_c	Parent altruism towards child	0.191	$\frac{\text{Average transfer}}{\text{GDP pc 18+ 2016-2018}}$, Table 17 and BEA (2022a)	*0.578*	*0.578*
$\hat{p}(e_1)$	Expected continuation probability given e	0.951	Expected graduation rate, Table 1	*0.809*	*0.818*
$\hat{p}(e_2)$		0.967		*0.872*	*0.874*
$\hat{p}(e_3)$		0.983		*0.934*	*0.936*
Panel C: Moments from other sources related to education					
$\bar{c}$	College room and board consumption	0.147	$\frac{\text{Average room + board}}{\text{GDP pc 18+ 2016-2018}}$, NCES (2019) and BEA (2022a)	*0.147*	*0.147*
κ	Annual tuition	0.171	Annual net tuition and fees, NCES (2019)	*0.088*	*0.088*
$\bar{y}$	Income exempt from garnishment	0.151	$\frac{\text{Exempt earnings}}{\text{GDP pc 18+ 2016-2018}}$, Yannelis (2020) and BEA (2022a)	*0.151*	*0.151*
ξ_D	Federal loan delinquency cost	0.190	Deliquency rate 2016-2018, FSA (2021)	*0.090*	*0.089*
ξ_D^{pr}	Private loan delinquency cost	1.275	$\frac{\text{Delinquent private debt}}{\text{Private debt in repayment}}$, Amir et al. (2021)	*0.074*	*0.075*
$\tau_{i,s}$	Student loan issuance cost	0.037	Interest rate comparison, Table 5	-	*0.065*
Panel D: Moments from other sources not related to education					
Z	Aggregate labor productivity	0.308	GDP pc 18+	*1.000*	*1.000*
β	Discount factor	0.972	Capital to output ratio, Figure 3 Jones (2016)	*3.000*	*3.000*
χ	Social Security replacement rate	0.187	$\frac{\text{SS expenditure}}{\text{GDP 2016-2018}}$, BEA (2022c) and BEA (2022a)	*0.048*	*0.048*

Notes: Panel A reports parameters related to data moments from the HSLS:09, where all moments use survey weights and specific weights used are noted in footnotes of referenced Tables; data source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Survey weights used are given in the referenced Tables of this panel. Panel B is parameters related to moments from the NLSY97; Panel C reports parameters and moments that use a variety of other sources and which are related to education; and Panel D presents parameters with related moments from a variety of other sources which are not related to education. Referenced tables with numbers above 12 are in the Supplementary Appendix.

average parent-to-child transfers in the NLSY97; Table 17 in Supplementary Appendix A.2 and surrounding discussion contain more information on how average transfers are computed. Lastly, Panel B also includes $\hat{p}(e)$, which is a vector of the expected yearly continuation probabilities for each skill endowment, chosen to align the implied expectations about graduation likelihood in the model with the data. The object $\hat{p}(e)$ and the true persistence probabilities disciplined by parameters in Panel A together determine the extent of over-optimism in our model.

Panel C of Table 8 contains the parameters which are governed by empirical targets from sources other than the HSLS:09 and NLSY97 and are related to education. First is college room and board costs, $\bar{c}$, which is set using the average annual value from 2016 to 2018 as reported in tabulations reported in NCES (2019). Second is the annual tuition, κ, which is set using information on net tuition and fees from the same NCES tabulation as a target. The third row is the income exempt from garnishment in delinquency, $\bar{y}$, which is set to 15.1 percent of GDP per capita for the population 18 and over, following our calculations using results from Yannelis (2020). The fourth and fifth rows of Panel C report the parameters governing the costs of being delinquent on public loans, ξ_D, or private loans, ξ_D^{pr}. For federal student loans, ξ_D is set so that the model delinquency rate matches the average cohort delinquency rate from 2016 to 2018, where the definition of deliquency in the data is 270 days or more. Fo private student loans, ξ_D^{pr} is set so that the model matches private loan balances 90 or more days deliquent as a fraction of total private loan balances.[39] For federal loans, this moment is reported by the Office of Federal Student Aid in FSA (2021); for private loans, we use the industry report Amir et al. (2021). The last row of this panel contains the student loan issuance cost, $\tau_{i,s}$, which is set so that the interest rates of federal and private student loans have the same mean, as documented in Table 5 of Section 2. This represents the two loan issuers using the same issuance technology.

Panel D contains the remaining jointly calibrated parameters. These parameters are governed by moments which are unrelated to education and which are not from the HSLS:09 or the NLSY97. Aggregate labor productivity, Z, is set so that GDP per capita for the population 18 and over is 1 in the model. The discount factor, β, is calibrated to target a capital to output ratio of 3, consistent with Jones (2016). Finally, the Social Security replacement rate, χ, is calibrated such that the model matches the average ratio of total Social Security expenditure to GDP from 2016 to 2018, as measured by the Bureau of Economic Analysis.

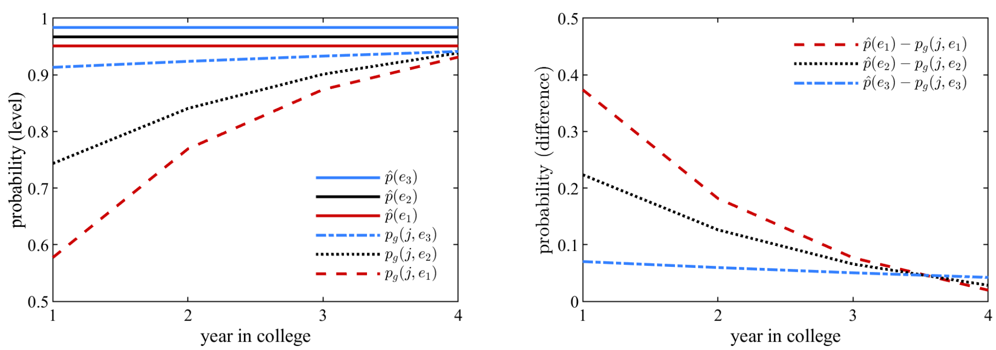
5 Properties of the Model Economy

This section presents several properties of the calibrated model economy which are related to our main policy exercises. Subsection 5.1 examines the role of over-optimism in generating observed enrollment patterns, and quantifies the extent of over-enrollment in college by skill quantile. This subsection also examines how over-optimism affects student loan borrowing choices. In Subsection 5.2, we examine federal student loan limit utilization rates in both the data and the model, as well as how federal student loan limits affect enrollment rates by family income and skill in the model framework.

[39] For federal student loans, after 270 days spent in deliquency the loan is in default. Since the model period is one year, we use the cohort default rate (270 or more days delinquent) as the empirical target for the per-period deliquency rate. For private loans, we use the available deliquency definition (90 or more days) closest to the length of a period in our model when selecting the empirical target.

5.1 Over-optimism's effects on enrollment and student loans

Figure 1 presents a visual illustration of college continuation probabilities and the extent of over-optimism in the model's baseline equilibrium. This information is broken down by student skill level, e, and is shown as students progress through four years of college, with college academic year on the x-axis of both subfigures. Subfigure 1a plots the calibrated true probability of continuing to the next academic year, j, symbolized by $p_g(j, e)$, along with the expected probability of continuing at the enrollment decision, $\hat{p}(e)$. Moving across academic years, the true probability of continuing increases, reflecting the data attribute that students who persist to their second year are much more likely to finish their degree than those who merely enroll in the first year (Table 8, Panel A). Subfigure 1b plots the extent of over-optimism in the model by academic year, which is computed as the difference between $\hat{p}(e)$ and $p_g(j, e)$ at each year of college j. Consistent with our findings in the NLSY97, in our model students in lower skill quantiles exhibit greater over-optimism, but all skill levels are overly optimistic to some extent (Table 1, Panel A). Note that the model is parameterized to yearly continuation probabilities, not graduation probabilities; Subfigure 1b highlights that student expectations about their likelihood of graduating indicate over-optimism about persisting through the earliest years of college enrollment in particular.



(a) Continuation probabilities

(b) Extent of over-optimism

Figure 1: Illustration of college continuation probabilities and over-optimism

Note: Figure 1 presents moments from the calibrated baseline equilibrium of the model. Figure 1a plots the true probabilities of continuing towards a college degree for another academic year, $p_g(j, e)$ along with the overly optimistic expected probability of this occuring, $\hat{p}(e)$. Figure 1b plots the extent of over-optimism about continuing towards a college degree, computed by subtracting the true probability from the expected probability.

We next examine the extent of over-enrollment in college generated by over-optimism. In column (1) of Table 9, we report enrollment rates for each skill quantile computed in the NLSY97. Column (2) contains enrollment rates for high school graduates for each skill quantile, e, in the model's calibrated baseline equilibrium. These rates align closely with the data because we target the overall college enrollment rate and the enrollment rate in the top skill quantile. Column (3) reports enrollment rates for the same group of students in the model's baseline equilibrium when we shut off over-optimism by setting $\hat{p}(e) = p_g(j, e)$. In this column, enrollment rates decrease compared to the baseline, especially among low-skill students. The difference between enrollment rates in columns (2) and (3), reported in column (4), we define as the over-enrollment in that row's skill quantile. Thus, because the model framework allows us to predict enrollment rates in a counterfactual world without over-optimism, we can use the model to conclude that over-enrollment due to mistaken beliefs is highest among low-skill students.

Table 9: College enrollment by skill quantile

	College enrollment rate			Over-enrollment
	Data	**Model baseline**	**No over-optimism**	**Percentage point difference**
Skill quantile	**(1)**	**(2)**	**(3)**	**(4) = (2) - (3)**
1	22.92	24.50	9.54	14.96
2	45.57	43.64	38.67	4.97
3	77.01	77.01	77.01	0.00

Note: Table 9 presents enrollment rates in the data and model by skill quantile, where skill quantile assigned with high school GPA in the data and represented with e in the model. Enrollment rates are computed after high school graduation as percentages of the skill quantile's population who enroll in a BA degree. Column (1) reports the enrollment rates in the data, column (2) reports the enrollment rate in the baseline equilibrium of the model, column (3) reports the enrollment rate in the baseline model equilibrium when $\hat{p}(e) = p_g(j, e)$, so that there is no over-optimism and consumers have correct beliefs, and column (4) reports over-enrollment, computed as the difference between columns (2) and (3).

Table 10 reports loan uptake by persistence status for a given cohort of enrollees in the data (Panel A, referencing Table 2 in Section 2), and in the model baseline (Panel B). Although we did not target these moments in our calibration, the model does reasonably well in accounting for aggregate balance shares and the magnitude of loan balances among student debtors. However, the model does not perform well in capturing the share of non-persisters with any student debt, which we attribute to fewer dropouts having small loan balances in the model compared to the data.

Table 10: Student loans by persistence status: data versus model baseline equilibrium

Panel	**Source**	**Persistence status**	**% of enrollees**	**% of SL $**	**% with SL**	**Average $**	**Median $**
A	Data	Did not persist	32	24	74	17,051	13,250
		Persisted	68	76	65	24,175	19,500
B	Model	Did not persist	36	13	18	21,301	16,761
		Persisted	64	87	61	22,891	11,174

Notes: Table 10 reports loan uptake patterns by persistence status to the fourth academic year for a given cohort of enrollees. Panel A contains moments from the data, as reported in Table 2. Panel B contains analogous statistics from the model baseline equilibrium. Data source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. See Table 2 for survey weights used.

The loan statistics in Table 10 condition on college enrollment. Holding everything else fixed, over-optimism mostly affects the enrollment decision rather than loan uptake conditional on enrollment. To see this, one can consider a partial equilibrium where only beliefs are corrected for high school graduates, after family transfers are made but before the enrollment decision. With correct beliefs, college enrollment falls, so that while dropouts have similar loan uptake behavior once enrolled, the mass of this group is now smaller. The aggregate debt owed by dropouts in the partial equilibrium with correct beliefs decreases accordingly. Specifically, the mass of student debtors who are dropouts out falls by 14 percent, while the aggregate balances held by dropouts fall by 11 percent. These changes are sizable, yet debt held by dropouts remains large even with correct beliefs. This illustrates that student debt held by dropouts, as observed in the model's baseline equilibrium, is mostly a consequence of the intrinstic riskiness of college as an investment.

5.2 The role of federal student loan borrowing limits

One of our main policy experiments is to study the impact of increasing the federal student loan limit in the presence of over-optimism. The impact of such a policy depends on the extent to which borrowing limits on federal student loans bind in the model's baseline equilibrium. In this subsection, we review empirical evidence showing that current federal student loan limits are not sufficient to finance the average total costs of college, and that many college students use up all of the federal loans they have access to. In the process we compare utilization rates for federal loans in the model with the data and find that these moments align reasonably well, although they are not targeted in the calibration. We then turn to the model to see how federal student loan limits affect the relationship between family income, student skill, and enrollment in the baseline equilibrium.

5.2.1 Federal student loan limits and utilization rates

To measure the extent to which students are constrained in their ability to finance college with federal loans, we begin by noting that the current federal student loan limit is enough to pay for 1.49 years of average tuition at a four-year college, net of grants, if we include the average expenditure for college room and board.[40] If we exclude college room and board expenditure, the current federal student loan limit is enough to pay for 3.96 years of average tuition net of grants. Therefore, a student who is attending a college that costs the average amount, and who does not have access to financing other than federal loans (e.g., family transfers, other income, or housing provided by their family) will not be able to finance their entire college degree under current borrowing limits. The model is calibrated to match this attribute of current federal loan policy.

[40] See Table 6 in Section 4 for data sources.

Under current policy, to what extent are college students using all of the federal loans they have access to? To measure utilization rates in the data, we turn to the HSLS:09, which allows us to see the free application for federal student aid (FAFSA) submission of every federal student loan recipient in the sample. The FAFSA forms are useful for identifying whether students file as a dependent or independent, which determines their yearly borrowing limit, and associating that limit with their stock of federal debt reported in the student records. With this information, we compute the federal loan utilization rate, which is the ratio of cumulative federal debt balance to total borrowing limits for three years of college (the latest we can see student debt balances). The results are reported in Table 11: 53 percent of incoming seniors in the 2016-2017 academic year utilized more than half of their federal student loan limit, and about 1 in 3 students utilized all of the federal loans they were allowed access to. This is direct empirical evidence that many college students are constrained with respect to the federal student loan limit; although these moments are not targeted in the calibration, the model's baseline equilibrium also exhibits a sizable share of students hitting this limit. Since we underestimate this share in the model baseline, our welfare gains from loan expansions can be considered lower bounds.

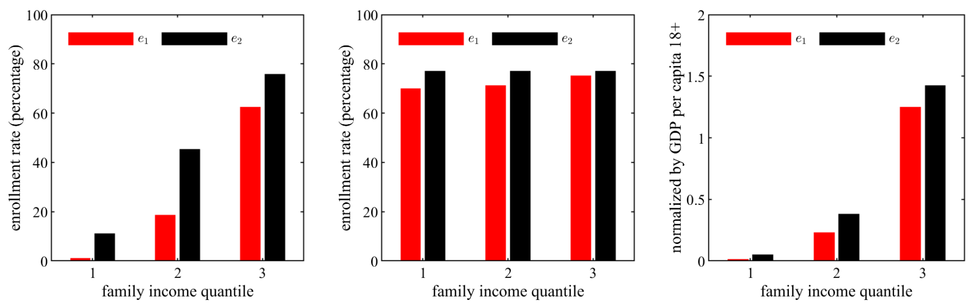
Table 11: Utilization rates for federal student loans

Utilization	**Data**	**Model**
$\geq 50\%$	53	41
$\geq 100\%$	33	15
Obs	1,940	

Notes: Table 11 reports utilization rates for federal student loans in the HSLS:09 and in the baseline model equilibrium. Sample: students who enrolled in a BA program in the fall of 2013 and persisted to their fourth year. Utilization rates of federal student loans by end of 3rd academic year and are in fractions of the total limit. The borrowing limit used to compute utilization rates in the data is assigned using reported dependency status and academic year from FAFSA records provided in the HSLS:09 student records. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights.

5.2.2 Federal student loan limits and enrollment rates in the model's baseline equilibrium

The qualitative properties of enrollment rate patterns are documented by Lochner and Monge-Naranjo (2011), who show that in the NLSY97 college enrollment rates are increasing in family income conditioning on student skill—especially for students with low skill. Federal student loan limits play a sizable role in allowing the model framework to generate patterns of enrollment similar to the data. In the first two panels of Figure 2, we plot the model's college enrollment by family income quantile for students in the lower two skill quantiles. Enrollment rates in the baseline equilibrium, shown in Subfigure 2a, are increasing in family income for a given skill quantile, consistent with the patterns documented in the data. The model framework captures this pattern because it incorporates borrowing constraints and heterogeneous family transfers (which are endogenous). To examine the contribution of borrowing constraints, Subfigure 2b shows enrollment rates in a counterfactual world where the federal student loan limit is expanded to finance four years of college costs (i.e., $\bar{A} = 4$). Comparing Subfigures 2a and 2b, the positive relationship between family income and enrollment rates for low-skill students is substantially reduced by this policy change, indicating that a lack of access to credit plays a significant role in generating the observed relationship between enrollment and family income for lower-skill students. The contribution of family transfers is shown in Subfigure 2c, which plots the inter-vivos transfers received by students in the baseline equilibrium by family income and student skill. We see that, conditioning on skill, inter-vivos transfers increase in family income. These transfers allow students from high income families to pay for college in the baseline equilibrium, despite the presence of borrowing constraints.



(a) Enrollment: baseline (b) Enrollment: $\bar{A} = 4$ (c) Family transfers: baseline

Figure 2: College enrollment and family transfers by family income and student skill quantiles

Notes: Figure 2 shows enrollment rates in the baseline equilibrium and a counterfactual equilibrium. Subfigure 2a shows enrollment rates by family income quantile, for the lower two skill quantiles $e = 1$ and $e = 2$, in the model's baseline equilibrium. Subfigure 2b shows enrollment rates in the model when the federal student loan limit, $\bar{A}$, is expanded from 1.49 to 4. Subfigure 2c shows family inter-vivos transfers by family income and student skill quantiles in the baseline equilibrium.

6 Policy Experiments

This section presents and discusses the results of two policy experiments: an information intervention, analyzed in Subsection 6.1, and a federal student loan limit expansion, analyzed in Subsection 6.2.[41]

Specifically, Subsection 6.1 reports the effects of eliminating over-optimism about college gradu-

[41] In Supplementary Appendix J, we analyze an expansion in public grants, another key source of college financial aid in the U.S..

ation probabilities by setting $\hat{p}(e) = p_g(j, e)$. This exercise is motivated by the model finding in Subsection 5.1, which demonstrated that over-optimism leads to significant over-enrollment. This is especially true among low-skill students in the calibrated baseline equilibrium. This differs from the partial equilibrium analysis of Subsection 5.1 because in this policy experiment we incorporate general-equilibrium adjustments that occur when over-optimism is eliminated: namely, changes in prices, transfers, the income tax, accidental bequests, and inter-vivos transfers from parents.[42] Besides illustrating the effect of an information intervention that eliminates over-optimism, this exercise also provides insight into the general-equilibrium impact of over-optimism about college completion on the economy.

In Subsection 6.2, we analyze the effects of expanding the federal student loan limit to $\bar{A} = 4$, so that federal loans are sufficient to pay for four years of college tuition plus room and board (net of grants). This expansion allows overly-optimistic high school students to access more credit if they enroll in college, potentially worsening time-inconsistent over-enrollment. At the same time, in the baseline model (as in the data) many students are fully utilizing their federal student loan limits, so expanding access to federal loans could increase their well-being by relaxing a binding borrowing constraint (Subsection 5.2). Therefore, the welfare consequences of a federal student loan limit expansion are ambiguous, with the model determining the relative magnitudes of each of these forces.

In both policy exercises, we assume that the economy is in its steady state in period 0. In period 1, the transition is announced unexpectedly, but there is perfect foresight thereafter.

6.1 Information intervention

We begin by analyzing the impact of an information intervention on education and skill, macro aggregates, and prices, taxes, and transfers. Next, we analyze implications for welfare. The effects of this policy on the model's steady-state equilibrium are shown in column (1) of Table 12. Effects on the model economy are summarized by changes in education and skill statistics (Panel A), macroeconomic aggregates (Panel B), and prices, the income tax rate, and transfers (Panel C).

Panel A indicates that an information intervention leads to lower enrollment in college, especially for low-skill students. Enrollment decreases because, when students use the true probabilities of college graduation in making their college enrollment decision, the value of going to college decreases. By construction, over-enrollment in the new equilibrium goes to 0. That statistic was highest for the lowest-skilled students in the baseline equilibrium, so over-enrollment changes

[42] This affects the parent's inter-vivos transfer decision and also decisions leading up to and including the age in which the inter-vivos transfer decision is made.

the most for those with the lowest skill. The elimination of over-enrollment leads to a higher graduation rate due to compositional changes: the average college student now has higher skill, and is therefore more likely to graduate. However, lower enrollment in college leads to fewer college graduates in the population at the new steady state. As a result, in the future generations, the mass of 18-year-olds with low skill increases and the mass with high skill decreases, because skill endowments depend on parent educational attainment.

Table 12: Steady state changes from policy experiments

Panel	Variable		Policy (1) Information intervention	Policy (2) Federal loan limit expansion
A: Education and skill statistics	College enrollment rate	e_1	-19.45	47.20
Units: percentage point change		e_2	-23.85	33.38
		e_3	0.00	0.00
	Over-enrollment	e_1	-14.94	44.50
		e_2	-4.98	34.62
		e_3	0.00	0.00
	Graduation rate		6.69	-5.33
	Population share college graduates		-7.87	13.04
	Share of 18-year-olds	e_1	1.88	-3.12
		e_2	0.17	-0.28
		e_3	-2.05	3.40
B: Macroeconomic aggregates	Output		-3.15	3.67
Units: percent change	Capital		-2.70	0.36
	Labor (efficiency units)		-3.39	5.59
	Consumption		-3.15	3.33
C: Prices, income tax rate, and transfers	Risk-free savings interest rate		-0.06	0.40
Units: percentage point/percent change	Wage rate		0.22	-1.81
	Private student loan interest rate		-0.27	-
	Income tax rate | Initial steady-state mean income		0.45	-0.27
	Inter-vivos transfers		-26.95	-9.48
	Accidental bequests		-2.92	5.51
	$\mathrm{ss}_{\ell,e}$	e_1	-2.12	2.02
		e_2	-2.11	1.98
		e_3	-2.08	1.93
	$\mathrm{ss}_{h,e}$	e_1	-1.68	1.11
		e_2	-1.60	1.14
		e_3	-1.44	0.90

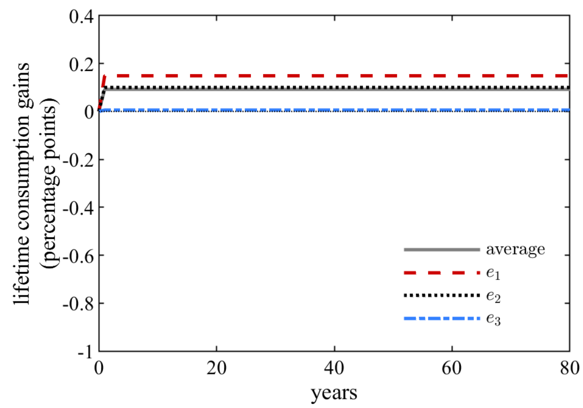
Notes: Table 12 provides results from a steady-state comparison of the baseline economy to: (1) an economy with an information intervention that eliminates over-optimism (i.e., $\hat{p}(e) = p_g(j,e)$), and (2) an economy with a federal student loan limit expansion to fund four years of college tuition plus room and board net of grants (i.e., $\bar{A} = 4$). Panels A, B, and C report changes in education and skill statistics, macroeconomic aggregates, and prices, the income tax rate, and transfers, respectively.

Moving to Panel B, note that the drop in the mass of college graduates reduces the total efficiency units of labor, which reduces total labor earnings. Lower earnings, in turn, lower both savings and aggregate capital. This reduction in factor inputs lowers output, and consequently, lowers consumption. Panel C of Table 12 indicates that the risk-free savings rate falls and the wage rate increases slightly, because aggregate labor falls more than aggregate capital. At the same time, the interest rate on private students loans decreases due to lower delinquency risk among private student loan borrowers. The information intervention's reduction of labor income, capital income, and consumption lead to lower tax revenue for the government at any given tax rate, so that the income tax rate increases in the new steady state in order to balance the government's budget. Inter-vivos transfers decline significantly relative to the baseline economy for three reasons: first, parents' altruistic incentive to provide inter-vivos transfers to their children might decrease because parents are no longer over-optimistic about their children's ability to graduate from college (see Figure 3d); second, the economy will have less wealth and income in the new steady state; and third, there will be fewer high-skill students, which will lower parents' incentive to pay for college (see Subfigure 2c). The last two rows of this panel show that transfers such as accidental bequests and Social Security also decrease, due to lower savings and lower labor earnings in the new steady state. The changes reported in Panel C will matter for welfare, which we turn to next.

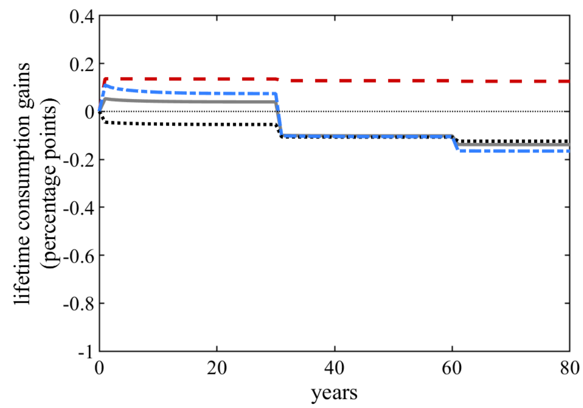
To analyze welfare we focus on 18-year-old consumers, the group most affected by the policy experiments.[43] Our measure of welfare for 18-year-old consumers is consumption-equivalent variation. As our model includes psychic costs (i.e., search costs for student loans, an effort cost for college, and stigma costs for delinquency on student loans), we follow Abbott, Gallipoli, Meghir, and Violante (2019) and use the value of not going to college, which does not include any psychic costs, to compute consumption-equivalent variation. We compute the lifetime change in consumption required in the initial steady state value of not going to college, in every period and at every state, in order for an 18-year-old to be indifferent between the initial steady state value of not going to college and the lifetime value before going to college in the initial steady state, the transition path, or the final steady state. After computing the consumption-equivalent variation, we report the change in lifetime consumption relative to period 0, when the economy is at the initial steady state. Therefore, positive values indicate gains and negative values indicate losses. Furthermore, when measuring welfare, we assume that the social planner is altruistic and has correct beliefs (commonly referred to as a "paternalistic government"). That is, the government knows the true payoff of choices, but internalizes that the consumer is overly optimistic when making the college enrollment decision, the inter-vivos transfer decision, and the decisions leading up to and including the age in which the inter-vivos transfer is made. The value functions and equations used to construct welfare estimates are provided in Supplementary Appendix H.

Figure 3 illustrates a welfare analysis of the information intervention in partial and general equilibrium. Subfigure 3a shows welfare changes by skill quantile, and on average, in a partial equilibrium in which the income tax rate, prices, bequests, Social Security transfers, and the 18-year-old joint distribution of assets, skill, and the AR(1) earnings shock are fixed at their initial steady-state values. In Subfigure 3a, consumers benefit in proportion to the extent of over-optimism for their skill

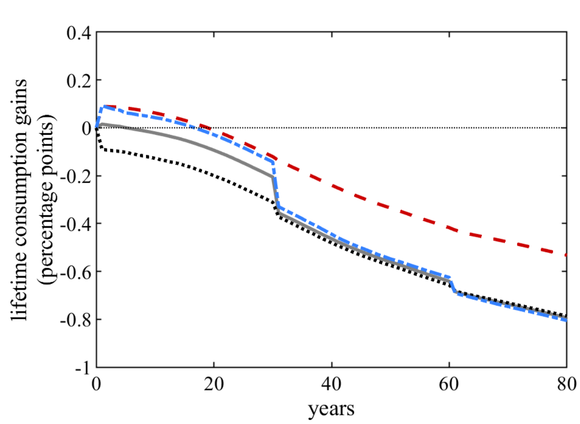
[43] In Supplementary Appendix I, Table 35, we report welfare implications for consumers that are 19 and older in the period of the transition. Although the magnitudes of welfare implications are smaller, the qualitative takeaways are the same.



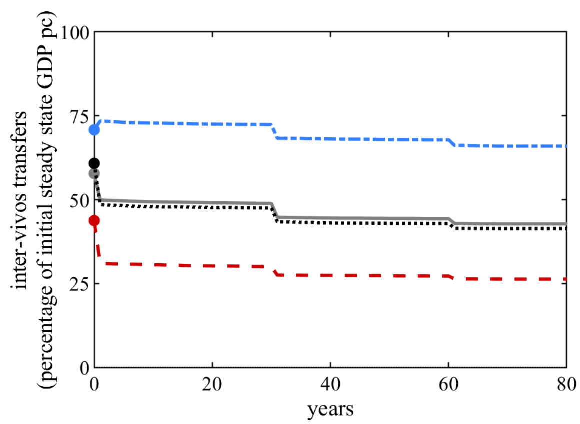
(a) PE: exogenous 18-year-old distribution



(b) PE: endogenous 18-year-old distribution



(c) GE: welfare



(d) GE: inter-vivos transfers

Figure 3: Information intervention welfare analysis: partial and general equilibrium effects

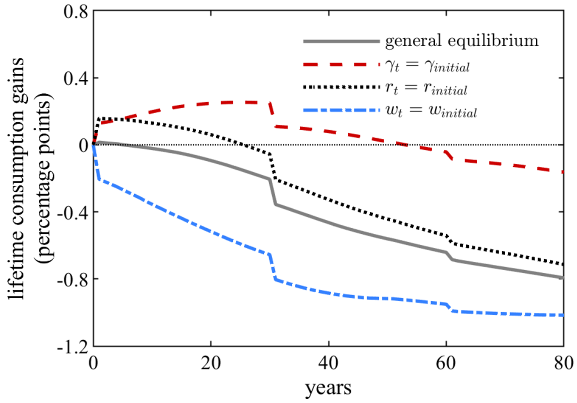
Notes: Figure 3 provides a welfare analysis of an information intervention for 18-year-old consumers in partial and general equilibrium. Subfigures 3a-3c report lifetime consumption gains and losses for the average 18-year-old and the average-18-year-old given skill in each period of the transition path under the following cases: (a) a partial equilibrium in which the income tax rate, prices, bequests, Social Security transfers, and the 18-year-old distribution are fixed at their initial steady state values, (b) a partial equilibrium in which the income tax rate, prices, bequests, and Social Security transfers are fixed at their initial steady state values, but the 18-year-old distribution is endogenous, and (c) general equilibrium. Subfigure 3d reports the average inter-vivos transfers received by the average 18-year-old and the average 18-year-old given skill in general equilibrium in each period of the transition path as a percentage of initial steady state GDP per capita.

bin. This is the direct impact of eliminating over-optimism: consumers correct their enrollment decisions and the transfers they make later in life as parents, both of which are changes that improve their well-being. Subfigure 3b plots welfare changes in a partial equilibrium which now endogenizes the 18-year-old joint distribution. Welfare gains in the initial periods of the transition are lower in Subfigure 3b than in Subfigure 3a, because parents with corrected beliefs reduce inter-vivos transfers to children with low or medium skill. In later periods of the transition, welfare changes decrease even further. This occurs because the population of parents becomes less educated, which lowers the skill of young adults and compounds the fall in inter-vivos transfers due to the lower earnings and wealth of less educated parents. Once we take general-equilibrium effects into account, welfare changes become even more negative (Subfigure 3c). This is due to an increase in the income tax rate, a decrease in the savings interest rate, and a fall in accidental bequests and Social Security transfers. Inter-vivos transfers over the transition, by skill level and on average, are shown in Subfigure 3d.

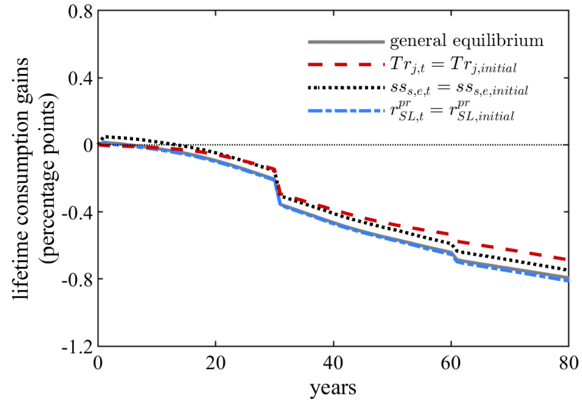
Figure 4 further decomposes the general-equilibrium effects on the 18-year-old's welfare. In Subfigure 4a, we plot lifetime consumption changes during the transition for the following partial equilibrium cases: the income tax level parameter, γ_t, the risk-free savings rate, r_t, and the wage rate, w_t, each fixed at their initial level while other variables adjust in equilibrium. General-equilibrium welfare changes are also included for comparison. When the income tax rate is fixed at its initial level, welfare losses for the average 18-year-old are reduced significantly in magnitude, and even turn into gains in the initial periods. This result indicates that higher income taxes stemming from an information intervention are a key driver of welfare losses. A similar pattern, although lower in magnitude, occurs when we hold fixed the risk-free savings rate at its initial level instead of allowing it to fall. In contrast, fixing the wage rate at its initial level magnifies welfare losses for the average 18-year-old consumer, indicating that equilibrium increase in this object act to mitigate welfare losses resulting from the information intervention.

Subfigure 4b plots welfare changes in partial equilibrium when accidental bequests, Social Security transfers, and private student loan interest rates are fixed at their initial steady state values, respectively. Lower accidental bequests and Social Security transfers hurt the consumer in general equilibrium, since holding these objects fixed lowers welfare losses. The fall in the private student loan interest rate has no significant impact. The magnitudes of the effects in Subfigure 4b are quite small compared to Subfigure 4a.

Overall, the information intervention policy experiment uncovers the complex role of over-optimism in the economy: although over-optimism leads to 18-year-old students to over-enroll in college, it also benefits them in three ways. First, over-optimism raises the inter-vivos transfers that 18-year-olds receive from their parents, because parents are also overly optimistic. Second, over-optimism raises the college education rate, which raises income and wealth and lowers income taxes. This benefits 18-year-olds via general-equilibrium effects. Third, the average 18-year-old is more skilled because the economy will have more parents who are college graduates. The results of our analysis indicate that a large-scale information intervention with strong general-equilibrium effects will in fact make the average 18-year-old worse off. In fact, even a small-scale information intervention without general equilibrium effects could hurt 18-year-old consumers due a fall



(a) Part 1



(b) Part 2

Figure 4: Decomposing general equilibrium welfare effects of an information intervention

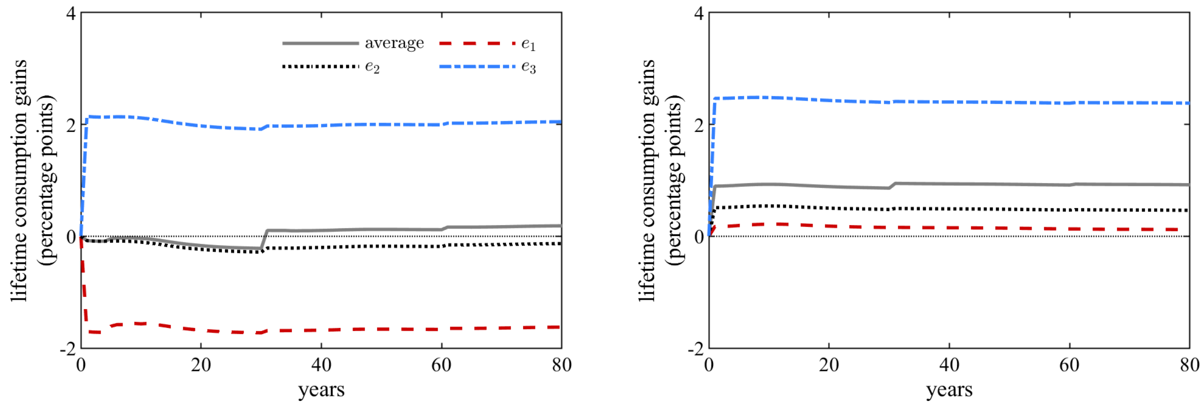
Notes: Figure 4 provides a welfare analysis of an information intervention for the average 18-year-old consumer to decompose general equilibrium effects. Subfigures 4a and 4b plot lifetime consumption gains and losses for the average 18-year-old in each period of the transition path under the following cases: general equilibrium, income tax level parameter γ_t fixed at its initial level, wage rate, w_t, fixed at its initial level, risk-free savings rate, r_t, fixed at its initial level, accidental bequests, $Tr_{j,t}$, fixed at its initial level, Social Security transfers, $ss_{s,e,t}$, fixed at their initial level, and private student loan interest rate, $r^{pr}_{SL,t}$, fixed at its initial level. For each partial equilibrium case, while the relevant variable is fixed at its initial level, the other variables change as they do in general equilibrium.

inter-vivos transfers.

6.2 Federal loan limit expansion

In our second policy experiment, we analyze the effects of expanding the federal student loan limit to $\bar{A} = 4$, so that federal loans are sufficient to pay for four years of college tuition plus room and board (net of grants). The effects of this loan limit expansion on education and skill and macroeconomic aggregates, as well as on prices, the income tax rate, and transfers, are shown in column (2) of Table 12. The mechanisms in this exercise parallel those from an information intervention, but move in the opposite direction—except for inter-vivos transfers.

Panel A of Table 12, column (2), shows that the expansion in the loan limit increases enrollment in college for the lowest two skill quantiles, which in turn raises over-enrollment for those quantiles. This happens because previously credit-constrained students can now enroll in college. Higher enrollment among low skill students leads to a lower graduation rate. However, higher enrollment also increases the share of college graduates in the population, which leads to more 18-year-olds with higher skill in the new steady state. Panel B reports the resulting increase in aggregate output, capital, labor, and consumption. In Panel C, we see that the risk-free savings interest rate rises and the wage rate drops, because efficiency units of labor rise by more than the capital stock. By construction, the private student loan market completely shuts down when students can use federal loans to pay for all college costs. Because of the expansion in the tax base, the income tax rate decreases. Public transfers from Social Security rise, and so do accidental bequests; however, because federal loans are now sufficient for financing college, inter-vivos transfers decrease.



(a) Baseline

(b) No over-optimism

Figure 5: Federal loan limit expansion welfare analysis: baseline vs. no over-optimism

Notes: Figure 5 provides a welfare analysis of an expansion in the federal student loan limit to fund four years of college net tuition plus room and board for 18-year-old consumers in the baseline economy (Subfigure 5a) and an economy without over-optimism (Subfigure 5b). Both subfigures report lifetime consumption gains and losses for the average-18-year-old and the average-18-year-old given skill in each period of the transition path.

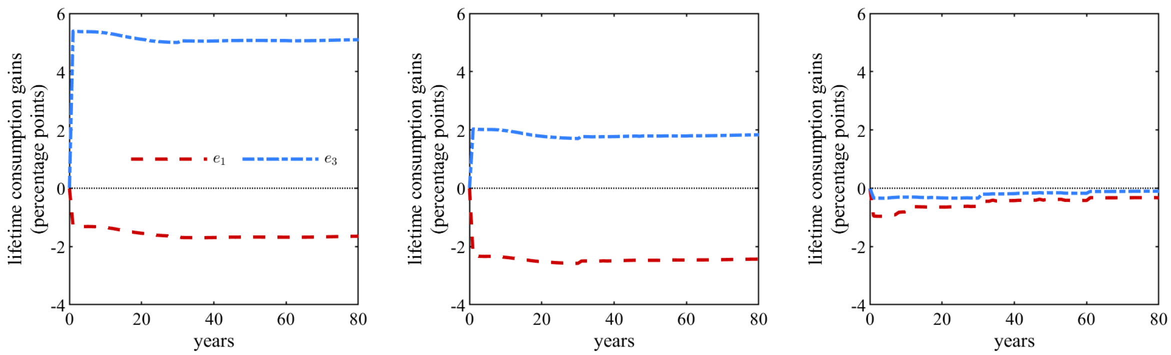
In Figure 5, we analyze the welfare implications of expanding the federal student loan limit for 18-year-old consumers in both the baseline economy (Subfigure 5a) and in an economy without over-optimism (Subfigure 5b). In the baseline economy with over-optimism, students in the bottom skill quantile experience welfare losses, while students in the highest skill quantile experience welfare gains. Students in the middle skill quantile are hurt, albeit marginally. Overall, the average 18-year-old is marginally worse off in the initial periods and is marginally better off in the later periods.

When we perform the same experiment in an environment without over-optimism (Subfigure 5b), 18-year-olds in all skill quantiles experience welfare gains. These gains are increasing in skill. This means that, without over-optimism, general-equilibrium effects and the public costs of subsidized federal student loans do not offset the welfare gains which stem from increased access to credit for financing college.[44]

A comparison of Subfigures 5a and 5b highlights the additional insight one gains from incorpo-

[44]The rest of the population experiences marginal gains from the loan limit expansion. See Supplementary Appendix I for details.

rating over-optimism about college graduation likelihood into the model environment. With this model ingredient, college enrollment increases for the lowest skill quantile when loan limits expand, but these students also drop out of college more often than they anticipate at the time of enrollment. Low-skill students are therefore hurt by this policy when over-optimism is taken into account, in stark contrast to their outcomes in a model where expectations accurately reflect true college graduation probabilities.



(a) Family income quantile 1 (b) Family income quantile 2 (c) Family income quantile 3

Figure 6: Federal loan limit expansion welfare analysis: by family income and student skill

Notes: Figure 6 provides a welfare analysis of an expansion in the federal student loan limit to fund four years of college net tuition plus room and board for 18-year-old consumers by family income quantile and skill quantile in general equilibrium. Panels 6a-6c report lifetime consumption gains and losses for the average-18-year-old in the lowest and highest skill quantiles in each period of the transition path by family income quantiles 1, 2, and 3, respectively.

The U.S. federal student aid program is intended to provide funding that facilitates college attendance for students without other forms of financing. These are primarily students from low-income families. In Figure 6, we plot welfare implications by family income quantile as well as student skill. Subfigures 6a and 6b show that students from low-income families in the lowest skill quantile experience large welfare losses while students from low-income families in the highest skill quantile experience large gains. Thus, among students raised by poor families, there are heterogeneous effects of the increased access to credit for financing college. At the same time, the impact of the loan limit expansion on students from high-income families is small. This is because students from high-income families receive large inter-vivos transfers from their parents before the policy change, and so are not as affected by the loan limit expansion.

To summarize, the results from this policy experiment show that an expansion in the federal loan limit will not be welfare improving for all students. In particular, the impact of the loan limit expansion is felt the most by students in families with low income: in this income group, low-skill students see welfare losses while high-skill students see welfare gains.

7 Conclusion

in this paper, we document that both college students and their parents are overly optimistic about college graduation likelihood. We incorporate this feature of the data into a structural model of college choice, parameterize the model, and use it to perform policy experiments highlighting the role of over-optimism in the economy and in the effects of policy. In addition to over-optimism, our quantitative model also features key sources of college financing, in particular federal and private student loans, family transfers, grants, and labor earnings.

Our analyses lead to two main findings. First, although over-optimism leads 18-year-old students to over-enroll in college, which lowers welfare, it also benefits these young adults once we consider the impact of parental transfers, general equilibrium effects, and inter-generational effects on student skill. Second, increasing financial aid through an expansion in the federal student loan limit leads to welfare losses for low-skill students from poor families, because more financial aid worsens over-enrollment for these students.

While we document and analyze the implications of over-optimism about college graduation, many questions remain for future research. How should student loan repayment policies be designed in the presence of over-optimism? To what extent should federal student loan limits depend on student attributes? We hope that our empirical findings and quantitative analysis will be useful for future researchers seeking to answer such questions about policy design.

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Online appendix

Supplemental material for the paper "Over-optimism About Graduation and College Financial Aid"

by Emily G. Moschini, Gajendran Raveendranathan, and Ming Xu

Not intended for publication – to be made available online

Contents

Part I

Data Appendix

A The 1997 National Longitudinal Survey of Youth

The 1997 National Longitudinal Survey of Youth, referred to as the NLSY97, is a nationally representative sample of people born between 1980 and 1984 who lived in the United States in 1997. This survey collected data annually from 1997 to 2011 and biannually from 2011 to the present. The latest round of data collection is round 19 (2019-2020).

This section proceeds as follows. Subsection A.1 extends the main text's analysis of over-optimism; Subsection A.2 explains the methodology and results for computing inter-vivos transfers in the NSLY97.

A.1 Educational attainment outcomes versus expectations

Table 13 reports enrollment rates by age 25 and by age 30 in the NSLY97, for each skill quantile (skill is measured with high school GPA quantile, assigned in the pool of high school graduates). These enrollment rates are very similar; most enrollment happens before age 25. We use enrollment by age 30 to compute over-optimism and enrollment by age 25 as the calibration target in the quantitative model.

Table 13: Enrollment rates by skill

Skill Q (HS GPA)	Obs(Q)	Enr BA by 25	Enr BA by 30
1	807	22.92	27.51
2	812	45.57	48.65
3	748	77.01	78.48
Obs	2,367		

Notes: Sample: high school graduates. Source: NLSY97.

In the NLSY97, parent and child expectations about college graduation are not only similar at the aggregate level, but also agree closely at the family level. Table 14 reports the difference between student and parent expected probabilities of obtaining a BA, within the same family, when both expectations are reported. This means the sample is much reduced relative to just student expectations, because parent beliefs are only reported with valid responses for a subset of the sample. As is evident in Table 14, on average parents and children agree within a few percentage points of each other within each skill bin. The median difference in expected probaiblities is 0. Percentiles of the difference other than p50 are also reported in the table.

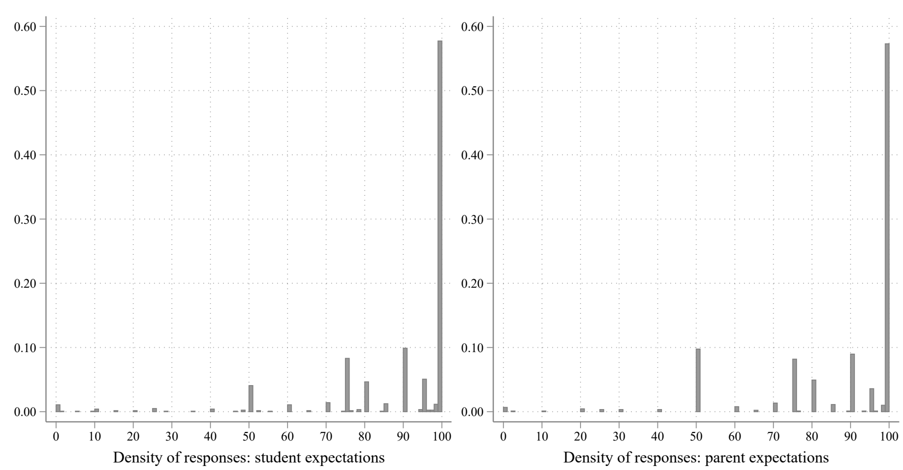
Table 14: Comparison Student and Parent Beliefs (Student-Parent): BA Enrollees

Skill Q (HS GPA)	Obs(Q)	mean	p10	p25	p50	p75	p90
1	166	0.99	-40	-10	0	20	40
2	297	2.09	-25	-1	0	15	28
3	429	0.31	-15	-5	0	0	20
Obs	892						

Notes: Sample: students who enrolled in a BA before age 30. Source: NLSY97.

Figure 7 shows a histogram of reported expected probabilities from the focal respondent and their parent, in regards to the respondents probability of earning a BA by age 30. In each of these panels, the distribution of beliefs is reported for those who enroll in college before age 30. This figure makes apparant that many college students, and their parents, believe that college graduation is certain. The qualitative properties of the distribution are the same when one looks at high school graduates without conditioning on BA enrollment.

Figure 7: Distribution of Expectations About BA Attainment Probability



Notes: Figure 7 plots the distribution of student responses about college graduation probability for the sample of those who enroll in a 4-year program before age 30 and where the parent responded to the beliefs question. The left panel plots student expectations; the right panel, expectations of the parent.

Over-optimism about attaining a BA could potentially vary by student gender or parental education, not just by skill. In Table 15 we report the graduation rate, expected graduation rate, and implied over-optimism by gender and student skill quantile (Panel A) and by parental education and student skill quantile (Panel B). In Panel A, we see that, among college enrollees, men are more overly optimistic than women for lower skills, but less overly optimistic at higher skills. The difference across genders within each skill bin is small. In Panel B, we see that parental education is more predictive of over-optimism than gender (note that parental education is defined at the family level where having at least one parent with a BA is "High", otherwise the family is a "Low" education family). Within a skill bin, low education families tend to be more overly optimistic than high education families. Nevertheless, within a skill bin there is more similarity across education categories than there is across skill bins within an education category.

Table 15: Over-optimism about BA attainment: breakdowns

Panel A: by student gender and skill	**Gender**	**Skill Q**	**Obs**	**Earned BA by age 30**	**Exp. Prob. BA by 30**	**Over-optimism**
	Male	1	127	30.71	81.67	50.96
		2	168	55.95	83.88	27.93
		3	226	79.20	91.94	12.74
	Female	1	95	33.68	81.93	48.24
		2	227	55.95	90.04	34.10
		3	361	77.56	94.57	17.00
	Obs	1,204				

Panel B: by parental education and skill	**Parental education**	**Skill Q**	**Obs**	**Earned BA by age 30**	**Exp. Prob. BA by 30**	**Over-optimism**
	Low	1	156	28.85	80.18	51.33
		2	292	51.71	87.66	35.95
		3	350	73.14	92.64	19.50
	High	1	56	42.86	85.57	42.71
		2	80	75.00	89.65	14.65
		3	214	86.45	95.67	9.22
	Obs	1,148				

Notes: Sample: panel A is students who enrolled in a BA before age 30, panel B is students who enrolled in a BA before age 30 and for whom parental education is observed. Source: NLSY97.

Table 16 contains summary statistics of the NLSY97 samples used in the tables of the main manuscript and in this appendix.

A.2 Inter-vivos transfers

To compute average inter-vivos transfers in the NLSY97, we proceed as follows. We use the cleaned data from the earnings process estimation, described in Section B.2 below. However, for this exercise we keep observations that are enrolled in school, which broadens the sample relative to the earnings estimation in any given year. Next, we restrict to the years 1997 to 2003, and

Table 16: Overconfidence about BA attainment: sample summary statistics

	Cleaned sample	With student beliefs	BA enr by 30	With parent beliefs	Learning sample
HS GPA	2.90	2.89	3.13	3.12	3.22
Age in 1997	14.40	15.25	15.21	15.75	15.83
Pr. BA by 30 (parent)	76.67	76.69	88.03	88.03	90.16
Pr. BA by 30 (student)	78.57	78.57	89.37	89.06	92.07
Enr BA by 25	49.22	47.78	93.94	93.50	100.00
Enr BA by 30	52.32	50.87	100.00	100.00	100.00
BA by 30	33.25	31.73	62.38	62.00	69.62
Obs	4,673	2,367	1,204	892	316

Notes: Table 16 reports summary statistics for cleaned sample, cleaned sample additionally imposing student beliefs, cleaned sample also additionally imposing student beliefs and enrollment by age 30, cleaned sample imposing parent beliefs, and the learning sample where the student was in high school in 1997 and had enrolled in a 4-year program by 2001. Data is at the individual level. Source: NLSY97.

restrict attention to sample members who are between the ages of 18 and 23 in those years and who are independents.[45] For this sample, we flag those who are cohabiting with their parents and paying no monthly rent. We then impute the average monthly rent paid by sample members in the same family income quantile, with the same college enrollment status, in the same year, as an implicit transfer from parents to their children who cohabit with them and do not pay rent. Next, we transform monthly rent to yearly rent, and add it to yearly net income received from parents (if both parents are present) or from both the mother and the father (if both parents are not present). We also add yearly allowances received, if any. The resulting quantity is the yearly nominal transfers from parents to their children. Within each year, we then multiply the quantity by 6 and divide by nominal GDP per capita in that year (for those over 18), to find a unitless ratio of lifetime transfers received to per capita income for each individual. We then average this ratio across invididuals and years to find the ratio reported in the first row of Table 17. The average real values of the components of transfers are also reported in Panel A. To convert these to real values in 2000 dollars, we use the Consumer Price Index (CPI). Panel B of Table 17 reports additional summary statistics for the inter-vivos transfer estimation sample.

B Earnings process estimation

The earnings process we use in our structural model realizes a quantity of efficiency units at each age j. This quantity has a deterministic component, $\epsilon_{j,s,e}$, and a stochastic component, η_j. The deterministic component depends on the consumer's age, j, their educational attainment, s, and

[45]For independence criteria see https://www.nlsinfo.org/content/cohorts/nlsy97/topical-guide/Income.

Table 17: Inter-vivos transfers and sample summary statistics

Category	**Variable**	**Mean**
Panel A: Inter-vivos transfers	Transfer ratio	0.578
	Transfers	4,706
	Transfers not allowance	539
	Allowance	138
	Imputed rent	4,671
Panel B: Summary statistics	HS GPA	2.951
	Age in 1997	15
	Parent exp(prob) BA by 30	77.51
	Student exp(prob) BA by 30	80.17
	Enr BA by 25	53.09
	Enr BA by 30	56.52
	BA by 30	37.10
	Not currently enrolled	49.89
	Obs	8,114
	Individuals	2,991

Notes: Table 17 reports average transfers and other summary statistics for the sample used to estimate inter-vivos transfers. Sample: independents between 18 and 23 observed 1997-2003. Units for transfer amounts: 2000 $'s. Data is at the individual-year level. Source: NLSY97.

their skill endowment (high school GPA), e,:

$$\epsilon_{j,s,e} = \exp\left(\beta^A_{s,1} j + \beta^A_{s,2} j^2 + \beta^A_{s,3} j^3 + \beta^e_{s,e}\right)$$

The stochastic component is an AR(1) process where the persistence parameter depends on the consumer's educational attainment, as does the distribution from which the error term is drawn:

$$\begin{aligned} \eta_j &= \rho_{\eta,s}\eta_{j-1} + \nu_{s,j} \\ \nu_{s,j} &\sim \mathbb{N}\left(0, \sigma_{\nu,s}\right) \end{aligned}$$

To estimate the earnings process for each education category s, we implement a modification of the approach described in Abbott, Gallipoli, Meghir, and Violante (2019). First, we use the Panel Study of Income Dynamics (PSID) to estimate how logged real wages depend on a third order polynomial of age for a given education group, $s = \ell$ (HS or some college) or $s = h$ (BA or higher). This identifies $\beta^A_{s,1}$, $\beta^A_{s,2}$, and $\beta^A_{s,3}$ for each education group s. We use the PSID to estimate the age polynomial because it allows us to see more of the life cycle than the NLSY97. Next, we take logged hourly real wages in the NLSY97, clean them of age effects with the PSID estimation results, and regress the resulting age-free log hourly real wages on indicators for skill quantiles. The coefficients on skill quantile indicator controls are the factor loadings on skill e for a given education s, $\beta^e_{s,e}$. Finally, using the residuals from the NLSY97 regression, we jointly estimate $\rho_{\eta,s}$ and $\sigma_{\nu,s}$ for each education group.

B.1 Estimating age profiles in the PSID

The PSID collects data on the household head and, if present, their resident spouse. We use information on the educational attainment of the household head and resident spouse (if any), as well as each individual's sex, total income, total income from transfers, total labor earnings, labor component of business income, hours worked, marital status (a flag equal to 1 if married with spouse present, 0 if not) and employment situation (which is used to identify the self-employed). Using this information, we construct unearned income as total income net of earnings and transfers. We construct hourly wages by dividing the individual's labor earnings (plus labor component of business income when necessary) by total hours worked for the individual.[46] We correct all income and wage variables for inflation using the CPI and thereafter use real dollar values in our analysis. We the reshape the data into an individual-level panel where each male or female adult in the household is followed over time.

We exclude observations from the SEO census sample, and drop observations for whom we do not observe state of residence, marital status, or sex of the household head. We then count the number of times an individual is observed, and drop individuals observed fewer than 8 times. We compute yearly real wage growth, and drop observations with a yearly real wage growth of more than 4 percent or less than -2 percent, or where the level of real wages exceeds 400. We define those with a high school education as individuals who have between 12 and 15 years of schooling; those with a college education are individuals with 16 years of schooling or more. We then restrict the sample to those 65 and younger who are greater than 17 if they have a high school degree, greater than 19 if they have some college, and greater than 21 if they have a BA or more. Next, we drop those who are self-employed.

Using this estimation sample, we proceed in two stages to account for selection into working within each education category. In the first stage, we regress an indicator for working positive hours on an age polynomial and a set of standard controls (an indicator for being married, a set of dummies for the year, and a set of dummies for the state of residence) for those with a given educational attainment. In addition to the standard controls, X (where Xincludes a constant), in the first stage we also control for Z, which is unearned real income. This first-stage regression can be written as:

$$\mathbb{I}_{hrs>0} = \gamma_{s,Z} Z + \alpha_s X + \epsilon$$

where ϵ is the residual. This first stage regression is estimated using a probit estimator and the

[46]The labor component of business income is not included in labor earnings for some years of the PSID. For years when it is not included, we manually add it to reported labor earnings.

result is used to construct an inverse Mills ratio, which is included in a second stage regression that has all of the same controls but with unearned income replaced with the estimated inverse Mills ratio, IM, from the first stage. In this second stage regression, the dependent variable is the log of the real wage, w, and we use an OLS estimator. This regression estimated on a given education group can be written as:

$$w = \gamma_{s,IM} IM + \beta^A_{s,0} + \beta^A_{s,1} age + \beta^A_{s,2} age^2 + \beta^A_{s,3} age^3 + \gamma_s \times [i.state + i.year + i.married] + u$$

where u is the i.i.d. residual. The coefficients of interest for estimating the age profile of education category s are $\beta_{s,1}$, $\beta_{s,2}$, and $\beta_{s,3}$. Since the average offerred wages which is rejected is likely lower than the average offer wage that is accepted, the expected sign of the inverse mills ratio coefficient in the second stage, $\gamma_{s,IM}$, is positive. In our estimation, this coefficient has the expected sign for both education groups. Table 18 presents second stage regression results. The sample summary statistics for the first and second stage regressions are presented in Table 19. As a check on our model specification, we examine the marginal effect of some college or an associate's degree on the age profile of earnings by running a regression with an interaction of a flag for some college, $\mathbb{I}_{SC}$ with the age polynomial. Results are presented in Table 20. The coefficients from the interaction are statistically insignificant.

Table 18: Wages as a function of age

	(1) HS or some college	(2) BA or higher
$\beta^A_{s,1}$	0.105***	0.182***
	(0.0119)	(0.0230)
$\beta^A_{s,2}$	-0.00174***	-0.00309***
	(0.000343)	(0.000604)
$\beta^A_{s,3}$	0.00000874**	0.0000165**
	(0.00000321)	(0.00000513)
R^2	0.109	0.171
Obs	85,898	65,042

Notes: Table 18 reports regression results. The effect of age on earnings by education level $s = \ell$ (HS or Some College) and $s = h$ (BA). Not shown in table but included as controls: state and year FE, married indicator, inverse mills ratio, constant.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Data source: PSID.

B.2 Estimating skill loadings in the NLSY97

We clean the NLSY97 data before estimation in the following way. We begin with the "cleaned sample" in Table 22. We keep only observations where we observe high school GPA, wage, educational attainment, and completion of high school. We correct for inflation using the CPI, and drop observations with real wages in dollar units above 400 and below 1 or wage growth above 4

Table 19: Summary statistics

Panel	Sample	Variable	High school + some college	BA or higher
A	**Selection into working**	Age	39.13	38.37
		Married	0.81	0.77
		HS only	0.35	0.00
		Some college	0.65	0.00
		BA+	0.00	1.00
		Obs	104,006	71,401
B	**Age earnings profiles**	Age	38.24	37.94
		Married	0.80	0.77
		HS only	0.34	0.00
		Some college	0.66	0.00
		BA+	0.00	1.00
		Obs	85,898	65,042

Notes: Table 19 reports summary statistics by education category for first stage regression (Panel A) second stage regression (Panel B). Data is at the individual-year level. Source: PSID

percent or below -2 percent. We also drop those with either some high school or with a GED, and those currently enrolled in a BA. We restrict ages to be above 24 and below 39 so that each age bin has at least 100 observations. We group observations as either “high school”, meaning those with a high school degree or some college, or “BA”, meaning those with a BA or more. Since the NLSY97 records information at the individual level, we reshape the data to be a panel at the individual-year level. We estimate the factor loadings on skill using these remaining observations in the resulting panel data, the “regression sample”.

Using the estimated age contributions to log wages from the PSID, we log real wages in the NLSY97 and, using the observation’s associated age, clean logged real wages of their estimated age component. The resulting “age-free” log wages, w_{AF}, are then regressed on dummies for high school GPA quantiles, as well as a set of controls X which includes indicators for the year, a set of indicators for the number of children (top-coded at 4), an indicator for being married, and a control for being in the supplemental sample for the NLSY97. Standard errors in this regression are clustered at the individual level. The estimation equation can be written as:

$$w_{AF} \quad = \quad \beta^e_{s,0} + \beta^e_{s,e} \times i.\left[GPA_Q = e\right] + \chi X + u$$

where u is the i.i.d. residual. Table 21 presents the skill loadings in this equation estimated in the NLSY97. Note that, comparing across education groups within a given skill level, this estimation indicates that the college wage premium is lower for those with lower skill endowments. Table 22 contains summary statistics for the cleaned sample, the regression sample, and regression samples two subgroups: those with high school or some college, and those with a BA or more.

Table 20: Log wages as a function of age: robustness on pooling assumption

	$\log(wage)$
$\mathbb{I}_{SC} \times age$	0.0130
	(0.0138)
$\mathbb{I}_{SC} \times age^2$	-0.0000750
	(0.000351)
$\mathbb{I}_{SC} \times age^3$	-0.000000944
	(0.00000285)
$\mathbb{I}_{SC}$	-0.167
	(0.174)
age	0.0995***
	(0.0124)
age^2	-0.00182***
	(0.000345)
age^3	0.0000110***
	(0.00000310)
R^2	0.119
Obs	85,898

Notes: Table 20 reports regression results. Not shown but included: state and year FE, flag for married, inverse mills ratio, constant. Note: a positive sign for the inverse Mills ratio means that observed wages are, on average, higher than offered wages. Source: PSID. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

B.3 Estimating the stochastic component of earnings

After estimating the skill loadings in the NLSY97, we use the residuals of that regression and use them as inputs to estimate a shock process for each education category. Specifically, given a guess of parameters, we construct a variance-covariance matrix between lags of the residual component, and compare it with an analogous matrix constructed on the empirical residuals. We iterate on the parameter guess until the two matrices converge. In our estimation, we use 500 bootstraps.

We find that the stochastic component of the earnings process is more persistent for those with more education. The higher this persistence coefficient, the closer the stochastic process is to a random walk, and the harder it is for individuals to self-insure. The fact that self-insurance is harder for those with more education in our results means that higher educational attainment does not insulate workers from risk. Finally, in our estimation the random shock $\nu_{s,j}$ has a similar variance across the two education groups, although it is slightly lower for the $s = h$ group. Specific point estimates are reported in Table 23.

B.4 Summary of results

The results of the age profile from the PSID, the loadings on skill from the NLSY97, and the residual process estimation are presented in Table 23.

Table 21: Age-free wages as a function of skill

	(1) High school	(2) BA
$\beta^e_{s,e=1}$	-0.0426	-0.180***
	(0.0253)	(0.0381)
$\beta^e_{s,e=2}$	-0.0362	-0.132***
	(0.0262)	(0.0258)
R^2	0.0399	0.0555
Obs	14,961	8,545

Notes: Table 21 reports regression results. Model (1) is for high school or some college; model (2) is for BA or higher. Baseline skill quantile is the top quantile ($e = 3$). Not shown in table but included as controls: year FE, number of children (topcoded at 4) indicators, married indicator.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Data Source: NLSY97.

Table 22: Earnings process estimation: sample summary statistics at individual-year level

	Cleaned sample	Regression sample	High school	BA+
Real wage	12.68	15.61	13.14	19.93
Age	25.76	29.98	29.81	30.28
HS GPA	2.93	2.92	2.72	3.28
No. children	0.69	0.88	0.99	0.69
Married	0.27	0.41	0.36	0.49
BA or higher	0.24	0.36		
HS or some college	0.76	0.64		
Meets age restriction	0.53			
Not currently enrolled	0.76			
Obs	49,826	23,506	14,961	8,545

Notes: Table 22 reports summary statistics highlighting effects of restrictions on sample composition for skill loading regression. The level of observation in this table is the individual-year, so being in one estimation sample precludes being in the other (in principle, an individual could be in either sample over the course of their life, but not within a given year). Source: NLSY97.

C The High School Longitudinal Study of 2009

The High School Longitudinal Study of 2009 (HSLS:09) is a representative panel of ninth-grade students in the United States beginning in 2009 who attended high schools that had both ninth and eleventh grades (HSLS, 2009). The survey collection occurs over several waves, with the most recent wave being the collection of post-secondary transcripts and student records, for those enrolled in post-secondary education, up to and including in the 2016-2017 academic year (HSLS, 2020).

Table 24 presents an outline of the structure of the HSLS:09.[47] The study covers several waves; in each wave, several questionnaires may be collected from people or institutions related to the focal sample member or from the sample member themselves. As the outline indicates, the focal sample member is referred to as "Student" while they are in high school and as "Sample member"

[47] Questionnaires are available here: https://nces.ed.gov/surveys/hsls09/questionnaires.asp.

Table 23: Earnings process estimation results

Parameter	**Description**	**Value**
Life cycle productivity: high school or some college ($\epsilon_{j,s=\ell,e}$)		
$\rho_{\eta\|\ell}$	Persistence AR(1)	0.855946
$\sigma^2_{\nu\|\ell}$	Variance AR(1)	0.082112
$\beta^A_{\ell,1}$	Age third-order polynomial	0.105
$\beta^A_{\ell,2}$		-0.00174
$\beta^A_{\ell,3}$		0.00000874
$\beta^e_{\ell,1}$	Skill endowment shifter	-0.0426
$\beta^e_{\ell,2}$		-0.0362
Life cycle productivity: college graduate ($\epsilon_{j,s=h,e}$)		
$\rho_{\eta\|h}$	Persistence AR(1)	0.879158
$\sigma^2_{\nu\|h}$	Variance AR(1)	0.078444
$\beta^A_{h,1}$	Age third-order polynomial	0.182
$\beta^A_{h,2}$		-0.00309
$\beta^A_{h,3}$		0.0000165
$\beta^e_{h,1}$	Skill endowment shifter	-0.180
$\beta^e_{h,2}$		-0.132

Notes: Table 23 summarizes results from the earnings process estimation. Sources: PSID and NLSY97.

during the 2013 Update, because they are between educational programs. Regardless of the focal individual's educational status after the base year, the HSLS:09 makes an effort to collect data from them when student or sample member questionnaires are implemented. Thus the second follow-up in 2016 includes information from students who are currently enrolled in post-secondary education, as well as those who are not enrolled but used to be, and those who did not pursue post-secondary education. If sample members begin a 4-year degree program in the fall after high school graduation (the fall of 2013), and do not take any time off from school, then they complete the second follow up questionnaire right after their third year of college. Additionally, post-secondary education transcripts and student records are collected until up to the student's fourth academic year after enrollment.

Survey information about the focal sample member includes their high school GPA as well as financial aid and private loans they took out to pay for the post-secondary education they did complete. The financial aid information in the student questionnaire is also collected from institutions themselves in the post-secondary transcripts and student records data collection wave, implemented after the second follow-up. Our methodology emphasizes student record information, when available, over student recollection in the student questionnaire. Of course, even if students enroll but do not persist in college, we are able to see information on student debt, grant receipt amounts, and other characteristics.

This section proceeds as follows. Subsection C.1 tabulates college students' expected educational

Table 24: Structure of the HSLS:09

Wave Calendar Year(s) Academic Year (if enrolled) Questionnaire	Base Year 2009 (Fall) 1st year HS (Fall)	1^{st} Follow-up 2012 (Spring) 3rd year HS (Spring)	2013 Update 2013 (Summer) Graduated HS	HS Transcripts 2013-2014 Graduated HS	2^{nd} Follow-up 2016 3rd year PS (Spring)	PS Transcripts + SR 2016-2017 4th year PS (Fall)
Student	X	X				
Parent	X	X				
Student/Parent			X			
Sample Member					X	
Counselor [1]	X	X				
Aministrator [2]	X	X				
Teacher [3]	X					
Institution Attended				X		X

[1] Lead counselor at student's high school.
[2] Administrator (principal) at student's high school.
[3] Math or science teacher at student's high school.

Notes: Table 24 describes the survey structure of the HSLS:09. In this table, HS stands for "high school" and PS stands for "post-secondary". Each row is a type of questionnaire respondent and each column is a different point in time. An "X" represents that a questionnaire is completed by the recipient in a given row at a particular point in time. Calendar years and academic years are distinguished in the table because academic years overlap two calendar years and the semester of data collection is indicated for the academic year except for the 2013 Update and HS transcript collection when this is not relevant. The focal sample member is referred to as "Student" while they are in high school and as "Sample member" during the 2013 update, because they are between educational programs. Regardless of the focal individual's educational status after the base year, the HSLS:09 makes an effort to collect data from them. This ensures that the second follow-up in 2016 includes information from students who are currently enrolled in post-secondary education as well as those who are not.

attainment, and their parents expecations of their educational attainment, along with education outcomes (to the extent they can be observed given the short panel dimension of the HSLS:09). Qualitatively, these findings complement similar findings in the NSLY97. Subsection C.2 presents additional tabulations on student aid. Subsection C.3 reports HSLS:09 statistics used in model specification and calibration. Finally, Subsection C.4 presents summary statistics for the various subsamples used in the tabulations from the HSLS:09 both in this appendix and in the main text. Note that, in all of the tabulations, the data moments are weighted using survey weights and the sample counts are rounded to the nearest 10 as per NCES requirements (HSLS, 2020). The specific survey weights used vary and are noted in the table footnotes.

C.1 Expected educational attainment versus outcomes

In the second wave of data collection, which occurs in the spring of the sample member's junior year of high school (assuming they are still enrolled), the HSLS:09 asks students what their expected educational attainment is. This survey subsequently allows us to check whether the sample members enroll in a 4-year BA program after high school and whether they persisted in their program after enrollment. With this information, we examine the relationship between student skill (high school honors-weighted GPA) and educational outcomes (both expected and realized). In the process we establish that students over-estimate their future educational attainment, especially those with low skill. Unfortunately, the phrasing of the question in the HSLS:09 on BA attainment does not allow us to directly compare expectations with outcomes, unlike the phrasing of the similar question in the NLSY97. Because of this, in the main text we rely on our preferred evidence for this point from the NLSY97 to establish over-optimism about BA attainment. In the HSLS:09, the specific wording of the question when asked to students is "As things stand now, how far in school do you think you will actually get [in your education]?". The survey also asks the same question about the focal student of the student's parent. The possible answers to this question are reported in Table 25. A valid response is one in which students select a code between 1 and 13 ("Don't Know" is a valid response). To flag those who expect to complete a 4-year program, a flag is created which is set to 0 for valid responses and replaced with a 1 if the response x is such that $8 \leq x < 13$. A flag for those who expect to earn at least a masters degree is constructed the same way, but with the lower bound starting at 10.

Table 25: Possible responses to expected educational attainment question in the HSLS:09

Value	Response
1	Less than high school completion
2	Complete a high school diploma, GED or alternative high school credential
3	Start, but not complete a certificate or diploma from a school that provides occupational training
4	Complete a certificate or diploma from a school that provides occupational training
5	Start, but not complete an Associate's degree
6	Complete an Associate's degree
7	Start, but not complete a Bachelor's degree
8	Complete a Bachelor's degree
9	Start, but not complete a Master's degree
10	Complete a Master's degree
11	Start, but not complete a Ph.D., M.D., law degree, or other high level professional degree
12	Complete a Ph.D., M.D., law degree, or other high level professional degree
13	You don't know

Table 26 shows educational attainment expectations and outcomes for several samples of students who enrolled in a 4-year program. This table presents, by high school GPA quantile, the percent of each skill bin that expected to complete college and the percent of the bin that persisted in college into their fourth academic year. Note that, since in the HSLS:09 we observe the student up to four academic years after high school graduation, we cannot definitively say if they permanently drop out of college or fail to ever enroll during the course of their life. For this reason, we use terms like "persistence" and "non-persistence" when discussing findings from the HSLS:09, as opposed to more definitive terms like "dropping out" and "graduating", respectively, which are terms we favor when describing our model framework. In parcticular, Panel A of Table 26 demonstrates that the sample of students who enroll in a 4-year program in 2013 tend to overestimate their educational attainment, given their skill. This is especially the case for those in the first (lowest) skill quantile.

One concern with the findings reported in Panel A of Table 26 is that perhaps restricting to only those who enroll in a 4-year program right after college (in the fall of 2013) restricts to a distorted sample of students. It could hypothetically be the case that these students are the most overly optimistic of high school graduates, while those who take a gap year (or several) are more realistic.

In Panel B of Table 26, we present the results of a robustness exercise where we broaden the sample to include those who enroll in a 4-year program at any point between the 2013-2014 academic year and the 2016-2017 academic year. Persistence in this context means continued enrollment once enrolled, for however long that observable interval is in the HSLS:09. For example, someone who enrolls in the 2016-2017 academic year automatically counts as a student who persists. This is a looser criterion for persistence to compare with expected educational attainment, compared to Panel A. Even with this relaxed criterion, although persistence rates do increase, students still tend to overestimate their persistence on average given their level of skill.

Another concern is that when students answer that they expect a BA (or a higher degree) they are simply responding in this way because admitting they probably will stop after high school is embarrassing (that is, it generates a stigma cost). Such respondents are right on the boundary between admitting they will not attend a BA program and claiming that they will. To address this concern, in Panel C we show a tabulation restricting to those who expect a master's (MA) degree or higher. Note that, by implication, in this group everyone expects to get a BA. This eliminates students who are fibbing in their responses that they expect to earn a BA or more because of stigma costs, by dropping those right on the threshold of admitting they won't get a BA. It seems less likely that stating you expect to get an MA or more, relative to a BA, is driven by fear of stigma costs. The tabulation demonstrates that the fraction who persist in each quantile still remains well below the expected graduation rate from college.

Finally, what do parents think of their child's likelihood of graduating from a 4-year degree? In Panel D of Table 26, we tabulated the parent responses to what they expect their child's educational attainment will be, with the response choice set shown in Table 25.[48] Panel D shows that, for the sample of students who enrolled in a BA program in the fall of 2013, most parents were not surprised (they expected their children to do so). Nevertheless, parents in this group tend to overestimate the likelihood of college graduation for their children, and this is especially true when their child belongs in a lower skill quantile.

Patterns of over-optimism by skill quantile in the HSLS:09 are very similar to the analogous NLSY97 results in the main text, both for college students and their parents. However, since the survey question asks about ever completing college (presumably at some point in the student's life), the data counterpart to precisely check the realized outcomes against the student's expectation is impossible to construct in the HSLS:09. One would need to observe the survey respondent until the end of their life.

[48] The sample size of families with responses to this questionnaire is much smaller than the sample of valid student responses because the parent questionnaire was only administered to a random sample of 48% of families in the sample.

Table 26: Educational attainment outcomes vs. expectations

Panel	Sample	Sample obs	Q	Obs(Q)	% Persisted in BA	% Expect BA
A	Fall 2013 enrollees	2,670	1	190	38.81	76.33
			2	800	56.30	82.22
			3	1,680	78.70	92.27
B	Ever enrolled	3,270	1	290	54.38	72.25
			2	1,030	60.00	81.62
			3	1,950	79.98	91.33
C	Expect MA+	1,580	1	70	37.83	100
			2	390	57.33	100
			3	1,110	79.47	100
D	Parent expectations	1,240	1	80	35.50	71.20
			2	370	56.08	94.62
			3	790	79.31	94.38

Notes: Sample: 2013 BA enrollees with additional restrictions that differ across panels; see second column. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to the nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights.

C.2 Graint aid and the borrowing-constrained

Table 27 reports statistics on grant aid receipt in dollar amounts and uptake rates, across persistence statuses. Grants are cumulative as of the summer of 2016. Non-persisters receive a sizeable amount of aggregate grants allocated: almost 1 in 4 dollars allocated in grants go to this group (Panel A). Like student loan balances, the average grant aid received is slightly lower among non-persisters who received any grants, because they received it for fewer years than students who persisted in college. The two groups receive similar amounts of merit aid, but persisters tend to receive slightly higher amounts of need-based grants. In Panel B, it is evident that grant receipt rates are similar across the two persistence categories. The type of grant is also similar, although non-persisters are more likely to receive merit grants that persisters. Table 28 reports the fraction of

Table 27: Grant aid by persistence status

Panel A: $ amounts	**Persistence status**	**Group obs**	**Total**	**Merit**	**Need**	**% of agg $**
	Did not persist	730	9,573	7,302	6,980	22.73
	Persisted	1,940	12,630	8,856	10,106	77.27
Panel B: % received	**Persistence status**	**Group obs**	**% need only**	**% merit only**	**% both**	**% either**
	Did not persist	730	17	32	26	76
	Persisted	1,940	21	28	24	74
	Obs	2,670				

Notes: grant aid in the HSLS:09. Panel A gives dollar amounts and share of total grant dollars by persistence status; panel B gives the composition of grants received, on average, by persistence status. Sample: students who enrolled in a 4-year program in the fall of 2013. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to the nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights.

college students who utilize a given fraction of their federal student loan borrowing limit, either 50 or 100%. These statistics are reported for all fall 2013 enrollees who persist until their fourth academic year of college, and excluding independent borrowers (to whom the federal student aid rules give higher limits). The numbers are very similar across the two samples, because very few students file an application for federal student aid (the FAFSA) as independents. Who are

Table 28: Utilization rates for federal student loans

	Samples	
Utilization rate	**Fall 2013 enrollees**	**No independents**
$\geq 50\%$	0.529	0.529
$\geq 100\%$	0.328	0.325
Obs	1,940	1,870

Sample: students who enrolled in a 4-year program in the fall of 2013 and persisted to their 4th year (first column); and, non-filers and those whose most recent filing was as a dependent, dropping those who most recently filed as independents (second column). Utilization rates of federal SL by end of 3rd academic year. Borrowing limit computed using reported dependency status and academic year from FAFSA. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights.

the borrowing-constrained, when it comes to federal student loans? Table 29 reports descriptive statistics of the pool of enrollees who persist until their fourth year (first sample starting on the left), as well as that sample but excluding independents, and then for those who utilize at least 50% and 100% of their federal borrowing limits. Moving from left to right across these samples, it seems that the borrowing constrained (when it comes to federal loans) are middle-income and middle-skill, relative to the student population (Panels A and B). They tend to pay higher tuition than average, and to have higher private student loan balances (Panel C). They also are more likely to be employed, and less likely to be out of the labor force, than the average college student (Panel D).

C.3 Calibration targets and model primitives

Table 30 reports moments computed by skill quantile in the HSLS:09 which are used to motivate various attributes of the model in the main text, as well as moments used to calibrate our quantitative model. There are three categories of moments, indexed with roman numerals, in the table: child skill by parental education, tuition and grant aid, and persistence rates. Category I shows that parents with higher education tend to have children in higher skill quantiles. Here, a skill quantile refers to the focal sample member's high school GPA tercile. The first category of moments is reported for students who have graduated from high school without conditioning on college enrollment outcomes. Category II, tuition and grant aid, reports the average tuition paid by each skill

Table 29: Attributes of students with binding constraints vs enrollees

			Samples			
Panel	**Category**	**Statistic**	**Enr fall 2013**	**No independents**	**50% limit**	**100% limit**
A	Fraction per income Q	$Q = 1$	0.153	0.151	0.155	0.140
		$Q = 2$	0.314	0.307	0.377	0.403
		$Q = 3$	0.534	0.542	0.468	0.457
B	Fraction per GPA Q	$Q = 1$	0.050	0.052	0.075	0.077
		$Q = 2$	0.270	0.272	0.334	0.323
		$Q = 3$	0.680	0.676	0.592	0.601
C	Tuition and fees + cumulative SL balances	Tuition and fees (1st Inst)	18,530	18,639	19,810	20,716
		Private Loans	4,790	4,910	8,067	8,619
		Federal Loans	10,746	10,686	18,371	20,773
D	Labor force status, Y3	Full-Time	0.064	0.064	0.073	0.082
		Part-Time	0.546	0.541	0.589	0.605
		Unemployed	0.067	0.068	0.055	0.057
		NILF	0.323	0.327	0.283	0.256
		Obs	1,940	1,870	900	540

Notes: each Panel reports a set of statistics for various samples. Samples: first column is students who enrolled in a 4-year program in the fall of 2013 and persisted to their 4th year; second column is non-filers and those whose most recent filing was as a dependent, dropping those who most recently filed as independents; third and fourth columns additionally restrict by utilization rates as indicated by column header. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights for all of the panels.

quantile of college students in the HSLS:09 (here, college students means those who enroll immediately after high school graduation, in the fall of 2013). The fact that tuition does not vary greatly across skill quantiles is why the model of the main text includes a pre-subsidy tuition level set to the same value for all college students. The second column in this category is the ratio of aggregate grants to aggregate tuition and fees within each skill quantile. This ratio is used to compute the subsidy rate from public and private grants, along with findings from previous studies. Finally, Category III in Table 30, persistence rates, is used to discipline the dropout shock primitive for those enrolled in college. From left to right, these persistence rates are for those enrolled in their first year (the percent reaching their fourth year) and those enrolled in their second year (again, the percent reaching their fourth year, given the enrollment criterion). Table 31 reports moments describing average labor supply among enrollees (Panel A), FAFSA filing rates (Panel B), dependency status of FAFSA filers (Panel C), and reasons for not enrolling in post secondary education (Panel D). Panel A reports a fraction of the time endowment spent working, on average, among fall 2013 enrollees who are enrolled during their third year of college. This is used to parameterize the quantitative model. Panel B reports FAFSA filing rates among college students, which are quite high, while Panel C reports the fraction of FAFSA filers who are filing as dependents, which is nearly 100 percent. Together, these two panels motivate why we use dependent borrowing terms

Table 30: Statistics by skill quantile

	Category:	(I) Child skill by parent education		(II) Tuition and grant aid		(III) Persistence rates to Y4	
	Sample:	High school grads		Enr fall 2013 BA (Y1)		Enr Y1	Enr Y2
	Statistic:	$\pi\left(e \mid s=\ell\right)$	$\pi\left(e \mid s=h\right)$	Tuition + Fees	$\frac{\text{Agg Merit + Need Grants}}{\text{Agg Tuition + Fees}}$	% Enr. Y4	% Enr. Y4
Skill Q:	1	42.43	18.53	15,834	0.408	38.81	67.23
	2	34.32	32.19	16,457	0.474	56.30	75.74
	3	23.25	49.28	17,907	0.514	78.70	86.17
	Obs	5870	4980	2670	2670	2670	2310

Notes: Sample: see column note. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to the nearest 10 per NCES requirements. Weights: for category (I), weights are 2013 Update longitudinal weights; for cateogry (II) and (III), weights are PETS-SR student records longitudinal weights.

from the federal student loan program in our model parameterization. Finally, in Panel D, we report suggestive evidence for why students never enroll in post secondary education, to motivate the introduction of the q shock in the quantitiative model. This evidence is constructed from responses to the question "why did you never enroll in college?" (in this context, unlikely in our paper generally, college means any postesecondary education). Respondents are only asked this question if they say they never enrolled in post secondary education, so those who never enroll in a 4-year degree are frequently not asked this question. Even conditioning on being asked, non-response rates are high. Nevertheless, when presented with a menu of possible reasons for not enrolling, many respondents indicate that factors like academics, family, or other reason that do not include financial or work factors led to them not enrolling in college.

Finally, in Table 32, we present regression results for an exercise in which we regress an indicator for persisting to the next academic year on various attributes of the student in the current year. We use an OLS estimator, and perform the exercise using as a dependent variable an indicator for persisting from year 1 to year 2 (model 1 in the table), from year 2 to year 3 (model 2), and from year 3 to year 4 (model 3). The results indicate that high school GPA plays a sizable role in predicting persistence early in one's college career, reinforcing our model specification linking the probability of college dropout to student skill and year of enrollment. Despite being statistically significant, the coefficients on family income are quite small in magnitude. Parental education and hours worked, as well as the stock of student loans in the current year (which varies across models in the table) all have predictive power for persistence early on but this fades in the third year of college.

Table 31: Labor supply, FAFSA filing rates and dependency status, and reasons never enrolled

Panel	**Category**	**Variable**	**Mean value**	**Panel sample obs**
A	Labor supply junior year	$\frac{\text{Ave. weekly hours worked}}{40}$	0.319	2090
B	FAFSA filing rate	in AY 14	0.797	1940
		in AY 15	0.739	
		in AY 16	0.676	
		in AY 17	0.689	
C	Fraction FAFSA filers dependents	in AY 14	0.992	1550
		in AY 15	0.987	
		in AY 16	0.982	
		in AY 17	0.948	
D	Reason never enrolled in PSE (answered "yes" for a given reason)	Academic, personal/family, other reason	0.238	4660
		Financial	0.185	
		Work, military, career	0.155	

Notes: Sample: Panels A and B: students who enrolled in a 4-year program in the fall of 2013 and persisted to their fourth year. Panel C: 2013 enrollees who persisted to their fourth year who filed a FAFSA. Panel D: sample members who graduated from high school in 2013 and either did not enroll in any PSE and respondended to the question about why, or who enrolled in a 4-year degree in the fall of 2013. For the purpose of computing frequencies reported in Panel D of this table, students who enrolled in 2013 are counted as answering 'No' (value of 0) for each possible reason. Academic years in this table are referenced with the year in which the academic year ends (e.g., enrolling in the fall of 2013 is academic year 2013-2014 or AY14). Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample sizes are rounded to the nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights for Panels A, B, and C, and Second Follow-up longitudinal weights for Panel D.

Table 32: Predicting enrollment persistence

	(1) Y2|Y1	(2) Y3|Y2	(3) Y4|Y3
HS GPA (Honors Wgtd)	0.185^{***}	0.0730^{***}	-0.00472
	(0.0237)	(0.0207)	(0.0222)
Household income	0.000000167^{***}	-1.67e-09	$7.55\text{e-}08^{**}$
	(5.79e-08)	(5.57e-08)	(3.48e-08)
At least 1 Parent BA+	0.0686^{***}	0.0538^{**}	0.0125
	(0.0218)	(0.0210)	(0.0216)
Log(Hrs)	-0.0626^{***}	-0.0364^{**}	-0.0313
	(0.0232)	(0.0183)	(0.0201)
Not Working	-0.171^{***}	-0.102^{**}	-0.0787
	(0.0576)	(0.0506)	(0.0586)
Log(SL)	0.175^{***}	0.0123	-0.0170
	(0.0294)	(0.0234)	(0.0201)
No SL	1.501^{***}	0.119	-0.147
	(0.255)	(0.212)	(0.193)
R^2	0.173	0.0785	0.0829
Obs	2670	2310	2090

Notes: Sample: students who enrolled in a 4-year program in the fall of 2013; the second column additionally conditions on being enrolled in Y2; the third column additionally conditions on being enrolled in Y3. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to the nearest 10 per NCES requirements. Weights are PETS-SR student records longitudinal weights. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

C.4 Summary statistics

This section reports summary statistics for the samples used to compute the HSLS:09 findings reported in the main text.

Table 33: Summary Statistics

Panel A: Expectations and outcomes	**Sample**							
Variable	HS Grads	Enr BA Ever	Enr BA 2013 (Y1)	Enr Y2	Enr Y3	Enr Y4	Enr Y1 + Exp MA	Enr Y1 + Parents Exp.
Student Exp. HS	0.901	0.932	0.938	0.945	0.948	0.946	1.000	0.946
HS Degree or Equivalent	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Student Exp College Enr.	0.684	0.866	0.884	0.899	0.905	0.902	1.000	0.896
Enr Fall 2013 in BA	0.275	0.798	1.000	1.000	1.000	1.000	1.000	1.000
Ever Enr by Summer 2016 in BA	0.366	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Student Exp College Pers.	0.672	0.858	0.876	0.893	0.900	0.898	1.000	0.887
Persisted to 2016-2017 AY	0.693	0.679	0.679	0.820	0.913	1.000	0.709	0.687
Std Pers (Ever Enr BA)	0.722	0.703	0.679	0.820	0.913	1.000	0.709	0.687
PETS: BA deg as of June 2016	0.018	0.026	0.031	0.037	0.042	0.045	0.036	0.030
Obs	9280	3270	2670	2310	2090	1940	1580	1240

Panel B: Demographics	**Sample**							
Variable	HS Grads	Enr BA Ever	Enr BA 2013 (Y1)	Enr Y2	Enr Y3	Enr Y4	Enr Y1 + Exp MA	Enr Y1 + Parent Exp
Household income	81,210	103,603	106,750	112,775	113,963	116,512	111,787	107,495
	(60,000)	(82,500)	(85,000)	(90,000)	(90,000)	(90,000)	(87,500)	(85,000)
HS GPA (Honors Wgtd)	2.69	3.11	3.18	3.25	3.27	3.28	3.28	3.21
	(2.74)	(3.20)	(3.26)	(3.34)	(3.36)	(3.36)	(3.35)	(3.28)
Fed SL Balance Y1	2,506	3,182	3,425	3,454	3,374	3,308	3,315	3,485
	(0)	(3,175)	(3,500)	(3,500)	(3,500)	(3,500)	(3,500)	(3,500)
Prv SL Balance Y1	546	786	821	857	831	769	786	671
	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
T+F (1st Inst)	11,630	15,501	17,253	18,059	18,312	18,530	17,695	17,745
	(7,343)	(10,002)	(11,127)	(11,845)	(12,541)	(12,450)	(11,373)	(11,632)
Female	0.50	0.52	0.53	0.53	0.54	0.53	0.55	0.54
At least 1 Parent BA+	0.37	0.54	0.56	0.60	0.62	0.63	0.60	0.61
Obs	9280	3270	2670	2310	2090	1940	1580	1240

Notes: Panel A shows means for variables related to educational attainment expectations and outcomes; Panel B shows meands (medians) related to the demographic characteristics of each sample. Medians for moments that are frequencies are suppressed. Source: U.S. Department of Education, National Center for Education Statistics, High School Longitudinal Study of 2009 (HSLS:09) Restricted-Use Data File. Sample size rounded to nearest 10 per NCES requirements. Weights are Second Follow-Up weights for the HS grads sample and PETS-SR student records longitudinal weights for the other samples.

D The 2019 Survey of Consumer Finances

The Survey of Consumer Finances (SCF) is a triennial survey sponsored by the Federal Reserve Board and the U.S. Department of the Treasury. We use the 2019 wave of the SCF (SCF, 2019). Table 34 contains SCF codebook variable codes corresponding to variables discussed in the text.

Table 34: Mapping from variables to 2019 Survey of Consumer Finances codebook codes

Category	Variable	Description using SCF codebook codes
Survey	Survey weight	X42001
Income	Total income	(A) + (B) + (C) + (D)
	Wages and salaries (A)	X5702
	Self employment (B)	X5704
	Capital income (C)	X5706 + X5708 + X5710 + X5712 + X5714
	Other (D)	X5724 + X6558 + X6566 + X6574 + max(0,X6464) + max(0,X6469) + max(0,X6474) + max(0,X6479) + max(0,X6965) + max(0,X6971) + max(0,X6977) + max(0,X6983)
Student loans	Current balance	X7824 + X7847 + X7870 + X7924 + X7947 + X7970 + X7179
	Interest rate	X7822, X7845, X7868, X7922, X7945, X7968
	Borrower	(respondent if=1, spouse if=2): X7978, X7883, X7888, X7893, X7898, X7993
	Loan type	(federal if=1, private if=5): X7879, X7884, X7889, X7894, X7899, X7994
	Graduate	(Yes if=1, No if=5): X7881, X7886, X7891, X7896, X7901, X7996
	Delinquent	if=3: X9300, X9301, X9302, X9303, X9304, X9305

Notes: Table 34 contains the 2019 Survey of Consumer Finances codebook codes corresponding to variables used in analysis. Total income is manually constructed from components for accuracy. Source: https://www.federalreserve.gov/econres/files/codebk2019.txt.

Part II

Model Appendix

E Value functions

The over-optimistic value of college for $j = 4$ is given by

$$\hat{V}(j,h,e,\eta,a,x) = \max_{\hat{c}\geq 0,\hat{a}',\hat{x}'} U(c,j,h) \; - \xi 1_{a\geq 0 \text{ and } x=0 \text{ and } (\hat{a}'<0 \text{ or } \hat{x}'>0)} - \xi^{pr} 1_{x=0 \text{ and } \hat{x}'>0} \tag{23}$$

$$+ \beta\psi_j \left[\hat{p}(e) E_{\eta'|h,\eta} V(j+1,h,e,\eta',\hat{a}',\hat{x}') \; + (1-\hat{p}(e)) E_{\eta'|\ell,\eta} V(j+1,\ell,e,\eta',\hat{a}',\hat{x}') \right]$$

$$s.t.$$

$$(1+\tau_c)\hat{c} + \hat{a}' + (1-\theta(e)-\theta^{pr}(e))\kappa = y_{j,h,e,\eta,a} + a + Tr_j - T(y_{j,h,e,\eta,a}) + (\hat{x}'-x)$$

$$\hat{a}' \geq -\frac{\bar{A}[(1-\theta(e)-\theta^{pr}(e))\kappa + \bar{c}]j}{4}$$

$$\hat{a}' \leq a \;\; \text{if} \;\;\; a \leq 0$$

$$\hat{x}' - x \in \left[0, [(1-\theta(e)-\theta^{pr}(e))\kappa + \bar{c}] - [\max(-\hat{a}',0) - \max(-a,0)]\right]$$

F Equilibrium definition

To define the equilibrium, we must first discuss notation, define the Social Security transfer function, and present the zero expected profit condition that pins down the private student loan interest rate. Let $\overrightarrow{\omega}$ denote the idiosyncratic state of a consumer. This state depends on age and enrollment status in the following way:

$$\overrightarrow{\omega} = \begin{cases} (e, \eta, a) & \text{for 18-year-olds, before making the college entrance decision} \\ (j, h, e, \eta, a, x) & \text{for consumers in college} \\ (j, s, e, \eta, a, x) & \text{for consumers not enrolled, dropouts, or graduates, unless } j = j_f + j_a \\ (j, s, e, \eta, a, x, e_c) & \text{if } j = j_f + j_a \end{cases} \tag{24}$$

Furthermore, let $\hat{d}_{d,t}(\overrightarrow{\omega})$ and $d_{d,t}(\overrightarrow{\omega})$ denote the dropout decisions that solve the endogenous discrete dropout problems in the continuation values of equations (10) and (11), respectively.

Private loan interest rate: $r^{pr}_{SL,t}$ is such that the lender makes zero expected profits in pooling each cohort of 18-year-old-consumers. The zero expected profit condition is given by

$$\Bigg[\sum_{i=1}^{4}(\beta)^{i-1}\int((1+\tau_{is})x'_{t+i-1}(\overrightarrow{\omega}) - x)\Omega_{t+i-1}d(\overrightarrow{\omega}|j=i)\Bigg] = \tag{25}$$
$$\sum_{i=5}^{J}(\beta)^{i-1}\int\Bigg[(1-d_{x,t+i-1}(\overrightarrow{\omega}))\rho^{pr}_{R}(j,x)+$$
$$d_{x,t+i-1}(\overrightarrow{\omega})\big[\rho^{pr}_{D}(j,x,y_{j,s,e,\eta,a}) - \phi_D[\rho^{pr}_{R}(j,x) - \rho^{pr}_{D}(j,x,y_{j,s,e,\eta,a})]\big]\Bigg]\Omega_{t+i-1}d(\overrightarrow{\omega}|j=i),$$

where β is the lender's discount factor and τ_{is} is a student loan issuance cost. We assume the same student loan issuance cost for federal student loans, which ensures that both federal and private student loans have the same technology for issuing debt.

Social Security transfer function: Social Security transfers replace a fraction χ of: the average labor earnings for the 30 years before retirement conditional on education and skill plus the average unconditional labor earnings for the 30 years before retirement, divided by two. The transfer function is given by

$$ss_{s,e} = \frac{\chi}{2}\left[\frac{\int w\eta\epsilon_{j,s,e}\Omega_t d(\overrightarrow{\omega}|18 \leq j < j_r, s, e)}{\int \Omega_t d(\overrightarrow{\omega}|18 \leq j < j_r, s, e)} + \frac{\int w\eta\epsilon_{j,s,e}\Omega_t d(\overrightarrow{\omega}|18 \leq j < j_r)}{\int \Omega_t d(\overrightarrow{\omega}|18 \leq j < j_r)}\right] \tag{26}$$

Definition Given an initial level of capital stock K_0 and an initial distribution over idiosyncratic states $\Omega_0(\overrightarrow{\omega})$, a competitive equilibrium consists of sequences of household value functions $\{\hat{W}_t(\overrightarrow{\omega}), V_t(\overrightarrow{\omega}), \hat{V}_t(\overrightarrow{\omega}), V_t^R(\overrightarrow{\omega}), V_t^D(\overrightarrow{\omega}), V_t^{D_f}(\overrightarrow{\omega}), V_t^{D_x}(\overrightarrow{\omega})\}$, household college entrance and dropout policy functions $\{\hat{d}_{s,t}(\overrightarrow{\omega}), \hat{d}_{d,t}(\overrightarrow{\omega}), d_{d,t}(\overrightarrow{\omega})\}$, household consumption and next period asset policy functions $\{\hat{c}_t(\overrightarrow{\omega}), \hat{a}'_t(\overrightarrow{\omega}), c_t(\overrightarrow{\omega}), a'_t(\overrightarrow{\omega})\}$, household delinquency policy functions $\{d_{f,t}(\overrightarrow{\omega}), d_{x,t}(\overrightarrow{\omega})\}$, household inter vivos transfer policy function $\{b_t(\overrightarrow{\omega})\}$, production plans $\{Y_t, K_t, L_t\}$, sequence of federal student loan policies $\{\bar{A}_t, \tau_{SL}, \bar{y}, \tau_g, T_{SL}\}$, sequence of tax, government consumption, public education subsidy, and Social Security policies $\{\tau_p, \gamma_t, \tau_c, g, \theta(e), \chi\}$, sequence of prices $\{r_t, w_t, r_{SL,t}^{pr}\}$, sequence of Social Security transfers $\{ss_{t,s,e}\}$, sequence of accidental bequests $\{Tr_{t,j}\}$, and sequence of measures $\{\Omega_t(\overrightarrow{\omega})\}$ such that:

(i) Given prices, transfers, and policies, the value functions and household policy functions solve the consumer problems in equations (8)-(18) and (23);

(ii) The saving interest rate and wage rate satisfy equations (21) and (22), respectively;

(iii) The private student loan interest rate satisfies equation (25);

(iv) Social Security transfers satisfy equation (26);

(v) Accidental bequests are transferred to households between ages 50 and 60 $(33 \leq j \leq 43)$ after deducting expenditure on private education subsidies[49]

$$Tr_{t+1,j} = \frac{\int (1-\psi_j)a'_t(\overrightarrow{\omega})\Omega_t d(\overrightarrow{\omega}) - \kappa \int \theta^{pr}(e) 1_{s=h \text{ and } j\in\{1,2,3,4\}}\Omega_{t+1} d(\overrightarrow{\omega})}{\sum_{j=33}^{43} N_{t+1,j}} \tag{27}$$

where $N_{t,j}$ denotes the mass of population at time t of age j;

(vi) Government budget constraint balances as follows, by adjusting γ:

$$\int [\tau_c c_t(\overrightarrow{\omega}) + T(y_{t,j,s,e,\eta,a})]\Omega_t d(\overrightarrow{\omega}) = G_t + E_t + D_t + SS_t \tag{28}$$

where G_t, E_t, D_t, and SS_t are government consumption, total public education subsidy, federal

[49]In our baseline calibration, and all of the counterfactual exercises, accidental bequests are always positive, because the assets of those who die exceed the expenditure on private subsidies to education costs. If they did not exceed private subsidies, then bequests would be negative, which is equivalent to a lump-sum tax.

student loan program expenditure, and Social Security expenditure, and are computed as follows:

$$
\begin{aligned}
G_t =& gY_t = gK_t^{\alpha}(ZL_t)^{1-\alpha} \\
E_t =& \kappa \int \theta(e) 1_{s=h \text{ and } j\in\{1,2,3,4\}} \Omega_t d(\overrightarrow{\omega}) \\
D_t =& \int \Big[1_{j\leq 4}[\min[a,0] - \min[(1+\tau_{is})a_t'(\overrightarrow{\omega}),0]] + \\
& 1_{j>4}(1-d_{f,t}(\overrightarrow{\omega}))[\min[a,0](1+r_{SL}) - \min[a_t'(\overrightarrow{\omega}),0]] + \\
& 1_{j>4} d_{f,t}(\overrightarrow{\omega})[-\rho_D(j,a,y_{t,j,s,e,\eta,a}) + \phi \max[\rho_R(j,a) - \rho_D(j,a,y_{t,j,s,e,\eta,a}),0]\Big] \Omega_t d(\overrightarrow{\omega}) \\
SS_t =& \int 1_{j\geq j_r} ss_{t,s,e} \Omega_t d(\overrightarrow{\omega})
\end{aligned}
$$

(vii) Labor, capital, and goods markets clears in every period t:

$$
\begin{aligned}
L_t =& \int [1_{j\leq 4, s=h} \eta \epsilon_{j,\ell,e} l_{pt} + 1_{4<j<j_r, s=h} \eta \epsilon_{j,s,e} + 1_{j<j_r, s=\ell} \eta \epsilon_{j,s,e}] \Omega_t d(\overrightarrow{\omega}) \\
K_{t+1} =& \int \max[a_t'(\overrightarrow{\omega}),0] \Omega_t d(\overrightarrow{\omega}) \\
Y_t =& C_t + K_{t+1} - (1-\delta)K_t + G_t + \kappa \int 1_{j\leq 4, s=h} \Omega_t d(\overrightarrow{\omega}) + \\
& \phi \int \Big[d_{f,t}(\overrightarrow{\omega}) \max[\rho_R(j,a) - \rho_D(j,a,y_{t,j,s,e,\eta,a}),0] + \\
& d_{x,t}(\overrightarrow{\omega}) \max[\rho_R^{pr}(j,x) - \rho_D^{pr}(j,x,y_{t,j,s,e,\eta,a}),0] \Big] \Omega_t d(\overrightarrow{\omega}) + \\
& \tau_{is} \int 1_{j\leq 4} \Big[-\min[a_t'(\overrightarrow{\omega}),0] + x_t'(\overrightarrow{\omega}) \Big] \Omega_t d(\overrightarrow{\omega})
\end{aligned}
$$

where C_t is aggregate consumption; and

(viii) $\Omega_{t+1} = \Pi_t\Big(\Omega_t\Big)$, where Π_t is the law of motion that is consistent with consumer household policy functions and the exogenous processes for population, labor productivities, skill, and college dropout probabilities.

G Computational algorithm

To solve for the stationary equilibrium, we proceed as follows.

1. Guess prices (interest rate r_{guess}, wage rate w_{guess}, and private student loan interest rate

$r^{pr}_{SL,\text{guess}}$) and taxes and transfers (income tax rate γ_{guess}, accidental bequests $Tr_{j,\text{guess}}$, and Social Security transfers $ss_{s,e,\text{guess}}$).

2. Use backward induction to solve the consumer's problem from $j = j_f + j_a + 1, \ldots, J$ (equations (12)-(16)).

3. Guess overly optimistic value function before college, $\hat{W}_{\text{guess}}(e, \eta, a)$ (equation (8)).

4. Use backward induction to solve for the consumer's problem from $j = 1, \ldots, j_f + j_a$ (equations (8)-(18) and (23)).

   - In solving the consumer's problem at $j = j_f + j_a$, the guess $\hat{W}_{\text{guess}}(e, \eta, a)$ is used for the child's value function.

   - For consumers before college graduation age who are not in college and do not have outstanding student loans, ($j \leq 4, s = \ell, a \geq 0, x = 0$), and for consumers after college graduation age who do not have outstanding student loans, ($j > 4, a \geq 0, x = 0$), we use golden-section search to solve their consumption-savings problems. This is because, in our model, after any outstanding student loans are paid off, there is no other form of borrowing. Hence, these consumers will not choose any form of delinquency, and we can use continuous optimization methods to solve their problems.

   - For consumers before college graduation age who are in college or have outstanding student loans ($j \leq 4, s = h$ or $a < 0$ or $x > 0$) and for consumers after college graduation age who have outstanding student loans ($j > 4, a < 0$ or $x > 0$), we use discrete grid search to solve their problems. This is because the delinquency decision could lead to discontinuities in the objective functions.

5. Use newly computed estimates for value before college $\hat{W}(e, \eta, a)$ to update $\hat{W}_{\text{guess}}(e, \eta, a)$, and repeat 4.-5. until convergence.

6. Guess initial distribution of 18-year-old consumers $\Omega(j = 1, e, \eta, a)_{\text{guess}}$.

7. Given policy functions, exogenous processes, and $\Omega(j = 1, e, \eta, a)_{\text{guess}}$, simulate and solve for distribution of Ω for $j = 2, \ldots, J$.

8. Use distribution of Ω for $j = j_f + j_a$ and inter-vivos transfers policy function of consumers at $j = j_f + j_a$ to compute new estimates for distribution of intial 18-year-old consumers $\Omega(j = 1, e, \eta, a)$.

9. Update $\Omega(j = 1, e, \eta, a)_{\text{guess}}$ and repeat 7.-9. until convergence.

10. Given the stationary distribution of Ω for $j = 1, \ldots, J$, solve for new guesses for prices,

income tax rate, and transfers:

- Compute the new values for the interest rate and wage rate using first order conditions from the firm's profit maximization problem (equations (21) and (22)).
- Compute the new value for private student loan interest rate using the zero-expected-profit condition (equation (25)).
- Compute the new value for γ (determines the average income tax rate) using the government budget constraint (equation (28)).
- Compute the new guess for accidental bequests (equation (27)).
- Compute the new guesses for the Social Security transfers using the Social Security transfer function (equation (26)).

11. Update guesses for prices, income tax rate, and transfers, and repeat steps 2.-11. until convergence.

Solving for the transition path is analogous to the algorithm discussed above except that there are time subscripts for all value functions, policy functions, prices, taxes, transfers, and distributions. We proceed as follows.

1. Solve for the initial stationary equilibrium (algorithm described above).
2. Solve for the final stationary equilibrium (algorithm described above).
3. Guess prices (interest rate $r_{t,\text{guess}}$, wage rate $w_{t,\text{guess}}$, and private student loan interest rate $r^{pr}_{SL,t,\text{guess}}$) and taxes and transfers (income tax rate $\gamma_{t,\text{guess}}$, accidental bequests $Tr_{t,j,\text{guess}}$, and Social Security transfers $ss_{t,s,e,\text{guess}}$) for all periods of the transition path.
4. Given the value functions from the final stationary equilibrium, use backward induction to solve for the value functions and policy functions for all periods of the transition path.
   - Within a period, the value function for $j = j_f + j_a$ needs to be solved for after solving for $\hat{W}_t(e, \eta, a)$. For the other consumer problems, the order within a period does not matter.
5. Given policy functions and the initial stationary distribution of consumers, i.e., Ω_{initial} for $j = 2, \ldots, J$, simulate the economy and solve for Ω_t for all periods of the transition path.
   - Within a period, the distribution of Ω_t for $j = j_f + j_a$ and inter-vivos transfers policy function of consumers at $j = j_f + j_a$ is used to compute the distribution of intial 18-year-old consumers $\Omega_t(j = 1, e, \eta, a)$.

6. Use the distribution of consumers in period t, Ω_t, to compute the new guesses for prices, taxes, and transfers for every period of the transition path (equations described in algorithm above).

7. Update the guesses and repeat 4.-7. until convergence.

H Measuring welfare

To measure welfare, we assume that the social planner is altruistic and has the correct beliefs. That is, the planner is not overly optimistic, understands that consumers are overly optimistic, and internalizes their decision rules in computing expected lifetime utilities. This type of a planner is also referred to as a paternalistic government in the literature.

Let value functions with a tilde denote expected lifetime utilities computed by the planner. For $j = j_f + j_a + 1, \ldots, J$, the values computed by the planner are equal to that of the consumer, i.e., $\tilde{V}(\overrightarrow{\omega}) = V(\overrightarrow{\omega})$. This is because over-optimism about college graduation likelihood only affects the college enrollment decision, the inter-vivos transfer decision, and the decisions leading up to and including the age in which the inter-vivos transfer decision is made $(j_f + j_a)$. After that, the consumers' over-optimism about college graduation likelihood no longer affects their decision rules and they have the correct beliefs about their future outcomes.

For $j = j_f + j_a$, the age at which the consumer makes the inter-vivos transfer decision, the planner's value function is given by

$$\tilde{V}(j,s,e,\eta,a,x) = \sum_{e_c} \pi(e_c|s)\big[(1-d_f)(1-d_x)\tilde{V}^R(j,s,e,\eta,a,x,e_c)+ \tag{29}$$
$$d_f(1-d_x)\tilde{V}^{D_f}(j,s,e,\eta,a,x,e_c) + (1-d_f)d_x\tilde{V}^{D_x}(j,s,e,\eta,a,x,e_c) + d_f d_x \tilde{V}^D(j,s,e,\eta,a,x,e_c)\big]$$

In computing $\tilde{V}(j,s,e,\eta,a,x,e_c)$, the planner takes as given the delinquency decisions $d_f(j,s,e,\eta,a,x,e_c)$ and $d_x(j,s,e,\eta,a,x,e_c)$, which solve equation (17). Note that there is no optimization problem for the planner (i.e., no $\max$ operator). The values for $\tilde{V}^R(j,s,e,\eta,a,x,e_c)$, $\tilde{V}^{D_f}(j,s,e,\eta,a,x,e_c)$, $\tilde{V}^{D_x}(j,s,e,\eta,a,x,e_c)$, and $\tilde{V}^D(j,s,e,\eta,a,e,x,e_c)$ are given by

$$\tilde{V}^R(j,s,e,\eta,a,x,e_c) = U(c,j,s) + \beta\psi_j E_{\eta'|s,\eta}\tilde{V}(j+1,s,e,\eta',a',x') + \beta_c E_{\eta'|\ell}\tilde{W}(e_c,\eta',b)$$
$$\tilde{V}^{D_f}(j,s,e,\eta,a,x,e_c) = U(c,j,s) - \xi_D + \beta\psi_j E_{\eta'|s,\eta}\tilde{V}(j+1,s,e,\eta',a',x') + \beta_c E_{\eta'|l}\tilde{W}(e_c,\eta',b)$$
$$\tilde{V}^{D_x}(j,s,e,\eta,a,x,e_c) = U(c,j,s) - \xi_D^{pr} + \beta\psi_j E_{\eta'|s,\eta}\tilde{V}(j+1,s,e,\eta',a',x') + \beta_c E_{\eta'|l}\tilde{W}(e_c,\eta',b)$$
$$\tilde{V}^D(j,s,e,\eta,a,e,x,e_c) = U(c,j,s) - \xi_D - \xi_D^{pr} + \beta\psi_j E_{\eta'|s,\eta}\tilde{V}(j+1,s,e,\eta',a',x') + \beta_c E_{\eta'|l}\tilde{W}(e_c,\eta',b)$$

where $\tilde{W}(e_c, \eta', b)$ is the value before college computed by the planner (given below) and policy functions $\{c(j,s,e,\eta,a,x,e_c), a'(j,s,e,\eta,a,x,e_c), b(j,s,e,\eta,a,x,e_c)\}$, taken as given, solve equations (18) and the parent's delinquency value functions at age $j = j_f + j_a$. These value functions are the first of the two instances in which the planner's computation differs from that of the overly-optimistic consumer. The planner uses $\tilde{W}(e_c, \eta', b)$, whereas the overly-optimistic consumer uses $\hat{W}(e_c, \eta', b)$.

For $j = 5, \ldots, j_f + j_a - 1$, the planner's value function is given by

$$\begin{aligned}\tilde{V}(j,s,e,\eta,a,x) &= (1-d_f)(1-d_x)\tilde{V}^R(j,s,e,\eta,a,x) + \\ & d_f(1-d_x)\tilde{V}^{D_f}(j,s,e,\eta,a,x) + (1-d_f)d_x\tilde{V}^{D_x}(j,s,e,\eta,a,x) + d_f d_x \tilde{V}^D(j,s,e,\eta,a,x)\end{aligned} \tag{30}$$

where the planner takes as given $d_f(j,s,e,\eta,a,x)$ and $d_x(j,s,e,\eta,a,x)$, which solve equation (12). The values for $\tilde{V}^R(j,s,e,\eta,a,x)$, $\tilde{V}^{D_f}(j,s,e,\eta,a,x)$, $\tilde{V}^{D_x}(j,s,e,\eta,a,x)$, and $\tilde{V}^D(j,s,e,\eta,a,x)$ are given by

$$\begin{aligned}\tilde{V}^R(j,s,e,\eta,a,x) &= U(c,j,s) + \beta\psi_j E_{\eta'|s,\eta}\tilde{V}(j+1,s,e,\eta',a',x') \\ \tilde{V}^{D_f}(j,s,e,\eta,a,x) &= U(c,j,s) - \xi_D + \beta\psi_j E_{\eta'|s,\eta}\tilde{V}(j+1,s,e,\eta',a',x') \\ \tilde{V}^{D_x}(j,s,e,\eta,a,x) &= U(c,j,s) - \xi_D^{pr} + \beta\psi_j E_{\eta'|s,\eta}\tilde{V}(j+1,s,e,\eta',a',x') \\ \tilde{V}^{D}(j,s,e,\eta,a,x) &= U(c,j,s) - \xi_D - \xi_D^{pr} + \beta\psi_j E_{\eta'|s,\eta}\tilde{V}(j+1,s,e,\eta',a',x')\end{aligned}$$

where policy functions $\{c(j,s,e,\eta,a,x), a'(j,s,e,\eta,a,x)\}$, taken as given, solve equations (13)-(16).

For $j = 4$, the planner's value of college is given by

$$\begin{aligned}\tilde{V}(j,h,e,\eta,a,x) &= U(c,j,h) - \xi 1_{a\geq 0 \text{ and } x=0 \text{ and } (a'<0 \text{ or } x'>0)} - \xi^{pr} 1_{x=0 \text{ and } x'>0} \\ &+ \beta\psi_j\Big[p_g(j,e)E_{\eta'|h,\eta}\tilde{V}(j+1,h,e,\eta',a',x') + (1-p_g(j,e))E_{\eta'|\ell,\eta}\tilde{V}(j+1,\ell,e,\eta',a',x')\Big]\end{aligned} \tag{31}$$

and for $j = 1, 2, 3$, the planner's value of college is given by

$$\begin{aligned}\tilde{V}(j,h,e,\eta,a,x) &= U(c,j,h) - \xi 1_{a\geq 0 \text{ and } x=0 \text{ and } (a'<0 \text{ or } x'>0)} - \xi^{pr} 1_{x=0 \text{ and } x'>0} \\ &+ \beta\psi_j E_{\eta'|\ell,\eta}\Big[p_g(j,e)[(1-d_d)\tilde{V}(j+1,h,e,\eta',a',x') + d_d\tilde{V}(j+1,\ell,e,\eta',a',x')] \\ &+ (1-p_g(j,e))\tilde{V}(j+1,\ell,e,\eta',a',x')\Big]\end{aligned} \tag{32}$$

where policy functions $\{c(j,h,e,\eta,a,x), a'(j,h,e,\eta,a,x), x'(j,h,e,\eta,a,x), d_d(j,h,e,\eta,a,x)\}$, taken as given, solve equations (11) and the value function for $j = 4$.

The planner's value of not going to college (as well as the value of dropping out) for $j \leq 4$ is given by

$$\tilde{V}(j, \ell, e, \eta, a, x) = U(c, j, \ell) + \beta\psi_j E_{\eta'|\ell,\eta}\tilde{V}(j+1, \ell, e, \eta', a', x) \tag{33}$$

where policy functions $\{c(j, \ell, e, \eta, a, x), a'(j, \ell, e, \eta, a, x)\}$, taken as given, solve equation (9).

The planner's value before college is given by

$$\begin{aligned}\tilde{W}(e, \eta, a) =& q\Big[(1-\hat{d}_s)\tilde{V}(1, \ell, e, \eta, a, x=0) + \hat{d}_s\tilde{V}(1, h, e, \eta, a, x=0)\Big] \\ &+ (1-q)\tilde{V}(1, \ell, e, \eta, a, x=0)\end{aligned} \tag{34}$$

where the planner takes as given the enrollment decision $\hat{d}_s(e, \eta, a)$, which solves equation (8). This value function is the second of the two instances in which the planner's computation differs from that of the overly-optimistic consumer. The planner uses $\tilde{V}(1, h, e, \eta, a, x = 0)$, which uses the true probability $p_g(j, e)$ for graduation likelihood, whereas the over-optimistic consumer uses $\hat{V}(1, h, e, \eta, a, x = 0)$, which uses the over-optimistic probability $\hat{p}(e)$ for graduation likelihood.

To measure welfare for the 18-year-old consumer, we use consumption equivalent variation. Following Abbott, Gallipoli, Meghir, and Violante (2019), we measure consumption equivalence units relative to the value of not going to college in the initial stationary equilibrium. We do this because the value of not going to college does not include any utility/psychic costs (i.e., search costs for student loans, an effort cost for college, and stigma costs for delinquency on student loans). For the average 18-year-old in period t, consumption equivalent variation, $g_{c,t}$, is computed using the following equation

$$(1+g_{c,t})^{1-\sigma}\int 1_{\{j=1\}}\tilde{V}_{\text{initial}}(1, \ell, e, \eta, a, x=0)\Omega_{\text{initial}}d(\overrightarrow{\omega}) = \int 1_{\{j=1\}}\tilde{W}_t(e, \eta, a)\Omega_t d(\overrightarrow{\omega}) \tag{35}$$

where in the left-hand side of the equation, "initial" refers to the initial stationary equilibrium. Note that when measuring welfare for the 18-year-old in period t, there could be a change not only in lifetime expected utility $\tilde{W}_t(e, \eta, a)$, but also the distribution Ω_t because the distribution of 18-year-olds is endogenous in our model. To compute the resulting gains or losses from a policy change, we report the difference in lifetime consumption units between period t and the initial stationary equilibrium, i.e., $100 \times (g_{c,t} - g_{c,\text{initial}})$. When measuring welfare holding the distribution of 18-year-old consumers fixed to that from the initial stationary equilibrium, we use distribution Ω_{initial} instead of Ω_{t} for the RHS of the equation above.

To measure welfare for the population that is 19 and over in the period of the transition, we proceed as follows. First, note that the distribution for the population that is 19 and over is the same in the initial stationary equilibrium and in the period of the transition because the transition is unexpected. Therefore, changes in welfare to this population can result only due to changes in expected remaining lifetime utilities. Because the remaining lifetime utilities for this population include psychic costs, we compute the percentage change in welfare measured by expected life time utility as in Abbott, Gallipoli, Meghir, and Violante (2019). To report the welfare gains and losses to the population that is 19 and over, we compute welfare as follows.

$$\frac{\int 1_{\{j>1\}}\tilde{V}_1(\overrightarrow{\omega})\Omega_{\text{initial}}d(\overrightarrow{\omega}) - \int 1_{\{j>1\}}\tilde{V}_{\text{initial}}(\overrightarrow{\omega})\Omega_{\text{initial}}d(\overrightarrow{\omega})}{|\int 1_{\{j>1\}}\tilde{V}_{\text{initial}}(\overrightarrow{\omega})\Omega_{\text{initial}}d(\overrightarrow{\omega})|} \tag{36}$$

where $\tilde{V}_1$ is the planner's value function for the first period of the transition ($t = 1$). We also report a modified consumption equivalence computed as

$$\left[\frac{\int 1_{\{j>1\}}\tilde{V}_1(\overrightarrow{\omega})\Omega_{\text{initial}}d(\overrightarrow{\omega})d(\overrightarrow{\omega})}{\int 1_{\{j>1\}}\tilde{V}_{\text{initial}}(\overrightarrow{\omega})\Omega_{\text{initial}}d(\overrightarrow{\omega})}\right]^{1/(1-\sigma)} - 1 \tag{37}$$

In this calculation, with $\sigma = 2$, the assumption is that consumption is scaled by $(1 + g)$ and the psychic costs are scaled down by $\frac{1}{1+g}$ in the allocations of the initial stationary equilibrium.

Part III

Results Appendix

I Policy experiments: additional welfare change statistics

Table 35 reports additional welfare change statistics for the two main policy exercises from Section 6: (1) information intervention and (2) federal loan limit expansion. These statistics are computed in the period of the transition for two populations, those 19 and over and parents at the age in which they make the inter-vivos transfer decision ($j = j_f + j_a$). We report welfare in general and partial equilibrium.

In the case of an information intervention, shown in column (1) of Table 35, in partial equilibrium the cohort of consumers that is 19 and over and the cohort of parents who are at age $j_f + j_a$ experience gains (Panel A). However, once we take general equilibrium effects into account, the gains turn to losses (Panel B). In the case of a federal student loan limit expansion, which is shown in column (2), the cohort that is 19 and over and the cohort of parents who are at age $j_f + j_a$ benefit in general and partial equilibrium. General equilibrium effects amplify the gains.

Table 35: Policy experiments: additional welfare change statistics

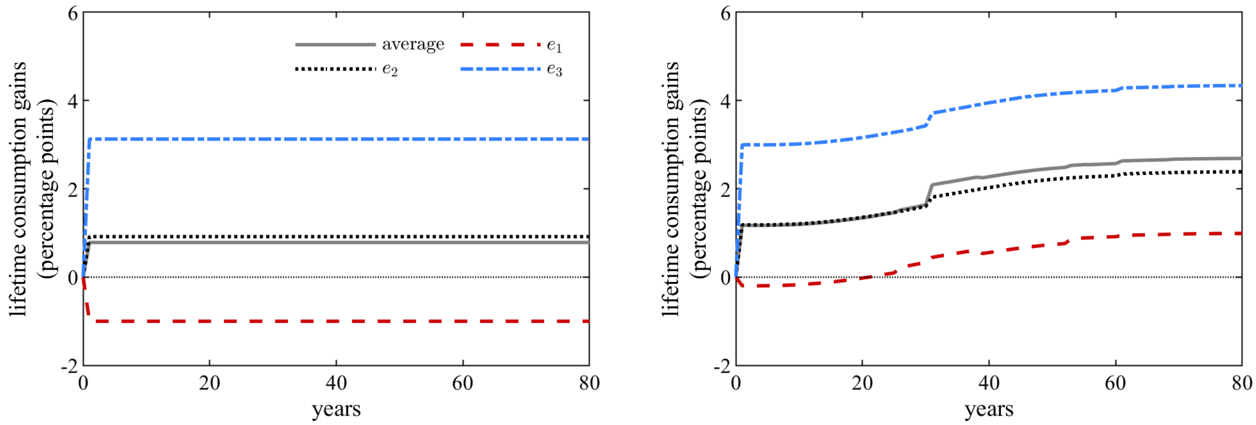
			(1) Information intervention		(2) Federal loan limit expansion	
Panel	**Equilibrium**	**Welfare group**	**%Δ welfare**	**%Δ cons.**	**%Δ welfare**	**%Δ cons.**
A	Partial	Population 19 and over	0.02	0.02	0.04	0.04
		Parents at $j = j_f + j_a$	0.07	0.07	0.10	0.10
B	General	Population 19 and over	-0.05	-0.05	0.14	0.14
		Parents at $j = j_f + j_a$	-0.03	-0.03	0.27	0.27

Notes: Table 35 provides welfare implications for the population 19 and over and the parents at age $j_f + j_a$ in the period of the transition under the following two exercises: (1) information intervention that eliminates over-optimism, and (2) federal loan limit expansion to fund four years of college net tuition plus room and board. Panels A and B reports lifetime welfare and consumption gains and losses under partial equilibrium and general equilibrium, respectively. In partial equilibrium, the income tax rate, prices, bequests, and Social Security transfers are fixed at their initial steady state values.

J Public grant expansion

In Section 6.2, we analyzed the implications of an expansion in federal student loans. In this section, we consider an expansion in federal grants, another important source of college financial aid. We consider a transition where the public grant parameter $\theta(e)$ increases to $1 - \theta^{pr}(e)$, so that public grants fully fund four years of college tuition net of private grants.

Figure 8 provides a welfare analysis of the public grant expansion in partial and general equilibrium, divided into two Subfigures. Subfigure 8a shows welfare changes by skill quantile, and on average, between the baseline equilibrium and a partial equilibrium in which the income tax rate, prices, bequests, Social Security transfers, and the 18-year-old distribution are fixed at their initial steady state values. In this case, students in the bottom skill quantile experience welfare losses, while students in the middle and highest skill quantile experience welfare gains. Therefore, students with the highest over-optimism are worse off after an expansion in college grants. This is because, although the expansion in grants eliminates the college tuition cost, students still incur other costs of college such as foregoing earnings by working part time and the effort cost. Once we take general-equilibrium effects into account, as in Subfigure 8b, the losses to the low-skill 18-year-olds in the initial periods of the transition are reduced to roughly zero and and the losses to low skill 18-year-olds in the later periods of the transition turn to gains. The gains to 18-year-olds in the middle and highest skill quantiles are amplified. This is due to a fall in the income tax rate,



(a) Partial equilibrium (exogenous 18-year-old distribution)

(b) General equilibrium

Figure 8: Public grant expansion welfare analysis: partial and general equilibrium effects

Notes: Figure 8 provides a welfare analysis of an expansion in the public grant to fund four years of college tuition net of private grants for 18-year-old consumers in partial and general equilibrium. Subfigures 8a and 8b report lifetime consumption gains and losses for the average 18-year-old and the average-18-year-old given skill in each period of the transition path under the following cases: (a) a partial equilibrium in which the income tax rate, prices, bequests, Social Security transfers, and the 18-year-old distribution are fixed at their initial steady state values, and (b) general equilibrium.

an increase in the savings interest rate, and an increase in inter-vivos transfers, accidental bequests, and Social Security transfers (see Table 36).

K Sensitivity analyses

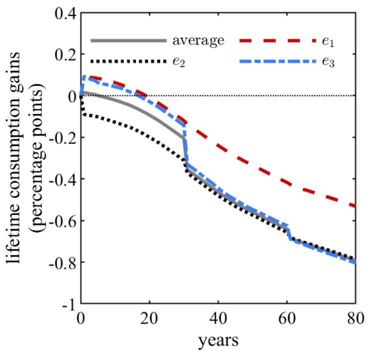
In this section, we perform two sensitivity analyses relative to the baseline model. First, in the baseline model, we assumed that students learn their true graduation probabilities in the first year of college. In this section, we consider the case where students never learn their true graduation probabilities and continue to be over-optimistic for the whole duration of college. Second, in the baseline model, we abstracted from unsubsidized loans and loan fees, which meant the baseline model underestimated the cost of borrowing from the federal student loan program. In this section, we consider the case where students pay a higher add-on to the federal student loan interest rate by increasing τ_{SL} from 0.0205 to 0.0305. Figure 9 compares welfare implications under the baseline case and the two cases for the sensitivity analyses for both an information intervention (Subfigures 9a-9c) and a federal student loan limit expansion (Subfigures 9d-9f). The welfare implications barely change which imply that our baseline model is not sensitive to assumptions on students learning about over-optimism and the abstraction from unsubsidized loans and loan fees. The assumption about learning does not matter because most students drop out after the first year of

Table 36: Steady state changes due to a public grant expansion

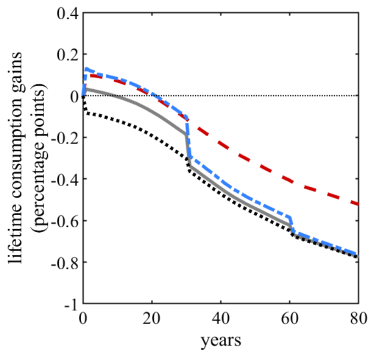
Panel	Variable		Change
A: Education and skill statistics	College enrollment rate	e_1	50.43
Units: percentage point change		e_2	33.95
		e_3	0.00
	Over-enrollment	e_1	18.84
		e_2	6.33
		e_3	0.00
	Graduation rate		-5.58
	Population share college graduates		13.57
	Share of 18-year-olds	e_1	-3.24
		e_2	-0.29
		e_3	3.53
B: Macroeconomic aggregates	Output		5.51
Units: percent change	Capital		4.99
	Labor (efficiency units)		5.80
	Consumption		5.45
C: Prices, income tax rate, and transfers	Risk-free savings interest rate		0.06
Units: percentage point/percent change	Wage rate		-0.29
	Private student loan interest rate		-0.43
	Income tax rate | Initial steady-state ave. income		-0.40
	Inter-vivos transfers		13.43
	Accidental bequests		5.40
	$\mathrm{ss}_{\ell,e}$	e_1	3.72
		e_2	3.69
		e_3	3.64
	$\mathrm{ss}_{h,e}$	e_1	2.91
		e_2	2.80
		e_3	2.55

Notes: Table 36 provides results from a steady-state comparison of the baseline economy to an economy with an expansion in public grants from $\theta(e)$ to $1 - \theta^{pr}(e)$, so that public grants fully fund four years of college tuition net of private grants. Panels A, B, and C report changes in education and skill statistics, macroeconomic aggregates, and prices, the income tax rate, and transfers, respectively.

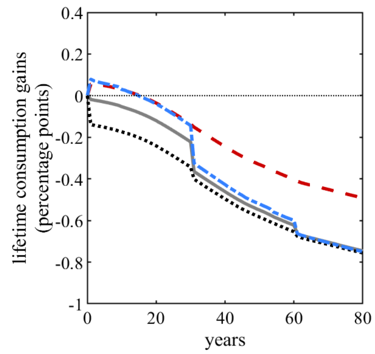
college. The lack of impact of a higher add-on to the federal interest rate suggests that students are interest inelastic around the parameter space for the cost of borrowing implied by the baseline model.



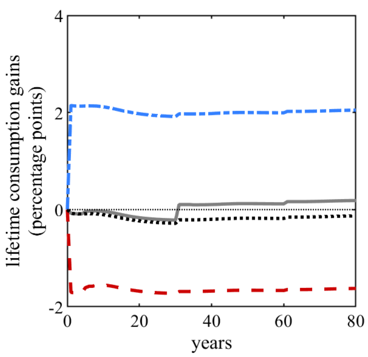
(a) Info. intervention: baseline



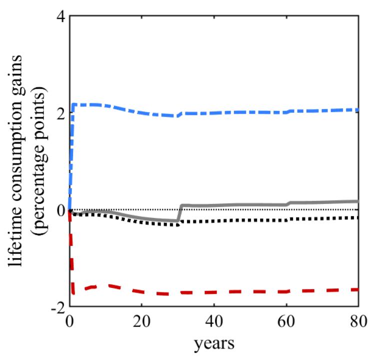
(b) Info. intervention: no learning



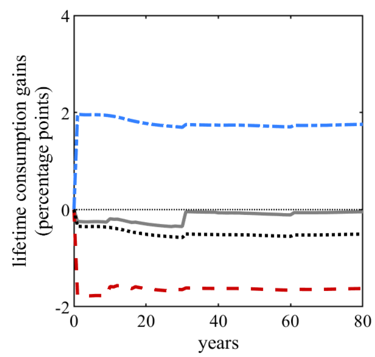
(c) Info. intervention: higher add-on



(d) Federal limit exp.: baseline



(e) Federal limit exp.: no learning



(f) Federal limit exp.: higher add-on

Figure 9: Sensitivity analyses: welfare

Notes: Figure 9 compares welfare implications under the following cases: the baseline model, a model where students do not learn about over-optimism for the whole duration of college, and a model with a higher add-on for the federal student loan interest rate. Subfigures 9a-9c plot welfare implications for an information intervention and Subfigures 9d-9f plot welfare implications for an expansion in the federal student loan limit to fund four years of college tuition and room and board (net of grants).