DEPARTMENT OF ECONOMICS
WORKING PAPER SERIES

2022-09

McMASTER UNIVERSITY

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Over-optimism About Graduation and College Financial Aid*

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First version: January 5, 2022
This version: December 21, 2022

Abstract

In the United States, one in three students enrolled in a bachelor's degree program eventually drops out, and the stock of student loans held by these dropouts is sizable. 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 impact of over-optimism and of expanding federal student loan limits in the presence of over-optimism. We find that over-optimism, despite reflecting mistaken beliefs, increases welfare for 18-year-olds as a result of equilibrium adjustments in income taxes, family transfers, and skill. Expanding federal student loan limits reduces welfare for low-skill 18-year-olds from poor families, a result driven by the presence of over-optimism.

JEL classification numbers: I22, I26, E7, G28, G5
Keywords: Post-secondary education, Over-optimism, Student loans.

*We are grateful to Dirk Krueger, Igor Livshits, Todd Schoellman, Brant Abbott, Adam Blandin, Christopher Herrington, and Sergio Ocampo Dìaz for their detailed comments on this paper, and also thank Stefania Albanesi, Maria Jose Carreras-Valle, Nicholas Petrosky-Nadeau, Richard Rogerson, Pawel Krolikowski, Pau Pujolàs, Nathaniel Throckmorton, Zachary Mahone, Alok Johri, Bettina Brüggemann, Mons Chan, Eugenia Gonzalez, Hyunju Lee, Marc-André Letendre, Radek Paluzinski, Thomas Phelan, George Stefanidis, Guillaume Sublet, and seminar and conference participants at the 2022 North American Summer Meeting of the Econometric Society, the 2022 Liberal Arts Macro Conference, Federal Reserve Bank of Kansas City, Université de Montréal, Queen's University, Federal Reserve Bank of Philadelphia, Western University, the 2022 Canadian Macro Study Group, and the Bureau of Labor Statistics. Sergio Salgado provided help with the Survey of Consumer Finances. All errors are ours.
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1 Introduction

In the United States, approximately one third of students who enroll in a bachelor's program fail to complete their degree; furthermore, these dropouts hold a significant amount of student debt.[1] Previous structural studies examining college financial aid policy in the presence of dropout risk have assumed that consumers' beliefs about dropout risk are accurate.[2] We provide new empirical evidence showing that both students and their parents are overly optimistic about the likelihood of completing a college degree. 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. Unlike previous studies, in our model consumers exhibit overly optimistic beliefs about the likelihood of college graduation, both when they choose whether to enroll in college and when they choose how much wealth to transfer to their child later in life. Such over-optimism leads to a higher college enrollment rate, and a higher level of transfers, than would occur with accurate beliefs. We use this framework to study, first, the impact of over-optimism on the aggregate economy and, second, the effects of expanding federal student loan limits in the presence of over-optimism. We find that, despite reflecting mistaken beliefs, over-optimism increases welfare for young adults because it lowers the average income tax rate, raises family transfers, and raises average skill.[3] Expanding federal student loan limits affects the welfare of 18-year-olds from low-income families the most. In this group, those with low skill see welfare losses, whereas those with high skill see welfare gains. Without overly optimistic beliefs, consumers of 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 NLSY97, we observe expectations about the high school students' probability of earning a 4-year bachelor's degree (BA) by age 30, solicited from both the student and from their parent. For those who later enroll in a BA program, we construct the realized graduation rate by age 30. We show that over-optimism about college graduation, computed as the difference between the expected and realized probabilities of BA completion, is widespread. On average, college enrollees believe they have a 92 percent chance of earning a BA by age 30, yet only 70 percent of this group actually go on to earn their degree. This over-optimism is especially pronounced among those with low skill (where skill is measured with high school grade point average, or GPA), a pattern that continues to hold even when we account for gender and parental

[1] Sources: 1997 National Longitudinal Survey of Youth, High School Longitudinal Study of 2009, and authors' calculations.

[2] Notable exceptions are Matsuda (2020, 2022). We compare those two studies with ours later in this introduction.

[3] Quantitatively, the income tax effect is the most significant.

education. Moreover, parents of college enrollees exhibit similar patterns of over-optimism. In the HSLS:09, our second main source of data, we observe uptake of federal financial aid and private student loans. By using the HSLS:09 to track a cohort of college enrollees until three years after college enrollment (before repayment begins), 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 loan uptake and repayment, and family transfers.[4] With the fully parameterized model, we perform two experiments. First, we study the impact of over-optimism by examining the effects of eliminating it from the baseline economy. We do this by setting the expected probability of continuing to the next academic year equal to the true probability.[5] Second, in the baseline model economy with over-optimism, we expand the federal student loan 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, on average annual federal student loan limits are enough to finance only 37.5 percent of annual college costs (i.e., the average value of tuition and fees, net of grants, plus room and board). Furthermore, we provide new empirical evidence motivating the loan expansion experiment by establishing that a significant share of recent college students fully utilize their federal student loan limits under current U.S. policy.[6] In both experiments, we measure welfare using lifetime utilities computed with the correct college continuation probabilities, but taking as given consumer choices which are made based on their beliefs.

In the first experiment, we find that eliminating over-optimism reduces welfare for the average 18-year-old in general equilibrium, despite correcting mistaken beliefs: although there are small gains for some skill levels in the initial periods of the transition, by the later periods of the transition losses reach 0.9 percent of lifetime consumption. Eliminating over-optimism uncovers its complex role in the economy: although the presence of over-optimism leads 18-year-olds to enroll in college when they otherwise would not (thereby generating "over-enrollment"), over-optimism also

[4] We are able to document that college students are overly optimistic on either side of the college enrollment decision, but the data are not sufficient to establish learning dynamics while enrolled in college. To be conservative about the consequences of over-optimism, in our model college students learn the truth about the likelihood of college graduation at the start of their first academic year, before making any decisions. College students are then are allowed to choose to drop out before beginning their second academic year.

[5] We view this experiment as providing insight into over-optimism's impact, rather than as a policy experiment, because we do not have specific recommendations for how policy makers can change consumer beliefs effectively. Designing and testing such information interventions is beyond the scope of this paper.

[6] Sources for borrowing limits: Smole (2019) and NCES (2019), authors' calculations. Sources for utilization rates: HSLS:09 and Smole (2019), authors' calculations. For a broader discussion of borrowing constraints and post-secondary education, see Lochner and Monge-Naranjo (2016).

benefits these young adults in general equilibrium. Most importantly, these benefits arise precisely because over-optimism raises the college education rate by boosting enrollment rates above what they would be with correct beliefs. A higher college education rate expands the income tax base and raises output. When this happens (even with government consumption specified as a constant fraction of output), our model's progressive income tax system allows the government to balance its budget with a lower average income tax rate, which benefits all 18-year-olds. This mechanism highlights that the positive fiscal externality of a college degree is partially offset by overly optimistic beliefs. Furthermore, over-optimism also raises the inter vivos transfer that 18-year-olds receive from their parents and raises the average skill endowment because child skill is positively correlated with parental education.

Our second experiment highlights the implications of over-optimism for the effects of college financial aid policy. In particular, we find that expanding federal student loans limits leads to heterogeneous welfare changes among 18-year-olds from poor families. In that group, those with low skill see losses ranging from 1.3 to 2.6 percent of lifetime consumption, whereas those with high skill see gains ranging from 1.4 to 4.3 percent of lifetime consumption. Welfare losses for those with low skill arise because access to more federal loans greatly increases their ability to finance college and thus worsens the extent of their over-enrollment. 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 18-year-old consumers at 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 and parent expectations about academic outcomes are consistent with realized outcomes; in those studies, a direct impact of higher financial aid is higher welfare. We build on that literature and, motivated by our empirical findings, incorporate over-optimism about the likelihood of college graduation. We demonstrate that, with over-optimism, more financial aid reduces welfare for some consumers.

Two structural studies that also consider over-optimism in the context of post-secondary education are Matsuda (2020) and Matsuda (2022). Both of these papers incorporate over-optimism about college "ability", which gives rise to over-optimism not only about graduation likelihood, but also the college wage premium and the ability of one's future children. Matsuda (2020) examines the design of public grants, while Matsuda (2022) compares public grants with progressive income taxation as sources of social insurance. In both Matsuda (2020, 2022), the comparison is solely across steady states. In contrast, we use new empirical evidence to motivate the over-optimism about graduation likelihood that we include in our model environment; additionally, our experiments focus both on uncovering the role of over-optimism and on examining its implications for federal student loan limit expansions. Our study also analyzes changes along transition paths as well as across steady states.

Our empirical evidence on over-optimism about the likelihood of college graduation 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 the likelihood of college graduation 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 the likelihood of attaining a bachelor's degree is widespread among both high school students and their parents.

Our empirical work also provides discipline for the private student loan market in our model environment. 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 into their model frameworks, there is less consensus about modeling the private student loan market. For example, Lochner and Monge-Naranjo (2011) assume that lenders set loan interest rates using repayment risk that depends on student skill, making low-skill students less likely to have access to private student loans relative to 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 contribute to the aforementioned literature 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 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. While our main empirical takeaways are similar, we expand this analysis in two ways. First, we use the HSLS:09 to document significant balances among dropouts by tracking a single cohort of college students until three academic years after enrollment. This approach 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, which are likely to be a more reliable source of information than self-reported balances recorded in the SCF.

Our study also contributes to the consumer credit literature on over-borrowing. Related work includes Nakajima (2012, 2017); these papers 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 resulting from 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 18-year-olds 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 the likelihood of earning a bachelor's degree and realized educational outcomes to pin down the extent of over-optimism.

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 experiments. Section 7 concludes.

2 Data

The two main datasets we draw on are the 1997 National Longitudinal Survey of Youth and the High School Longitudinal Study of 2009. These are 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 survey that follows young adults born between 1980 and 1984 ("sample members") from 1997 until 2019. It is collected by the U.S. Bureau of Labor Statistics (Bureau of Labor Statistics, U.S. Department of Labor, 2019). The NLSY97 provides information on expected probabilities of earning a bachelor's degree for sample members and their parents, as well as realized education outcomes, which we use to document over-optimism about the likelihood of college graduation.[7]

The HSLS:09 is a nationally representative panel survey that follows a sample of ninth-grade

[7] We use "college" to refer to a 4-year bachelor's degree program throughout this paper.

students from 2009 until 2016, although some information from post-secondary transcripts and student records is collected after 2016. It is conducted by the National Center for Education Statistics (NCES), a subsidiary of the U.S. Department of Education (U.S. Department of Education, 2020a). This is our preferred dataset for documenting patterns of student loan usage because the HSLS:09, unlike the NLSY97, follows a cohort that interacted with the most recent iteration of the U.S. financial aid policy, to which we calibrate our structural model (e.g., borrowing limits set in 2012). In particular, we use the HSLS:09 to document student loan uptake and balances by college persistence 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.

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 (Board of Governors of the Federal Reserve System, 2019). The SCF reports interest rates for federal and private student loans for which respondents still owe a positive amount when the survey is conducted. 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.

2.1 Over-optimism about the likelihood of college graduation

The NLSY97 asks sample members twice about their expected probability of earning a BA by age 30: once in 1997 and again in 2001. The survey also asks parents the same question about their child, but only once, in 1997. 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 percentage 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.[8] We also flag those who had enrolled in a BA program, as well as those who had earned a BA, by age 30. Note that all tabulations of NLSY97 data do not use survey weights, following Abbott, Gallipoli, Meghir, and Violante (2019).[9]

Using this information, Panel A of Table 1 compares averages of sample member expectations about the likelihood of college graduation with realized graduation rates, by skill quantile. Moving

[8] With regards to our preferred measure of skill, unlike the NSLY97 the HSLS:09 does not contain a variable recording a score for the Armed Services Vocational Aptitude Battery. We use high school GPA to measure skill because it is in both the NLSY97 and the HSLS:09, and we want to measure within-skill quantile values of various variables in both data sources.

[9] Abbott, Gallipoli, Meghir, and Violante (2019) state that "as suggested by the BLS, the use of weights is inappropriate in samples generated after dropping observations reporting item nonresponses."

from left to right within Panel A, the first column reports the skill quantile, which is assigned using the distribution of high school graduates (note that Panel A's sample is then restricted to those who enrolled in a BA program sometime before turning 30).[10] The second column contains the number of observations in each skill quantile for the sample of college enrollees. The mean expected probability of earning a BA by age 30 is reported in the third column; to construct expectations about the likelihood of college graduation collected before, but as close as possible to, the college enrollment decision, we use the most recent valid response to this question collected while the respondent was enrolled in high school. The fourth column contains the realized graduation rates computed as the frequency of BA attainment 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 overly optimistic beliefs collected while the respondents are in high school, conditional on their eventually enrolling in a BA program. Does the over-optimism documented in Panel A persist until the point of deciding whether to enroll in college? We 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 sample members who answer the 1997 question while still in high school and also answer the 2001 question while enrolled in a BA program. The results are shown in Panel B of Table 1.[11] Sample members maintain overly optimistic beliefs about the likehood of graduation after they enroll in college. If these individuals were changing their expectations right before college enrollment to be closer to the realized probability of graduation, then one could safely presume that the expected probability after enrolling would be closer to the realized probability of graduating, which is about

[10] The tabulation is done for the sample of high school graduates who eventually enroll in a BA program to focus on over-optimism about college *graduation*, rather than about college enrollment. Because of the way the survey question is structured, an expected probability response that is solicited in high school combines the expected probability of enrolling in college with the expected probability of completing college conditional on enrollment. For those who eventually enroll in college, it is not a heroic assumption to impose that expected probability of enrollment was 1 and interpret the response as the conditional probability of completion. Of course, for the same reported expected probability, lowering the expected probability of enrolling that we assume would raise the implied conditional probability of graduating once enrolled. In that sense our assumption makes the over-optimism findings in Table 1 lower bounds.

[11] We do not break down the statistics for Panel B by skill quantile because the sample size is small, which occurs for two reasons. First, a small proportion of respondents meet the education timing criteria. Second, in the 2001 NLSY97 questionnaire, respondents were divided into four groups for the beliefs questions, and only groups 1 and 3 were asked about educational attainment expectations.

Table 1: Over-optimism about the likelihood of graduating from a Bachelor's program by age 30

Panel A	**Skill**	**Obs**	(a) **Mean expected graduation prob.**	(b) **Realized graduation rate**	**Over-optimism** $(a)-(b)$
Student over-optimism by student skill quantile among college enrollees	1	222	81.78	31.98	49.80
	2	395	87.42	55.95	31.47
	3	587	93.56	78.19	15.36
	Obs	1,204			
Panel B	**Response timing**		(a) **Mean expected graduation prob.**	(b) **Realized graduation rate**	**Over-optimism** $(a)-(b)$
Student over-optimism by response timing among college enrollees	Before enrollment		92.07	69.62	22.45
	After enrollment		93.14	69.62	23.52
	Obs	316			
Panel C	**Skill**	**Obs**	(a) **Mean expected graduation prob.**	(b) **Realized graduation rate**	**Over-optimism** $(a)-(b)$
Parent over-optimism by student skill quantile among parents of college enrollees	1	166	80.93	31.33	49.61
	2	297	84.79	54.88	29.91
	3	429	93.03	78.79	14.24
	Obs	892			

Notes: Panel A of Table 1 compares students' mean expected probability of earning a BA program by age 30 with the realized graduation rate within each student skill quantile for the sample of respondents who enrolled in a BA program by age 30; Panel B compares the expected probability of earning a BA collected before and after college enrollment with the realized graduation rate for the sample of respondents who were enrolled in high school in 1997, were enrolled in a BA program in 2001, and who also answered the education expectations question in both years; Panel C compares mean parental expectations for their child's likelihood of earning a BA with realized graduation rates by student skill quantile for the sample of students who enroll in a BA before age 30 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. Expectations, graduation rates, and over-optimism are all in units of percentages. Source: NLSY97.

70 percent. This is not the case in the data, however: the expected probability of graduating from a BA program slightly increases after college enrollment, from 92 to 93 percent.

Panel C reports the same statistics as Panel A but for parental expectations. Because this panel conditions on observing the parents' expected probabilities of their child earning a BA, the sample differs slightly from that of 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]

Do educational attainment beliefs reported in the NLSY97 predict actions? We apply this question to the college enrollment decision in particular, and in Table 2 we report results for a regression

[12] For a comparison within families of student and parent expectations, see Table 16 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 when comparing parent and student expectations averaged across families as is shown in Panel C of Table 1.

in which the dependent variable is a flag for enrolling in a BA program before age 30 (which takes a value of 100 if the individual enrolled, 0 otherwise), and the independent variables include the respondent's expected probability of earning a BA degree before age 30 (a value between 0 and 100). Additional controls are also included: model (1) controls for the respondent's skill (measured with high school GPA) and gender, while model (2) adds family characteristics (i.e., family income and parent education). The estimator is Ordinary Least Squares. Our results indicate that enrollment in a bachelor's degree program is positively predicted by the sample member's expected probability of earning a BA, even when controlling for the respondent's individual and family characteristics. Specifically, in model (1) a 1 percentage point increase in the expected probability of earning a BA implies a 0.515 percentage point increase in the probability of enrolling in a BA program. This effect falls slightly to a 0.473 percentage point increase when we control for family characteristics in model (2). In both model (1) and model (2), the marginal effect of respondent beliefs is highly statistically significant.[13]

Our findings from the NLSY97 indicate that over-optimism about the likelihood of earning a bachelor's degree is widespread among those who enroll in college, especially among those with low skill.[14] This over-optimism appears to be stable around the college enrollment decision; additionally, parents exhibit a similar degree of over-optimism and with similar patterns across child skill quantiles. Moreover, beliefs predict actions: respondents who report higher expected probabilities of earning a bachelor's degree are more likely to enroll in a BA program, even when controlling for the sample member's skill, gender, and family attributes. In Table 17 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 college 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 31 of Supplementary Appendix C.1.[15] However, our main findings from the HSLS:09 relate to student loans, and in

[13]The fact that reported beliefs about college degree attainment are positively correlated with college enrollment rules out beliefs being driven entirely by a sense of "social desirability", that is, students saying what they think others want to hear.

[14]Although Table 2 shows that there is selection into college by expected probability of earning a BA, the beliefs of those who do not enroll still exhibit sizable over-optimism for those with low skill. Over-optimism is also present, but at lower magnitudes, for those with medium skill levels among non-enrollees. This is demonstrated in Table 18 and the surrounding discussion in Supplementary Appendix A.1.

[15]The HSLS:09 also provides a source of supporting evidence for the NLSY97 over-optimism findings via questions about educational attainment expectations which students in the HSLS:09 sample, and their parents, answered 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., "Bachelor's") rather than a continuous probability. That is why our main results on over-optimism are established with the NLSY97. However, if one is concerned about survey respondents being confused by probabilities, then the categorical form of the HSLS:09 expectations questions may make our over-optimism results more convincing.

Table 2: BA enrollment by age 30 as a function of the expected probability of earning a BA

	Enrolled in a BA program by age 30	
Controls	**(1)**	**(2)**
Expected probability of earning a BA by age 30	0.516 (0.0329)	0.473 (0.0403)
High school GPA	30.38 (1.652)	26.05 (1.975)
Male	-1.086 (1.806)	0.203 (2.139)
Age in 1997	0.220 (0.648)	-0.0833 (0.747)
Logged family income		6.395 (1.099)
At least one parent BA+		13.96 (2.695)
Constant	-80.32 (11.29)	-130.1 (16.06)
R^2	0.259	0.297
Obs	2,367	1,656

Notes: Table 2 presents estimation results from two models. The dependent variable for both models (1) and (2) is a flag for enrollment in a BA program by age 30, which takes a value of 100 if the individual enrolled in a 4-year program BA program by age 30 and 0 otherwise. From top to bottom, the controls are the expected probability of earning a BA by age 30 (respondent beliefs, with a range between 0 and 100); the respondent's high school GPA (between 0 and 4); an indicator set equal to 1 if the respondent is male and equal to 0 otherwise; the respondent's age in 1997; the log of family income for the respondent while they are in high school; an indicator equal to 1 if at least one resident parent has a bachelor's degree or more and equal to 0 otherwise; and a constant. Samples: model (1) is high school graduates; model (2) is high school graduates, conditional on observing family income and parent education. Standard errors in parentheses. Source: NLSY97.

the next section we use that dataset 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 institutions.[16] 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

[16] See Supplementary Appendix C for an outline of the HSLS:09.

here and in the Supplementary Appendix, use survey weights. The specific weights used for each tabulation are noted in each table's footnote.

We restrict our sample to students who 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, biological parental educational attainment, 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.[17] In Table 3, 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) through their third year (the 2015-2016 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 such as "dropout" in our discussion of the HSLS:09 findings.

Table 3 shows that 24 percent of the enrolled population fail to persist toward college completion. Students who do not persist owe 19 percent of the sample's student debt balances (either federal or private) and are more likely to have student debt relative to 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 using that money to finance fewer years of tuition, compared to students who persist toward degree completion.[18] 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 3: Student loan incidence by persistence status

Persistence status	**% of enrollees**	**% of SL $**	**% with SL**	**Average $**	**Median $**
Did not persist	24	19	78	15,270	12,238
Persisted	76	81	65	24,648	19,500
Obs	2,356				

Notes: Table 3 divides the pool of 2013 bachelor's degree 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 2013-2014 and 2015-2016. Within each persistence status group, the table reports the group's share of 2013 enrollees, the dollars owed by the group as a share of aggregated student debt among 2013 enrollees, 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 after three academic years, in 2016 dollars. Percentages are rounded to the nearest percentage point. Weights are PETS-SR student records longitudinal weights. Source: HSLS:09.

[17] This approach 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.

[18] Patterns of grant aid are similar, as shown in Table 32 of Supplementary Appendix C.2.

2.3 Private student loans

The private student loan market warrants further examination as it is the source of a potential substitute for federal loans, which is relevant for our loan limit expansion exercise. We begin with information from the HSLS:09 reported in Table 4, which summarizes sources of student loans three academic years after enrollment among 2013 college enrollees. Results are broken down separately for each persistence status. Moving from left to right, the columns report, first, the percentage of the group that has either federal or private student loans; second, the percentage that has only federal loans; third, the percentage with only private loans; and fourth, the percentage with debt from both kinds of student loans. This table has two main takeaways, which hold for both persistence statuses: first, that more than one in five students take out a private student loan during college, indicating that using this source of financing is somewhat common; and, second, that there is a pecking order for loan types, where students tend to 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 4 shows that this is not the case in the data: for both persistence groups the share with only private student loans is almost 0, whereas the share with only federal loans is quite large.

Table 4: Student loan portfolio composition

Persistence status	**Either**	**Only federal**	**Only private**	**Both**
Did not persist	78	53	1	24
Persisted	65	44	2	20
Obs	2,356			

Notes: Table 4 reports, by persistence status, the percentage of all 2013 bachelor's degree 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, so the sum of the last three columns may not exactly equal the value in the first column. Weights are PETS-SR student records longitudinal weights. Source: HSLS:09.

The HSLS:09 also sheds light on access to private student loans by key student characteristics. Table 5 reports uptake rates for private loans, computed as the percentage of each quantile of the joint distribution of family income and skill that has taken out a private student loan three academic years after they began college. Family income and skill quantiles are assigned using the distribution of each variable among high school graduates. This table illustrates that college students from the poorest families and college students from the lowest skill group take out private loans like their richer and higher-skill peers. Because access is a necessary condition for uptake, and in Table 5 quantiles are assigned using the distribution of high school graduates, the results in Table 5 reject the hypothesis maintained in previous studies that low-skill or low-income prospective college students are barred from the private student loan market.

To be clear, we do not claim to demonstrate that all prospective college students necessarily have access to private student loans. In order to examine what is driving the findings of Table 5, 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 for those with private loans, and is not highly correlated with skill or family income. Indeed, taking out a private student loan without a cosigner is rare: for the five largest private student lenders, 90 percent of undergraduate student loans issued since 2010 have had a cosigner (Amir, Teslow, and Borders, 2021).[19] Most adults qualify as cosigners for private student loans: for loan approval, the minimum credit score requirements range from none to 680, and even cosigners 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 5: Private loan uptake rates

		GPA		
	Q	**1**	**2**	**3**
Income	**1**	19	25	16
	2	26	31	24
	3	39	21	19
Obs	2,356			

Notes: Table 5 reports the percentage of each cell that has a positive private student loan balance three academic years after enrollment in the fall of 2013. Percentages are rounded to the nearest percentage point. Rows are student family income quantiles using parents' income during high school; columns are high school GPA quantiles. Quantiles are assigned using the distribution of high school graduates. Weights are PETS-SR student records longitudinal weights. Source: HSLS:09.

The HSLS:09 does not report the student loan's interest rate, so 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 six student loans; each loan is associated with a separate set of variables that 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 6, 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). The observed low standard deviation of private

[19]For students without a cosigner, 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).

loan interest rates (comparable to federal interest rates) is likely a result of most private student loans having a cosigner, where having a cosigner leads to more favorable terms regardless of other student attributes (Holhoski, Clark, and Beresford, 2022). Columns 3 to 6 of Table 6 break down interest rates by income quantile, while the remaining four columns break down interest rates by graduate status (that is, education outcome) for all families and for families who are delinquent.[20] 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 significantly in their interest rates, and that the the relationship between debtor attributes and interest rates on private loans is similar to that of debtor attributes and interest rates on federal loans (which are set by statute).

Table 6: Student loan interest rates

		All families					**Delinquent families**	
		Income quantile			**Graduate status**		**Graduate status**	
Loan type	**All families**	**1**	**2**	**3**	**Yes**	**No**	**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 6 reports interest rates for federal and private student loans for all families (column 2), by income quantile within all families (columns 3, 4, and 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 for which they took out their education loans. 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 from Sections 2.1 and 2.3 on over-optimism, uncertainty about college persistence, financial aid, and the private student loan market. Our findings on student loan uptake in Section 2.2 are used to validate the calibrated model in Section 5.1.

[20] Graduate families (for whom the graduate status is "Yes") have completed at least one of the programs for which they took out their education loans. Delinquent families have at least one education loan for which they are late making payments. See Table 37 in Supplementary Appendix D for mapping to SCF codebook variables.

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 2.1, we enrich the general equilibrium life cycle model with college choice of Krueger and Ludwig (2016) by incorporating over-optimism about likelihood of college graduation. 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.

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 enroll in 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.[21] The 18-year-old's college entrance decision will be based on their skill, s, idiosyncratic productivity, η, and initial net assets, a. Skill is an endowment that is drawn once from a conditional distribution that depends on parental education.[22] The skill endowment determines several things: the consumer's expectations about their continuation probability in each year of college at the time of enrollment, the true probability of continuation given enrollment, deterministic earnings productivity, and proportional 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 education, as in Krueger and Ludwig (2016). Net assets are determined at the start of adulthood by a one-time inter vivos transfer from the consumer's parent.

When making the college entrance decision, consumers have mistaken beliefs about the probability of college continuation, which leads to over-optimism about the likelihood of college graduation. At the time of enrollment, consumers with skill s believe they will continue their education in each

[21] See Table 34 in Supplementary Appendix C.3 for suggestive empirical evidence for this model object. 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.

[22] In Supplementary Appendix N, we consider the case where skill does not depend on parental education, and the main results do not change.

year of college with probability $\hat{p}(s)$. The true annual probability of continuing a college education is given by the function $p_c(j, s)$. Consumers are overly optimistic as long as $\hat{p}(s) > p_c(j, s)$ for all s and j, with higher $\hat{p}(s) - p_c(j, s)$ implying higher over-optimism. Note that, if $\hat{p}(s) = p_c(j, s)$, consumers have the correct beliefs about the probability of continuation (and therefore about the likelihood of graduation). Our first experiment will study the impact of over-optimism by setting $\hat{p}(s) = p_c(j, s)$ to eliminate it from the baseline equilibrium.

The over-optimism discussed in the previous paragraph implies that consumers in our model deviate from rational expectations in the following way: in our model, 18-year-olds making the college enrollment decision (and their parents) believe that they are unique when it comes to their probability (or their child's probability) of continuing from one academic year to the next in college. Consumers understand everything else about their environment: they know that others are overly optimistic, they know their own skill, and they know how skill affects earnings with and without a college degree. Because individuals are atomistic, they can believe that their own continuation probability is uniquely higher than others of the same skill type, and also take as given aggregate endogenous states which are computed using enrollment decision rules of overly optimistic consumers and then are simulated with the true continuation probabilities. For more details, see the computational algorithm presented in Supplementary Appendix H.

In the model, consumers learn their true probability of continuing in college immediately after enrollment. In principle, this assumption minimizes the impact of over-optimism on consumer behavior.[23] After the first year of college, consumers may be forced to leave college with an annual probability of $1 - p_c(j, s)$ (exogenous dropout); otherwise, consumers may choose to leave college (endogenous dropout). Exogenous dropout represents college students who leave because of a lack of academic ability.[24]

In the model economy, earning a college degree requires four completed years of enrollment. The benefits of graduating from college are higher labor earnings, a higher probability of having high-skill children, and higher Social Security transfers.[25] The costs of college stem from several factors. College students work part-time, $\ell_{pt} < 1$, and therefore forgo additional earnings from full-time work; they also incur a college effort cost net of college consumption value, λ. Finally,

[23] However, quantitatively, this assumption does not matter: in Supplementary Appendix N, we consider a sensitivity analysis where college students never learn about their true likelihood of continuation, and we find that the main welfare estimates barely change.

[24] This model attribute is 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, leads to college dropouts. For example, even for students in the same major who put in the same hours of study, they find significant differences in academic performance.

[25] Consumers must graduate from college to enjoy these benefits. In Table 24 of 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 the age profiles of earnings is approximately zero.

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 and the private loan market, inter vivos transfers from parents, grants from public and private sources, and earnings from part-time work.[26]

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 interest rate on savings and τ_{SL} is the add-on to the risk-free savings interest rate, which is set by the government. For our second experiment, an expansion in federal student loan limits, we increase $\bar{A}$ from its baseline value. Federal student loans are assessed interest starting from the year after the age of college graduation ($j > 4$). This 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, all federal student loans are subsidized).[27] Student loan payments are required to begin after the age of college graduation, and payments 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, the features of which are based on findings from our empirical analysis in Section 2.3. First, to capture the pecking order from federal to private student loans shown in Table 4, we introduce a loan uptake cost specifically for acquiring private student loans, ξ_L^{pr}. This cost makes private student loans an imperfect substitute for federal student loans; it represents the additional effort required in the private student loan market to avoid predatory lending and hidden fees, as well as potential difficulties in acquiring a cosigner or even finding a lender. Second, we do not explicitly exclude any consumer from access to the private student loan market based on their type, which is consistent with positive private loan uptake observed in every cell of the joint distribution of family income and student skill in Table 5. Third, 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 in the data, as

[26] In Supplementary Appendix N, we analyze the case where tuition depends on skill. The main results do not change. Furthermore, we do not allow for financial aid to affect college costs, because the level of tuition and fees does not respond to the demand for higher education in our framework. In this respect our modelling assumptions are in line with Chatterjee and Ionescu (2012), Krueger and Ludwig (2016), and Abbott, Gallipoli, Meghir, and Violante (2019). Evidence on how financial aid affects the price of college paid by students (e.g., tests of the "Bennett hypothesis") is mixed (Robinson, 2017), and taking a stand in this debate is outside the scope of this paper.

[27] 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 N, 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 an explicit model counterpart to 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 results from expanding federal student loan limits as lower bounds relative to a framework that directly models EFCs.

shown in Table 6. Fourth and finally, to capture the lack of variation in private student loan interest rates along key characteristics (Table 6), we assume that risk-neutral competitive lenders cannot price-discriminate by family income or 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_{SL}^{pr}.[28]

After the age of college graduation, consumers with a positive student loan balance (federal, private, or both) may be either college graduates or college dropouts. At this point in the life cycle, consumers 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.[29] Upon paying off their student loans, consumers may save and solve a standard consumption-savings problem.[30] Consumers who do not make payments on their student loans are considered delinquent, and their disposable income above the amount $\bar{y}$ is garnished at the rate τ_g. Delinquent debtors also incur a collection fee equal to a fraction ϕ_D of the missed payment for the particular year and loan on which they are delinquent. The collection fee and the missed payment are added to the outstanding balance for the next period.[31] Besides these pecuniary costs, delinquent consumers also incur a stigma cost indexed to the type of loan, where ξ_D and ξ_D^{pr} 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 (2019), each parent makes an inter vivos transfer to their child after observing the child's skill, s_c. This transfer is motivated by parental altruism, where the parent's beliefs about the likelihood of

[28]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. These loans would have worse terms than co-signed loans. This would make private student loans even more of an imperfect substitute for federal student loans for the average student, in which case the welfare implications from the federal loan limit expansion policy experiment will be larger in magnitude. Therefore, our model specification likely imposes a lower bound on the magnitude of welfare changes that we find.

[29]Note that, in our model, 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.

[30]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 by construction. This incentive is somewhat offset in our framework because of the delinquency choice we incorporate, but that is not a quantitatively significant concern.

[31]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.

their child persisting toward college completion 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 likelihood of continuing in college, 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 funding 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 a flat-rate consumption tax. Only the average income tax rate adjusts to balance the government's budget constraint in every period; the degree of income tax progressivity is held fixed.

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.

College continuation probability The true probability of continuing to the next year of college is given by $p_c(j, s)$. It is determined by two objects, $p(s)$ and $\rho_d(s)$, both of which depend on skill:

$$p_c(j, s) = 1 - (1 - p(s))\rho_d(s)^{j-1} \tag{1}$$

This equation implies that the exogenous dropout probability is given by $(1 - p(s))\rho_d(s)^{j-1}$. The object, $p(s)$, determines the common probability of continuing in college in any year of enrollment, while the object, $\rho_d(s)$, determines the persistence of the probability of dropping out of college conditional on college year. To illustrate, if $p(s)$ is high, the student is more likely to continue to the next academic year of college. If $\rho_d(s)$ 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.

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 $\rho_R(j,a)$ for federal student loans.

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

The federal loan payment amount depends on the age of the borrower and their stock of federal student debt. There are three possible cases. In the first case, when there is an outstanding balance (i.e., $a<0$) and 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}. In the second case, when there is an outstanding loan balance and the standard repayment period has expired ($j>T_{SL}+4$), the outstanding principal plus interest is due. Lastly, when $a\geq 0$ at any age j, there is no student loan debt, and hence, the payment amount is set to 0.

Instead of repayment, consumers may choose delinquency. Loans in delinquency are not discharged. Instead, the consumer's disposable 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 G). 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, $\rho_R^{pr}(j,x)$, and the partial payment function, $\rho_D^{pr}(j,x,y)$, for private loans are presented in Supplementary Appendix E.

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 education status, $e\in\{h,\ell\}$. It is given by

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

where h refers to a high-education consumer who either is 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, e 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 $e = h$ 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, an AR(1) earnings productivity, and net assets, summarized by the tuple (j, e, s, 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 elements of the tuple determine the income function y, which is given by

$$y_{j,e,s,\eta,a} = \begin{cases} e = h & \begin{cases} w\epsilon_{j,\ell,s}\eta\ell_{pt} & \text{if } j = 1 \\ w\epsilon_{j,\ell,s}\eta\ell_{pt} + r\left[\max(a,0) + Tr_j\right] & \text{if } 1 < j \leq 4 \\ w\epsilon_{j,h,s}\eta + r\left[\max(a,0) + Tr_j\right] & \text{if } 4 < j < j_r \\ ss_{h,s} + r\max(a,0) & \text{if } j \geq j_r \end{cases} \\ e = \ell & \begin{cases} w\epsilon_{j,\ell,s}\eta & \text{if } j = 1 \\ w\epsilon_{j,\ell,s}\eta + r\left[\max(a,0) + Tr_j\right] & \text{if } 1 < j < j_r \\ ss_{\ell,s} + r\max(a,0) & \text{if } j \geq j_r \end{cases} \end{cases} \tag{5}$$

where w is the wage rate and $\epsilon_{j,e,s}$ is a deterministic life cycle productivity component that depends on age, education level, and skill. The term Tr_j is accidental bequests, which depend on age; accidental bequests are a consequence of the aggregate 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 ($e = h$), they work part-time ($\ell_{pt} < 1$) and receive $w\epsilon_{j,\ell,s}\eta$ in labor earnings per unit of labor supply. Note that, because this consumer is still in college, their life cycle productivity component corresponds to that of someone without a college degree (indexed by ℓ). This is also true for the parameters of their AR(1) productivity process. If a working-age consumer does not go to college or drops out of college, they work full-time thereafter and receive $w\epsilon_{j,\ell,s}\eta$ 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 are given by $w\epsilon_{j,h,s}\eta$. In this case, the deterministic life cycle component is $\epsilon_{j,h,s}$, and the AR(1) productivity component, η, is drawn from the distribution for $e = h$. When consumers retire at age j_r, they receive Social Security $ss_{e,s}$. The level of Social Security transfers that a consumer receives depends on both their education and their skill (see equation (26) in Supplementary Appendix G for the Social Security transfer payment function).

When consumers are 18, at $j = 1$, their assets are determined by inter vivos transfers received from their parents. Interest income on the inter vivos transfer accrues to the parents, not the transfer recipient. 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.

3.3 Consumer life cycle problem

This section provides and explains the main value functions that consumers solve at each stage of their life in more detail. The remaining value functions are provided in Supplementary Appendix F.

Consumer problems before college graduation age (j $\leq$ 4) Given their type, (s, η, a), which reports skill, s, idiosyncratic AR(1) productivity, η, and net assets, a, an 18-year-old ($j = 1$) has a value function, given by

$$\begin{aligned}\hat{W}(s,\eta,a) =& q\Big[\max_{\hat{d}_e\in\{0,1\}}(1-\hat{d}_e)V(1,\ell,s,\eta,a,x=0)+\hat{d}_e\hat{V}(1,h,s,\eta,a,x=0)\Big] \\ &+(1-q)V(1,\ell,s,\eta,a,x=0)\end{aligned} \tag{6}$$

With probability q, the consumer may make a discrete college entrance decision by choosing $\hat{d}_e \in \{0, 1\}$, where $V(1, \ell, s, \eta, b, x = 0)$ is the value of not going to college and $\hat{V}(1, h, s, \eta, a, x = 0)$ 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 education 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 $e = \ell$.

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

$$
\begin{aligned}
& V(j,\ell,s,\eta,a,x) = \max_{c \geq 0, a'} U(c,j,\ell) + \beta \psi_j E_{\eta'|\ell,\eta} V(j+1,\ell,s,\eta',a',x) \\
& s.t. \\
& (1+\tau_c)c + a' = y_{j,\ell,s,\eta,a} + a + Tr_j - T(y_{j,\ell,s,\eta,a}) \\
& a' \begin{cases} = a & \text{if } a < 0 \\ \geq 0 & \text{otherwise} \end{cases}
\end{aligned} \tag{7}
$$

where β is the discount factor, τ_c is the consumption tax rate, and $T(y_{j,\ell,s,\eta,a})$ is the income tax function, which will be defined in Subsection 3.4. The AR(1) productivity process depends on completed education. 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 (7), the stock of any student debt is held fixed at a and x 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, $\hat{p}(s)$, whereas the true probability of continuing is $p_c(j,s)$. 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

$$
\begin{aligned}
& \hat{V}(j,h,s,\eta,a,x) = \max_{\hat{c} \geq 0, \hat{a}', \hat{x}'} U(c,j,h) - \xi_L \mathbb{I}_{a \geq 0 \text{ and } x=0 \text{ and } (\hat{a}'<0 \text{ or } \hat{x}'>0)} - \xi_L^{pr} \mathbb{I}_{x=0 \text{ and } \hat{x}'>0} \\
& + \beta \psi_j E_{\eta'|\ell,\eta} \left[\hat{p}(s) \max[\hat{V}(j+1,h,s,\eta',\hat{a}',\hat{x}'), V(j+1,\ell,s,\eta',\hat{a}',\hat{x}')] + (1-\hat{p}(s)) V(j+1,\ell,s,\eta',\hat{a}',\hat{x}') \right] \\
& s.t. \\
& (1+\tau_c)\hat{c} + \hat{a}' + (1-\theta(s)-\theta^{pr}(s))\kappa = y_{j,h,s,\eta,a} + a + Tr_j - T(y_{j,h,s,\eta,a}) + (\hat{x}' - x) \\
& \hat{a}' \geq -\bar{A}\left(\tfrac{j}{4}\right)[(1-\theta(s)-\theta^{pr}(s))\kappa + \bar{c}] \\
& \hat{a}' \leq a \ \text{ if } \ a \leq 0 \\
& \hat{x}' - x \in \Big[0, [(1-\theta(s)-\theta^{pr}(s))\kappa + \bar{c}] - [\max(-\hat{a}',0) - \max(-a,0)]\Big]
\end{aligned} \tag{8}
$$

where ξ_L is the loan search and debt aversion cost of acquiring any student loan and ξ_L^{pr} is the additional uptake costs associated with acquiring any private student loans.[32] Parameters $\theta(s)$ and $\theta^{pr}(s)$ 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.[33] These consumers may also choose to drop out after the first year of college, which is captured by the expression $\max[\hat{V}(j+1,h,s,\eta',\hat{a}',\hat{x}'),V(j+1,\ell,s,\eta',\hat{a}',\hat{x}')]$. College students can borrow from federal student loans up to a limit equal to $\bar{A}\left(\frac{j}{4}\right)[(1-\theta(s)-\theta^{pr}(s))\kappa+\bar{c}]$, 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 is sufficient to finance.[34] 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).[35]

The overly-optimistic value for the final year of college, when $j = 4$, is presented in equation (18) in Supplementary Appendix F. 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, no endogenous dropout decision will be made 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 (6), they are overly optimistic and will use the inflated value of college from (8) to compute their expected value. However, we assume that consumers learn their true continuation probabilities in the first year of college so that, while enrolled, the consumer's realized consumption-savings and dropout decisions

[32] The psychic costs of taking out any student loans 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).

[33] Although students can use federal student loans to finance room and board expenditure over and above tuition and fees, room and board is not a mandatory expenditure in our model because a majority of students live off campus, as shown in NCES (2020).

[34] 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 cumulative student loan limit increases with each year of college.

[35] In our model framework, the only benefit of a private loan over a federal loan is that with a private loan, the consumer can keep their savings, whereas with a federal student loan, a consumer must first dissave to borrow. With this feature, our model can generate uptake of only private student loans by a small minority of students, a pattern we see in the data (see Table 42 in Supplementary Appendix N). Specifically, students from rich families may turn to private loans. This outcome is consistent with an implication of the Expected Family Contribution, where in reality, federal student loan limits are tighter for students from income and wealth rich families, and hence, they may turn to private lenders.

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

$$V(j, h, s, \eta, a, x) = \max_{c \geq 0, a', x'} U(c, j, h) - \xi_L \mathbb{I}_{a \geq 0 \text{ and } x=0 \text{ and } (a'<0 \text{ or } x'>0)} - \xi_L^{pr} \mathbb{I}_{x=0 \text{ and } x'>0} \tag{9}$$

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

$$+ (1 - p_c(j, s)) V(j+1, \ell, s, \eta', a', x') \Big]$$

$$s.t.$$

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

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

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

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

The only difference between this value function and the overly-optimistic value function given by (8) is that, in (9), consumers use the true probabilities of continuing in each year of college, $p_c(j, s)$, rather than the over-optimistic probability, $\hat{p}(s)$, 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 (18) in Supplementary Appendix F, with the exception that the consumer will use the true continuation probability rather than the over-optimistic continuation probability.

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.[36]

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. In this section, we focus on the consumer's problem at age $j_f + j_a$, the age at which they make an inter vivos transfer, while Supplementary Appendix F presents the consumer's problem for ages where $j \neq j_f + j_a$.

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

[36]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.

they receive the transfer. The parent's value function is given by

$$V(j,e,s,\eta,a,x) = \sum_{s_c} \pi(s_c|e)\big[\max_{d_f\in\{0,1\},d_x\in\{0,1\}} (1-d_f)(1-d_x)V^R(j,e,s,\eta,a,x,s_c)+ \tag{10}$$
$$d_f(1-d_x)V^{D_f}(j,e,s,\eta,a,x,s_c)+(1-d_f)d_xV^{D_x}(j,e,s,\eta,a,x,s_c)+d_fd_xV^D(j,e,s,\eta,a,x,s_c)\big],$$

where $\pi(s_c|e)$ is the conditional distribution over child skill given parental education level, and $d_f \in \{0,1\}$ and $d_x \in \{0,1\}$ denote the federal and private student loan delinquency decisions, respectively. The term $V^R(j,e,s,\eta,a,x,s_c)$ denotes the value of repayment on both loans, $V^{D_f}(j,e,s,\eta,a,x,s_c)$ denotes the value of delinquency on only federal loans, $V^{D_x}(j,e,s,\eta,a,x,s_c)$ denotes the value of delinquency on only private loans, and $V^D(j,e,s,\eta,a,x,s_c)$ denotes the value of delinquency on both types of loans.

The value of repayment for $j = j_f + j_a$ is given by

$$V^R(j,e,s,\eta,a,x,s_c) = \max_{c\geq 0,a',b} U(c,j,e)+\beta\psi_j E_{\eta'|e,\eta}V(j+1,e,s,\eta',a',x')+ \tag{11}$$
$$\beta_c E_{\eta'|\ell}\hat{W}(s_c,\eta',b)$$
$$s.t.$$
$$(1+\tau_c)c+a'+b = y_{j,e,s,\eta,a}+a+\mathbb{I}_{\{a<0\}}r_{SL}a+Tr_j-T(y_{j,e,s,\eta,a})-\rho_R^{pr}(j,x)$$
$$a'\begin{cases} =(1+r_{SL})a+\rho_R(j,a) & \text{if } a<0 \\ \geq 0 & \text{if } a\geq 0 \text{ and } x=0 \\ =0 & \text{otherwise } (a\geq 0 \text{ and } x>0)\end{cases}$$
$$x' = x(1+r_{SL}^{pr})-\rho_R^{pr}(j,x)$$
$$b\begin{cases} =0 & \text{if } a<0 \text{ or } x>0 \\ \geq 0 & \text{otherwise } (a\geq 0 \text{ and } x=0)\end{cases}$$

where b is the inter vivos transfer to the child, $\hat{W}(s_c,\eta',b)$ is the child's value function, and β_c disciplines the intensity of parental altruism toward the child. Note that because the parent uses $\hat{W}(s_c,\eta',b)$ for their child's lifetime utility, the parent is also overly optimistic about the likelihood of their child's college continuation. 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.[37] See

[37] In the initial stationary equilibrium, this situation is rare: only 0.3 percent of consumers at age $j = j_f + j_a$ have any unpaid student debt.

Supplementary Appendix F for the value functions for delinquency.

3.4 The government budget constraint and production firm problem

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

$$T(y) = y - \gamma y^{1-\tau_p} \tag{12}$$

where τ_p governs the tax progressivity and γ is used to balance the government budget constraint in every period (see equation (28) in Supplementary Appendix G). The government uses its tax revenue to finance government consumption (set as a fixed fraction g of GDP), Social Security transfers, federal college grants, and the federal student loan program.

The production function is Cobb-Douglas, given by

$$K^{\alpha}(ZL)^{1-\alpha} \tag{13}$$

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. 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

$$r = \alpha K^{\alpha-1}(ZL)^{1-\alpha} - \delta \tag{14}$$

$$w = (1-\alpha)K^{\alpha}L^{-\alpha}Z^{1-\alpha} \tag{15}$$

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

4 Model Parameterization

The parameters of this model are divided into those estimated outside of the model, shown in Table 7 (and in Table 38 in Supplementary Appendix J), and those calibrated inside the model, shown in Table 8.

The externally estimated parameters presented in Table 7 relate to education. Panel A reports parameters governing the federal student loan program. First, we set the aggregate federal student loan 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.[38] We set the add-on for the federal student loan interest rate, τ_{SL}, to the most recent value of 2.1 percentage points announced by the Chief Operating Officer of the Office of Federal Student Aid (Chief Operating Officer for Federal Student Aid (FSA), 2021), and the maximum number of years that one can be in repayment for a student loan, T_{SL}, to 10 based on Smole (2019).[39] 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).[40] The student loan collection fee, ϕ_D, which is common to both federal and private loans, is set to 0.185 following Luo and Mongey (2019).

Table 7: Externally estimated parameters related to education

Parameter	Description	Data Target	Value
Panel A: Federal student loan program			
$\bar{A}$	Limit	Ave. 2016-2018, Smole (2019) and NCES (2019)	1.493
τ_{SL}	Interest rate add-on	Chief Operating Officer for FSA (2021)	0.021
T_{SL}	Maximum years to repay	Smole (2019)	10
τ_g	Federal SL garnishment rate	Yannelis (2020)	0.150
ϕ_D	Student loan collection fee	Luo and Mongey (2019)	0.185
Panel B: Tuition subsidies and college working hours			
$\theta(s_1)$	Public tuition subsidy given s	Table 33 (HSLS:09) and Krueger and Ludwig (2016)	0.285
$\theta(s_2)$			0.323
$\theta(s_3)$			0.364
$\theta^{pr}(s_1)$	Private tuition subsidy given s		0.122
$\theta^{pr}(s_2)$			0.139
$\theta^{pr}(s_3)$			0.156
ℓ_{pt}	Part-time working hours while in college	Table 34 (HSLS:09)	0.347
Panel C: Child skill distribution given parent education			
$\pi(s_{c,1}\|e=\ell)$	Parent does not have BA	Table 33 (HSLS:09)	0.426
$\pi(s_{c,2}\|e=\ell)$			0.341
$\pi(s_{c,3}\|e=\ell)$			0.233
$\pi(s_{c,1}\|e=h)$	Parent has BA		0.176
$\pi(s_{c,2}\|e=h)$			0.311
$\pi(s_{c,3}\|e=h)$			0.512

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 s_c (high school GPA) given parental education e. Data sources are provided in the second column. When the data target source is a table using HSLS:09 data, it is located in the Supplementary Appendix.

[38] This limit has been in place since July 1, 2012. The U.S. federal student loan program sets yearly limits and lifetime limits on borrowing. Yearly limits depend on one's academic year (e.g., freshman) and dependency status. We assume borrowers are dependents, and we use the cumulative limit over the first four years because college in our model lasts for four years.

[39] 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.

[40] 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.

Panel B of Table 7 reports the estimated proportional tuition subsidies (grants and scholarships) from public and private sources, as well as the working time available during college. To estimate shares of college tuition subsidized by the government, $\theta(s)$, and shares of college tuition subsidized by private beneficiaries, $\theta^{pr}(s)$, we combine estimates from HSLS:09 with estimates from Krueger and Ludwig (2016). First, we compute shares of tuition and fees subsidized via grants, from either government or private sources, by skill quantile in the HSLS:09. These findings are reported in Table 33 in Supplementary Appendix C.3. 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 that the government's share of total tuition subsidies is 70 percent and that the private beneficiaries' share of total tuition subsidies is 30 percent. To assign values to $\theta(s)$, we multiply the total share of tuition subsidized by the government or private entities by 0.7; to assign values to $\theta^{pr}(s)$, we multiply it by 0.3. The generosity of grants from both sources is increasing in skill quantile, s. The value for working hours while in college, ℓ_{pt}, is set to the average time spent working for students in their third year of a 4-year BA program, expressed as a fraction of full-time work (40 hours per week) as reported in Table 34 in Supplementary Appendix C.3.

Panel C of Table 7 reports parameter values for $\pi(s_c|e)$, 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. Table 38 in Supplementary Appendix J presents externally estimated parameters that are not related to education.

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 target moments. The first column of Table 8 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 $p\,(s)$, which determines the true continuation probability and the persistence of the true dropout probability, $\rho_d\,(s)$. Note that both of these objects depend on the student's skill endowment, s. These objects are governed by persistence rates to the end of the third academic year (Y3), given enrollment in a four-year degree (Y1) and persistence to the end of the third academic year conditional on persisting to the second academic year (Y2). The last two rows in Panel A contain the fixed costs that generate 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. The parameter ξ_L^{pr} allows private loans to have an uptake cost that differs from that of federal student loans. Consistent with the intuition outlined in Section 3.1, 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 empirical patterns of uptake rates for private student loans compared to any student loans, as shown in Table 4 and discussed in Section 2.3. Note that, even with a value of 0 for ξ_L, the model somewhat understates the overall student loan uptake rate. The value of ξ_L^{pr} is set so that the model matches the share of 2013 enrollees that have positive private student loan balances after completing their third academic year. In Table 42 in Supplementary Appendix N, we compare the student loan portfolio in the model with its data counterpart. We also consider an alternative calibration where we choose ξ_L^{pr} to target the share of students with only private loans.

Panel B of Table 8 reports parameters that 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 enrollment option shock, q, which represents unmodeled taste shocks or heterogeneous factors that lead some high school graduates to not attend college and is chosen to target the enrollment rate of the top skill quantile. The parameter β_c, which governs the degree of a parent's altruism toward their child, is set so that the model matches average parent-to-child transfers in the NLSY97; Table 21 in Supplementary Appendix A.3 and surrounding discussion contain more information on how average transfers are computed in the data. Lastly, Panel B also includes $\hat{p}(s)$, which is a vector of the expected yearly continuation probabilities for each skill endowment. The values of this parameter are chosen to align the implied expectations about graduation likelihood in the model with the data. The difference between the vector of expected probabilities, $\hat{p}(s)$, and the vector of true continuation probabilities, $p_c(j,s)$, determines the extent of over-optimism in our model for each skill quantile in academic year j.[41]

[41] The evidence in Table 2 of Section 2.1 indicates that in the NLSY97 the expected probability of earning a bachelor's degree positively predicts college enrollment, even conditioning for skill (high school GPA). In the model, we assume that those who do not enroll have the same beliefs as those who do (conditional on skill endowment). This abstraction from belief heterogeneity within skill quantiles does not affect the conclusions we draw about the role of over-optimism in the economy, because the beliefs of those not enrolled in the baseline do not matter for that experiment. However, the beliefs of those who do not enroll may affect the welfare implications of a federal loan limit expansion in the presence of over-optimism, as studied in our second experiment. To examine the extent to which this is the case, in Supplementary Appendix N we perform a robustness exercise where we calibrate the model to the over-optimism among non-enrollees observed in the NLSY97, which is reported in Table 18 of Supplementary Appendix A.1. We view over-optimism for this group as a lower bound on the extent of over-optimism in the population. The results of the second experiment performed in this recalibrated model show that our main results

Table 8: Internally calibrated parameters

Parameters			Moments		
Parameter	Parameter Description	Value	Data Target Description and Source	Data	Model
Panel A: Moments from the HSLS:09					
$p(s_1)$	Continuation probability parameter given s	0.615	Enrolled year 3 if enrolled year 1, Table 33	*0.476*	*0.476*
$p(s_2)$		0.823		*0.711*	*0.711*
$p(s_3)$		0.906		*0.829*	*0.829*
$\rho_d(s_1)$	Dropout probability persistence given s	0.586	Enrolled year 3 if enrolled year 2, Table 33	*0.774*	*0.774*
$\rho_d(s_2)$		0.772		*0.863*	*0.863*
$\rho_d(s_3)$		0.908		*0.913*	*0.915*
ξ_L	Loan search and debt aversion cost	0.000	Uptake of student loans if persisted, Table 4	*0.650*	*0.562*
ξ_L^{pr}	Private loan uptake cost	2.713	Uptake of private loans if persisted, Table 4	*0.220*	*0.220*
Panel B: Moments from the NLSY97					
λ	College effort cost net of consumption value	0.133	Enrolled in BA by age 25, Table 19	*0.478*	*0.478*
q	College enrollment option shock	0.770	Enrolled in BA by age 25 if highest skill, Table 14	*0.770*	*0.770*
β_c	Parent altruism toward child	0.198	$\frac{\text{Average transfer}}{\text{GDP pc 18+ 2016-2018}}$, Table 21 and BEA (2022a)	*0.578*	*0.578*
$\hat{p}(s_1)$	Expected continuation probability given s	0.951	Expected graduation rate, Table 1	*0.818*	*0.818*
$\hat{p}(s_2)$		0.967		*0.874*	*0.874*
$\hat{p}(s_3)$		0.983		*0.936*	*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	0.168	Delinquency rate 2016-2018, FSA (2021b)	*0.090*	*0.091*
ξ_D^{pr}	Private loan delinquency cost	1.207	$\frac{\text{Delinquent private debt}}{\text{Private debt in repayment}}$, Amir et al. (2021)	*0.074*	*0.075*
τ_{is}	Student loan issuance cost	0.040	Interest rate comparison, Table 6	-	*0.065*
Panel D: Moments from other sources not related to education					
Z	Aggregate labor productivity	0.308	GDP per capita 18 and over	*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; Panel B reports parameters related to moments from the NLSY97; Panel C reports parameters and moments that use a variety of other sources and that 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 13 are in the Supplementary Appendix.

Panel C of Table 8 contains the parameters related to education that are governed by empirical targets from sources other than the HSLS:09 and NLSY97. The first moment is the amount that can be borrowed for college room and board costs, $\bar{c}$, which is set using the average annual value for room and board at bachelor's programs from 2016 to 2018 as reported in NCES (2019). Second is annual tuition, κ, which is set using information on net tuition and fees also reported in NCES (2019). 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, based on 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's delinquency rate matches the average cohort delinquency rate from 2016

on the effects of loan limit expansion are robust to belief heterogeneity within skill quantiles, if that heterogeneity is like what is observed in the NLSY97.

to 2018, where the definition of delinquency in the data is a delay in payment of 270 days or more. For private student loans, ξ_D^{pr} is set so that the model matches private loan balances 90 or more days delinquent as a fraction of total private loan balances.[42] For federal loans, this moment is reported in a default rate briefing by the Office of Federal Student Aid in FSA (2021b); for private loans, we use the industry report Amir, Teslow, and Borders (2021). The last row of this panel contains the student loan issuance cost, τ_{is}, which is set so that the interest rates of federal and private student loans have the same mean, as documented in Table 6 of Section 2. This issuance cost τ_{is} represents the two loan issuers using the same issuance technology.[43]

Panel D contains the remaining jointly calibrated parameters. These parameters are governed by moments that are unrelated to education and which are not from either 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 in BEA (2022c) and BEA (2022a).[44]

5 Properties of the Model Economy

This section presents several properties of the calibrated model economy that are related to our main exercises. Subsection 5.1 examines over-optimism's effects on consumer choices, focusing on its role in generating observed enrollment patterns (and the extent of over-enrollment), student loan uptake by college students, and family inter vivos transfers to children in partial equilibrium. 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.

5.1 Over-optimism's attributes and effects on consumer choices

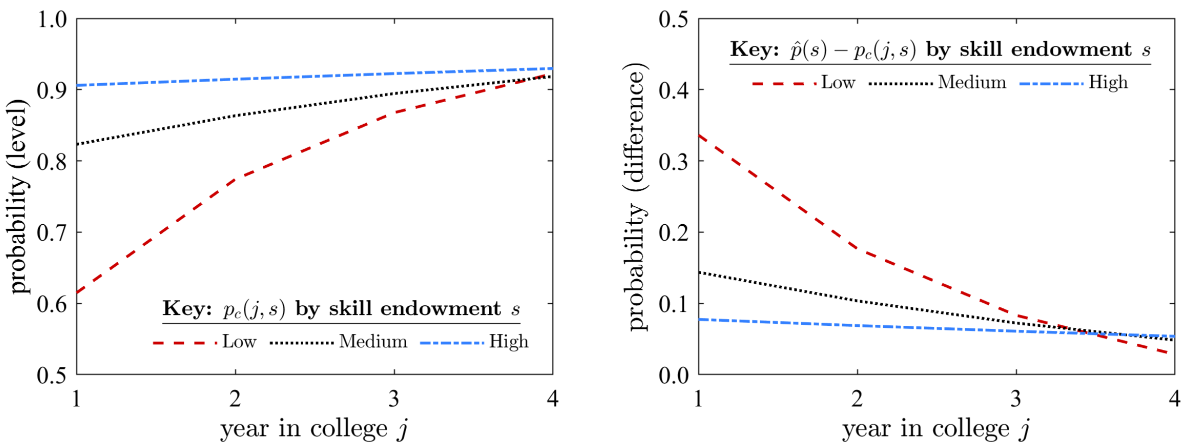
Figure 1 presents a visual illustration of true college continuation probabilities and the extent of over-optimism in the model's baseline equilibrium. This information is broken down by skill level, s, with college academic year on the x-axis of both subfigures. Subfigure 1a plots the calibrated

[42] For federal student loans, after 270 days spent in delinquency, 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 delinquency rate. For private loans, we use the available delinquency definition (90 or more days) closest to the length of a period in our model when selecting the empirical target.

[43] See equations 25 and 28 in Supplementary Appendix G.

[44] See equation 26 in Supplementary Appendix G.

true probability of continuing to the next academic year, j, symbolized by $p_c(j, s)$. Moving across academic years, the true probability of continuing to the next academic year of college increases. Subfigure 1b plots the extent of over-optimism in the model at the time of the enrollment decision by academic year, which is computed as the difference between $\hat{p}(s)$ and $p_c(j, s)$. In our model, 18-year-olds in lower skill quantiles exhibit greater over-optimism, but all skill levels are overly optimistic to some extent. This is consistent with the empirical findings presented in Panel A of Table 1. Subfigure 1b highlights that college enrollees' over-optimism about their likelihood of earning a bachelor's degree map into over-optimism about continuing through the earliest years of college in particular.



(a) True college continuation probabilities

(b) Extent of over-optimism

Figure 1: True college continuation probabilities and extent of over-optimism

Note: Figure 1 presents moments from the calibrated baseline equilibrium of the model. Figure 1a plots the true probabilities of continuing toward a college degree for another academic year, $p_c(j, s)$. Figure 1b plots the extent of over-optimism about continuing towards a college degree at the time of the enrollment decision, computed by subtracting the true probability from the expected probability, $\hat{p}(s) - p_c(j, s)$.

We next examine the extent of over-enrollment (defined below) in college that is generated by over-optimism. Our goal is to compare the extent of over-enrollment in the baseline equilibrium with an empirical counterpart, to verify that the model's enrollment sensitivity to beliefs is reasonable. In column (1) of Table 9, we report enrollment rates for each skill quantile computed in the NLSY97.[45] Column (2) contains enrollment rates for high school graduates for each skill quantile, s, 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 18-year-olds in the model's

[45]The details of this estimation are reported in Table 14 in Supplementary Appendix A

baseline equilibrium when we shut off over-optimism by setting $\hat{p}(s) = p_c(j, s)$. In this column, enrollment rates decrease compared to the baseline, especially among low-skill 18-year-olds. We define the difference between enrollment rates in columns (2) and (3), reported in column (4) as the over-enrollment in that row's skill quantile. Thus, because the model framework allows us to exactly predict enrollment rates in a counterfactual world without over-optimism, we can use the model to conclude that over-enrollment resulting from mistaken beliefs is highest among low-skill 18-year-olds.

Although we cannot exactly predict the extent of over-enrollment in the data, we can use the findings reported in model (1) of Table 2 to compute how enrollment would change for the sample of enrollees in the NLSY97 if they had the "correct" beliefs, where correct beliefs correspond to the true graduation likelihood for each skill quantile. Column (5) of Table 9 reports the share of college enrollees who would not enroll with correct beliefs, estimated in the NLSY97.[46] Column (6) reports the share of over-enrollment among enrollees in the baseline model. Although not targeted in our calibration, the model performs well in capturing the share of college students who are over-enrolled in the baseline equilibrium.

Table 9: College enrollment statistics by skill quantile

Statistic:	**College enrollment rate**			**Level of over-enrollment**	**Share of over-enrolled**	
Sample:	**High school graduates**			**High school graduates**	**College enrollees**	
	(1)	**(2)**	**(3)**	**(4) = (2) - (3)**	**(5)**	**(6) = 100 * (4) / (2)**
Skill	**Data**	**Model baseline**	**No over-optimism**	**Difference**	**Data**	**Model baseline**
1	22.92	25.10	9.33	15.77	69.40	62.83
2	45.57	44.35	38.77	5.57	28.45	12.57
3	77.01	77.01	77.01	0.00	10.09	0.00

Notes: Table 9 presents enrollment statistics in the data and model by skill quantile, where skill quantile is assigned with high school GPA in the data and represented with s 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 program. 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 $\hat{p}(s) = p_c(j, s)$, so that there is no over-optimism and consumers have correct beliefs, and column (4) reports the level of over-enrollment, computed as the difference between columns (2) and (3) in units of percentage points. Columns (5) and (6) report the share of over-enrollment for the sample of college enrollees in the data and model baseline, respectively. Data moments in columns (1) and (5) of this table are reported, and their estimation further explained, in Tables 14 and 20 of Supplementary Appendix A, respectively.

Table 10 reports loan uptake by persistence status for a given cohort of enrollees in the data (Panel A, referencing Table 3 in Section 2.2) 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 in column (2) and the magnitude of loan balances among student debtors in columns

[46] These moments are reported, and their estimation further explained, in Table 20 of the Supplementary Appendix.

(4) and (5). However, the model does not perform well in capturing the share of non-persisters with any student debt in column (3). We attribute this to fewer dropouts having small loan balances in the model as compared to the data.

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

Panel	Source	Persistence status	(1) % of enrollees	(2) % of SL $	(3) % with SL	(4) Average $	(5) Median $
A	Data	Did not persist	24	19	78	15,270	12,238
		Persisted	76	81	65	24,648	19,500
B	Model	Did not persist	27	8	14	21,898	16,755
		Persisted	73	92	56	25,478	12,100

Notes: Table 10 reports loan uptake patterns by persistence status to the third academic year for a given cohort of enrollees. Panel A contains moments from the HSLS:09, as reported in Table 3. Panel B contains analogous statistics from the model baseline equilibrium.

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. Therefore, the statistics reported in Table 10 will barely change if we computed the same statistics without over-optimism. Of course, total borrowing will be affected by over-optimism because total student debt depends on how many young adults choose to enroll in college. To see this, one can consider a partial equilibrium where 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, just before student loan repayment begins, for a given cohort of high school graduates, the mass of student debtors who are dropouts falls by 9 percent, while the aggregate balances held by dropouts also fall by 9 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 intrinsic riskiness of college as an investment, rather than being driven by over-enrollment due to overly optimistic beliefs.

Thus far, we have analyzed how over-optimism among young adults affects their enrollment decisions and borrowing behavior. In our model, parents are also overly optimistic, which may affect the transfers they make to their children. In Table 11, we analyze how family inter vivos transfers change when over-optimism is eliminated for all consumers. Panel A of Table 11 reports in column (1), the transfers parents make on average given the child's skill bin, whereas column (2) reports the transfers the same distribution of parents would make in the same baseline equilibrium

Table 11: Family transfer statistics by skill quantile

Panel A: Family transfers with and without over-optimism	**Skill**	**Average family transfer**		**Change in transfers**
		(1) Baseline	**(2) No over-optimism**	**(3) = (2) - (1)**
Units: percent of baseline p.c. GDP for 18+	1	44.23	31.43	-12.79
	2	61.45	51.40	-10.05
	3	69.14	73.20	4.07
Panel B: Distribution of changes in family transfers	**Skill**	**Changes in transfers after correcting beliefs**		
		(1) Increase	**(2) No change**	**(3) Decrease**
Units: percent of cohort	1	7.16	68.43	24.41
	2	2.33	71.03	26.64
	3	21.50	77.41	1.09

Note: Table 11 presents family transfer statistics by skill quantile in the baseline model equilibrium. In Panel A, columns (1) and (2) report the transfers parents would make in the baseline case and in the case without over-optimism; column (3) reports the difference between the no over-optimism and the baseline transfer levels. In Panel B, columns (1) to (3) report the share of children that experience an increase, no change, or decrease in transfers if over-optimism is eliminated.

if there were no over-optimism. Transfers in Panel A are reported as a percent of GDP per capita for the population that is 18 and over in the baseline equilibrium. Column (3) reports the difference between columns (1) and (2). If over-optimism is eliminated, parents with low- and medium-skill children will transfer lower amounts while parents with high-skill children will transfer higher amounts. To see what is driving these changes, Panel B reports the share of 18-year-olds in a given skill bin that would experience an increase, no change, or a decrease in transfers if over-optimism is eliminated. Conditional on parents changing their transfers, transfers decrease for most 18-year-olds with low and medium skill, whereas transfers increase for most 18-year-olds with high skill.

The reason for the changes in Panel B of Table 11 being negative for low- and medium-skill and positive for high-skill children is that transfers play different roles for those groups. Generally, transfers act as a source of funds for human capital investment and as a source of financing for consumption. For low- and medium-skill children, the transfer from their parents increase their incentive to attend college by alleviating credit frictions. Therefore, from the parent's perspective, the transfer acts to affect the enrollment decision and so predominantly plays the role of an investment in the child's education. Over-optimism inflates the expected return to the child's education, so that eliminating over-optimism makes incentivizing enrollment look less appealing for parents. Their transfers drop accordingly. By contrast, a high-skill child has a large incentive to go to college regardless of the transfer they receive from their parent. Family transfers for these children predominantly act to increase consumption directly, rather than indirectly by boosting human capital investment. When the parent realizes that their high-skill child is less likely to graduate (after beliefs are corrected), they respond by using transfers to directly raise their child's future consumption regardless of the graduation outcome.

5.2 The role of federal student loan limits

One of our main 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 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 to which they have access. 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, skill, and enrollment in the baseline calibration.

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 total college expenses at a four-year college, net of grants, if we include the average expenditure for college room and board.[47] If we exclude the college room and board expenditure, the current federal student loan limit is enough to pay for 3.96 years of average total tuition at a four-year college, 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 limits, even with minimal living expenses. The model is calibrated to match this attribute of current federal loan policy.

Under current policy, to what extent are college students using all of the federal loans to which they have access? To measure utilization rates in the data, we turn to the HSLS:09.[48] We compute the federal loan utilization rate for each college enrollee in the HSLS:09 who persists for three

[47] That is, over the first four years, federal limits for dependents can on average pay for 37.5 percent of annual college expenses. See Table 7 in Section 4 for data sources.

[48] To apply for federal aid, college students submit the Free Application for Federal Student Aid (FAFSA). On this form, students select a dependency status; dependency status determines annual borrowing limits for federal student loans. The public version of the HSLS:09 does not report which dependency status each FAFSA filer selects. We assume everyone files as dependents. This is a reasonable assumption because most undergraduate students (and all students in the HSLS:09 in 2016, the year in which we measure their utilization rates) are less than 24 years old. Other ways to be classified as independent are to be married, follow a graduate program, serve on active duty in the U.S. armed forces, be a veteran of the armed forces, have dependent children, have deceased parents, be an emancipated minor, or be determined as an unaccompanied minor (FSA, 2022b). Most undergraduate students do not satisfy these criteria.

academic years after enrollment, where the utilization rate is the ratio of the cumulative federal debt balance to cumulative borrowing limits after the first three years of college. The results are reported in Table 12: 54 percent of those who completed their third academic year have utilized more than half of their cumulative federal student loan limit, 34 percent of persisting students use more than 90 percent, and 28 percent of persisting students utilized all of their available federal loans. 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, Table 12 indicates that the model's baseline equilibrium also exhibits a sizable share of students using all of their available federal loans. Since we underestimate this share in the model baseline, our welfare gains from loan expansions can be considered lower bounds.

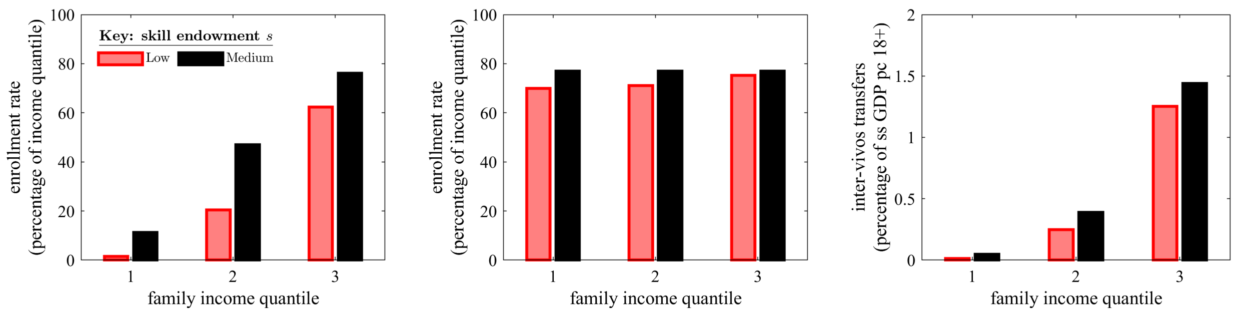
Table 12: Utilization rates for federal student loans

Utilization	**Data**	**Model**
$\geq$ 50%	54	40
$\geq$ 90 %	34	18
$\geq$ 100%	28	16
Obs	1,855	

Notes: Table 12 reports utilization rates for federal student loans in the HSLS:09 and in the baseline model equilibrium. The empirical moments are computed for students who enrolled in a BA program in the fall of 2013 and persisted to the end of their third academic year. Utilization rates of federal student loans are computed at the end of the students' third academic year, expressed as percentages of the cumulative limit up to that point (the sum of annual limits for the first three academic years). Weights are PETS-SR student records longitudinal weights. Data source: HSLS:09.

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

Federal student loan limits play a sizable role in allowing our model framework to generate patterns of enrollment similar to the data. The qualitative properties of enrollment rate patterns in the NLSY97 are documented by Lochner and Monge-Naranjo (2011), who show that college enrollment rates are increasing in family income conditioning on skill—especially at lower skill levels. In the first two panels of Figure 2, we plot the model's college enrollment by family income quantile for 18-year-olds in the lower two skill quantiles in the baseline equilibrium and a counterfactual world where the federal student loan limit is expanded to finance four years of college costs (i.e., $\bar{A} = 4$), respectively. Consistent with patterns documented in Lochner and Monge-Naranjo (2011), enrollment rates in the baseline equilibrium are increasing in family income for a given skill quantile. The model framework captures this pattern because it incorporates credit frictions (i.e., stringent limits on federal loans and high uptake costs for private loans) and heterogeneous family transfers (which are endogenous). To examine the contribution of federal student loan limits, Subfigure 2b shows enrollment rates when $\bar{A} = 4$. Comparing Subfigures 2a and 2b, the positive relationship between family income and enrollment rates for low-skill 18-year-olds is substantially reduced by this policy change. This indicates that in the model, limited access to federal student loans plays a significant role in generating the observed relationship between enrollment and family income for lower-skill 18-year-olds. The contribution of family transfers is shown in Subfigure 2c, which plots the inter vivos transfers received by 18-year-olds in the baseline equilibrium by family income and 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 stringent federal student loan limits.



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

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

Notes: Figure 2 shows examines the relationship between borrowing limits and college enrollment in the model. Subfigure 2a shows enrollment rates by family income quantile, for the lower two skill quantiles $s = 1$ and $s = 2$, 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 skill quantiles in the baseline equilibrium.

6 Main Experiments

This section presents and discusses the results of the two main experiments: the impact of over-optimism, analyzed in Subsection 6.1, and a federal student loan limit expansion, analyzed in Subsection 6.2.[49]

Specifically, Subsection 6.1 examines the macroeconomic and welfare impact of over-optimism about college graduation in general equilibrium by setting $\hat{p}(s) = p_c(j, s)$. This expands on the analysis of Subsection 5.1, which examined the partial equilibrium effects of such a change on enrollment and borrowing choices by students and transfer choices by parents. In our general equilibrium analysis, we incorporate adjustments in prices, Social Security transfers, the income

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

tax, accidental bequests, and inter vivos transfers from parents.

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, net of grants, plus room and board. This expansion allows overly-optimistic high school graduates to access more credit if they enroll in college, potentially worsening over-enrollment. At the same time, in the baseline equilibrium of the model (as in the data), many students are fully utilizing their federal student loan limits, so expanding access to federal loans could instead increase consumer well-being by relaxing a binding constraint (Subsection 5.2). Therefore, the welfare consequences of a federal student loan limit expansion are ambiguous, with the parameterized model determining the relative magnitudes of each of these forces.

In both 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 Impact of over-optimism

The effects of eliminating over-optimism on the model's steady state equilibrium are shown in column (1) of Table 13. Effects on the model economy are summarized by changes in education and skill statistics (Panel A), macroeconomic aggregates (Panel B), and prices, income tax rate, and transfers (Panel C).

In Panel A, the first three rows report changes in over-enrollment by skill. By construction, in the new equilibrium over-enrollment—which is the difference between equilibrium enrollment choices and predicted choices made with correct beliefs—goes to zero. That statistic was highest for the lowest-skilled students in the baseline equilibrium, so over-enrollment changes the most for those with the lowest skill. College enrollment falls for low- and medium-skill 18-year-olds for two reasons. First, when young adults use the true probabilities of college continuation in making their college enrollment decision, the value of going to college decreases to its true value, which is what reduces over-enrollment to zero and causes college enrollment to fall. Second, when parents use the true probabilities of college continuation for their children, the expected return on a college investment decreases, which reduces parental transfers and causes a further fall in college enrollment. The second reason explains why the observed decrease in college enrollment is higher than the observed decrease in over-enrollment, especially for medium-skill 18-year-olds. A more detailed discussion for the second mechanism is provided in Supplementary Appendix L. The elimination of over-enrollment leads to a higher graduation rate due to changes in the composition of college enrollees: 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. This occurs because skill endowments of children are positively correlated with parental educational attainment in the parameterized model, reflecting attributes of the data.

Table 13: Steady state changes from main experiments

Panel	Variable		Policy (1) Elimination of over-optimism	Policy (2) Federal loan limit expansion
A: Education and skill statistics	Over-enrollment	s_1	-15.77	44.34
Units: percentage point change		s_2	-5.57	26.60
		s_3	0.00	0.00
	College enrollment rate	s_1	-20.25	46.69
		s_2	-23.58	32.66
		s_3	0.00	0.00
	Graduation rate		5.27	-4.26
	Population share college graduates		-8.54	13.59
	Share of 18-year-olds	s_1	2.13	-3.40
		s_2	0.25	-0.40
		s_3	-2.39	3.80
B: Macroeconomic aggregates	Output		-3.44	3.94
Units: percentage change	Capital		-2.97	0.60
	Labor (efficiency units)		-3.70	5.86
	Consumption		-3.35	3.55
C: Prices, income tax rate, and transfers	Risk-free savings interest rate		-0.07	0.39
Units: percentage point/percentage change	Wage rate		0.35	-1.75
	Private student loan interest rate		-0.23	-
	Income tax rate | Initial steady state mean income		0.57	-0.31
	Inter vivos transfers		-26.17	-6.08
	Accidental bequests		-3.24	5.41
	$ss_{\ell,s}$	s_1	-2.09	2.29
		s_2	-2.07	2.25
		s_3	-2.04	2.19
	$ss_{h,s}$	s_1	-1.63	1.38
		s_2	-1.54	1.35
		s_3	-1.34	1.14

Notes: Table 13 provides results from a steady state comparison of the baseline economy to: (1) an economy without over-optimism (i.e., $\hat{p}(s) = p_c(j, s)$) 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, 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 13 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, lower delinquency risk among private student loan borrowers (which arises because of their higher skill composition) causes the interest rate on private student loans to decrease.

As mentioned above, eliminating over-optimism leads to lower college enrollment because 18-year-olds no longer over-enroll and also because parents reduce transfers. This means that there are fewer college graduates in the economy, and thus fewer high earners, which causes a reduction in income tax revenue at the initial steady state's tax rate. In the presence of progressive income taxation, the fall in income tax revenue is larger than the fall in government expenditure at the initial steady state tax rate, so that the average income tax rate increases in the new steady state in order to balance the government's budget. This fiscal externality of a college degree is not internalized by consumers: specifically, neither 18-year-olds making the college enrollment decision nor their parents making transfer decision take into account how these actions affect the average income tax rate. The progressive nature of the income tax system is a key feature of the model environment that introduces this fiscal externality to a college education.[50]

When over-optimism is eliminated, 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 overly optimistic about their children's ability to graduate from college (for intuition, see Table 11 in Section 5.1 and surrounding text); second, the economy will have less wealth and income in the new steady state; and, third, there will be fewer high-skill children, which will lower parents' incentive to pay for college. The third mechanism is illustrated in Subfigure 2c, which shows that conditional on family income, lower skill children receive a lower amount of inter vivos transfers. The last two entries of Panel C show that transfers such as accidental bequests and Social Security also decrease, because of 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.

In our welfare analysis, we focus on the group most affected by these experiments: 18-year-old consumers.[51] Our measure of welfare for 18-year-old consumers is 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.[52] 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

[50] In an alternative framework with flat income taxation ($\tau_p = 0$), which is re-calibrated to match the same set of target moments as the baseline model, we find that eliminating over-optimism leads to only a small change in the income tax rate of -0.07 percentage points, as opposed to 0.57 percentage points in the baseline.

[51] In Supplementary Appendix M, Table 41, we report welfare implications in the period of the transition, for consumers that are 19 and older and parents at the age of making the inter vivos transfer decision. Although the magnitudes of the welfare implications are smaller, the qualitative takeaways are the same.

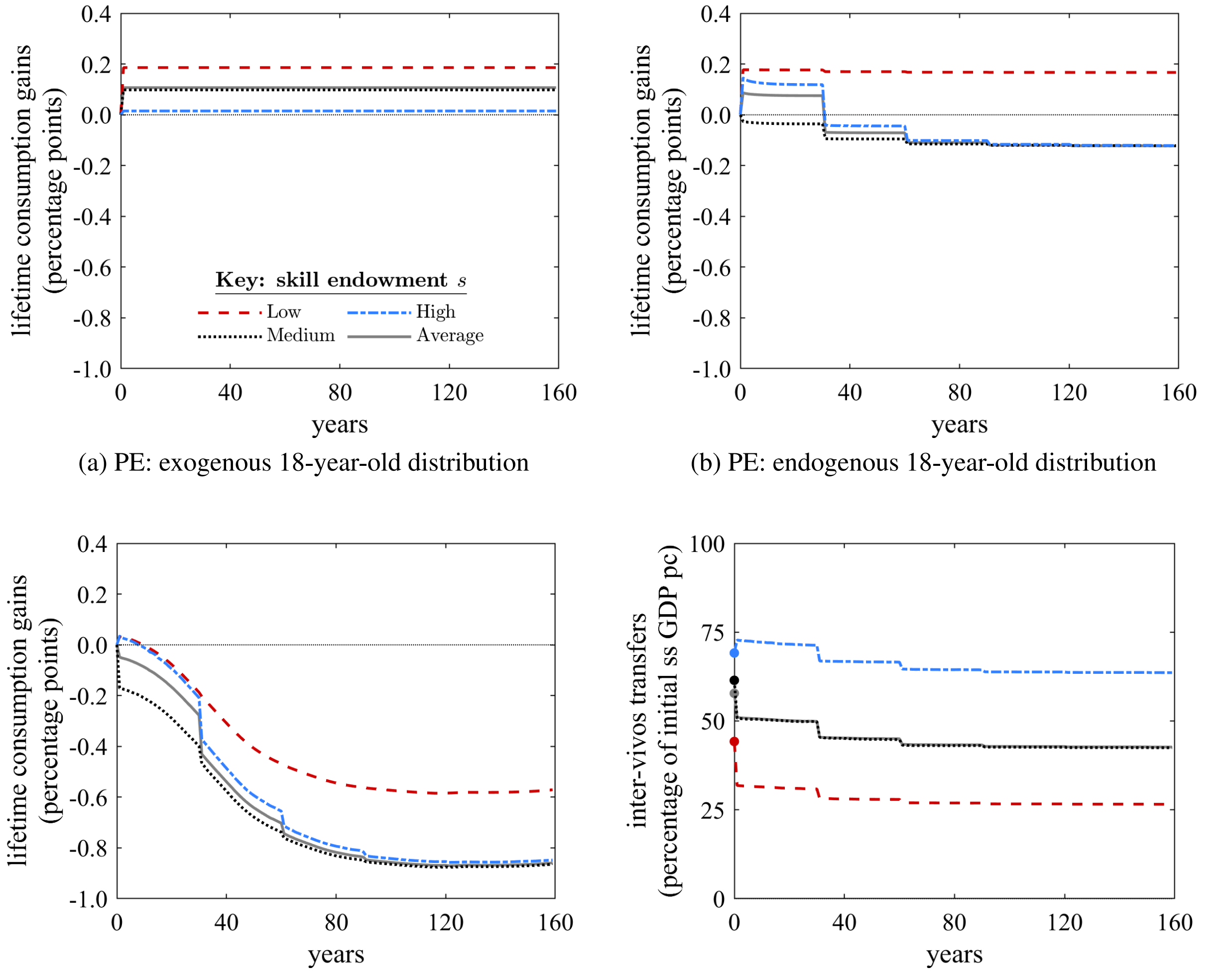
[52] Because our model includes psychic costs (i.e., search costs for student loans, an effort cost for college, and stigma costs for delinquency on student loans), we follow Abbott, Gallipoli, Meghir, and Violante (2019) and use the value of not going to college, which does not include any psychic costs, in order to compute this consumption-equivalent variation.

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 at which the inter vivos transfer is made. The value functions and equations used to construct welfare estimates are provided in Supplementary Appendix I. 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.

Figure 3 illustrates a welfare analysis of eliminating over-optimism. Results are shown in both 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 from having their beliefs corrected in proportion to the extent of over-optimism for their skill endowment. 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 that now endogenizes the 18-year-old joint distribution. For the low- and medium-skill, 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. On the other hand, for those with high skill, welfare gains in the initial periods of the transition are larger because parents increase inter vivos transfers.[53] In later periods of the transition, however, welfare decreases for all skill levels. This occurs because the population of parents become less educated over time, which lowers the earnings and wealth of parents and lowers the skill of young adults. Both of these effects compound the fall in inter-vivos transfers. Subfigure 3c indicates that, once we take into account general equilibrium effects, welfare changes become even more negative. This is primarily a result of an increase in the income tax rate, as discussed in the next paragraph, although the fall in the savings interest rate, accidental bequests, and Social Security transfers contribute as well. Inter vivos transfers over the general equilibrium transition, by skill level and on average, are shown in Subfigure 3d.

Figure 4 decomposes welfare changes by attributing them to each of the several objects that adjust in general equilibrium. 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 significantly reduced and even become gains in the initial periods of the transition. This result indicates that

[53] See Section 5.1 for a discussion of the opposing mechanisms.



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

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

(c) GE: welfare

(d) GE: inter vivos transfers

Figure 3: Elimination of over-optimism welfare analysis: partial and general equilibrium effects

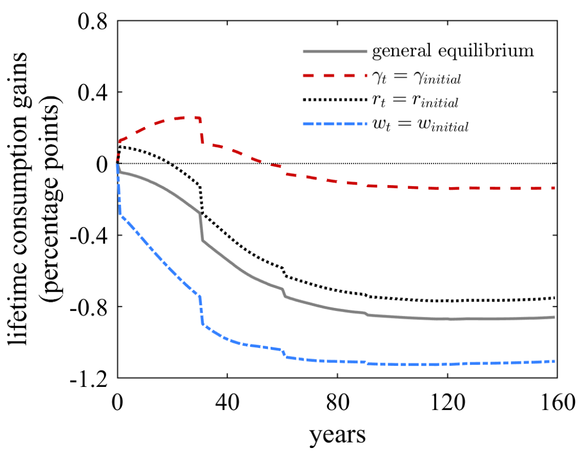
Notes: Figure 3 provides a welfare analysis of eliminating over-optimism for 18-year-old consumers in partial and general equilibrium. Subfigures 3a-3c report lifetime consumption gains and losses for the average 18-year-old and the average-18-year-old given skill in each period of the transition path under the following cases separately: (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 for those 18 and older.

higher income taxes stemming from eliminating over-optimism are a key driver of welfare losses.[54] A similar pattern, although to a lesser extent, occurs when we hold fixed the risk-free interest rate

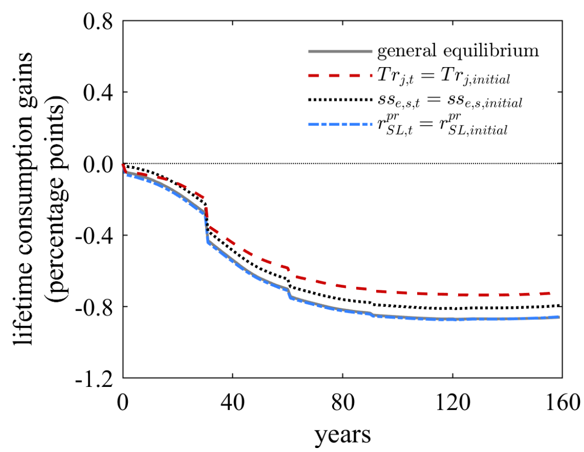
[54]As discussed above, progressive income taxation is a key ingredient for the elimination of over-optimism to lead to higher income taxes. In Supplementary Appendix N, we analyze welfare implications with flat income taxation. With flat income taxation, welfare losses are smaller, and low skill consumers experience gains.

on savings at its initial level instead of allowing it to fall. By contrast, fixing the wage rate at its initial level magnifies welfare losses for the average 18-year-old consumer, indicating that the equilibrium increases in this object act to mitigate the welfare losses resulting from eliminating over-optimism.

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.



(a) Part 1



(b) Part 2

Figure 4: Decomposing general equilibrium welfare effects of eliminating over-optimism

Notes: Figure 4 provides a welfare analysis of eliminating over-optimism 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, risk-free savings rate, r_t, fixed at its initial level, wage rate, w_t, fixed at its initial level, accidental bequests, $Tr_{j,t}$, fixed at its initial level, Social Security transfers, $ss_{e,s,t}$, 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.

Overall, the experiment of eliminating over-optimism uncovers its complex role in the economy: although over-optimism leads 18-year-olds to over-enroll in college, it also benefits them in three ways. First, over-optimism raises the college education rate, which lowers the average income tax rate in the presence of progressive income taxation. Second, over-optimism raises the inter vivos transfers that 18-year-olds receive from their parents. Third, the average 18-year-old has a higher skill endowment in an economy with over-optimism, because more parents in the economy have a college degree.

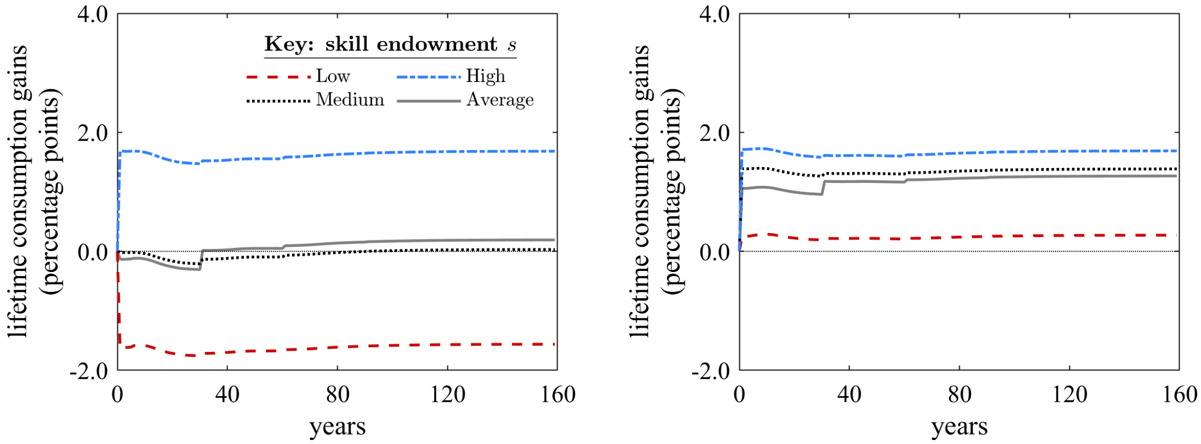
To summarize, in general equilibrium the average consumer is better off with over-optimism because everyone is overly optimistic at the same time. The fact that everyone is overly optimistic at the same time is what allows the average income tax rate to be lower in equilibrium. In such an environment, some groups of consumers drop out of college more often than they expected. Those individuals are still better off than in a world without over optimism, because the aggregate endogenous states are favorable to them (mainly lower income taxes). Of course, if mistaken beliefs of a few individuals are changed, or everyone's beliefs are changed without allowing for parent choices or aggregate quantities to adjust, then young people are better off when they correctly understand their own risks.

6.2 Federal loan limit expansion

In our second experiment, we analyze the effects of expanding the federal student loan limit from $\bar{A} = 1.49$ to $\bar{A} = 4$ in the presence of over-optimism. With this change, federal loans become 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, skill, and macroeconomic aggregates are shown in column (2) of Table 13.

Panel A of Table 13, column (2), shows that the expansion in the federal loan limit increases enrollment in college for the lowest two skill quantiles, which in turn raises over-enrollment for those quantiles. Enrollment increases because young adults previously constrained in their access to federal credit (which has a lower uptake cost compared to private loans) can now access more of it. Higher enrollment among low-skill 18-year-olds leads to a lower graduation rate overall. Nevertheless, higher enrollment also increases the share of college graduates in the population, which leads to more 18-year-olds with higher skill endowments 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 interest rate on savings 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 the borrowing limit on private loans is set as the residual of what can be financed with federal loans. With more college graduates, the income tax base expands; in particular, the mass of high-earners rises. Progressive income taxation allows the average income tax rate to decrease in response. Both public transfers from Social Security and accidental bequests rise, but inter vivos transfers decrease because federal loans are now sufficient for financing college expenses.

In Figure 5, we analyze the welfare implications of expanding the federal student loan limit for 18-



(a) Baseline (b) No over-optimism

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

Notes: Figure 5 shows 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 18-year-olds, both on average and by skill endowment level, in each period of the transition path.

year-old consumers in both the baseline economy (Subfigure 5a) and in an economy without over-optimism, where the latter is re-calibrated to match the same set of target moments as the baseline except for moments related to beliefs about the likelihood of college graduation (Subfigure 5b).

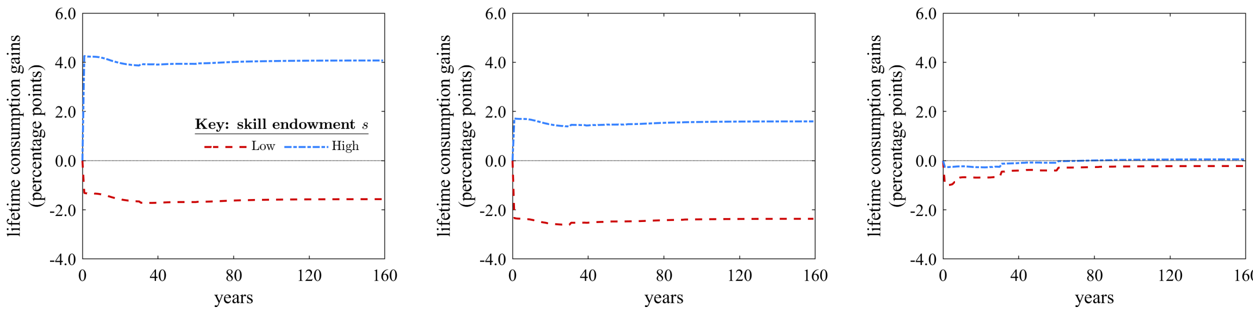
In the baseline economy with over-optimism, shown in Subfigure 5a, 18-year-olds in the lowest skill endowment quantile experience welfare losses whereas 18-year-olds in the highest skill endowment quantile experience welfare gains. Middle skill 18-year-olds are hurt in the initial periods of the transition, albeit slightly. Overall, the average 18-year-old is slightly worse off in the initial periods of the transition and slightly better off in the later periods.

When we perform the same experiment in an environment without over-optimism (Subfigure 5b), we find that 18-year-olds in all skill quantiles experience welfare gains. These gains are increasing in skill. Without over-optimism, general equilibrium effects and the public costs of subsidized federal student loans do not offset the welfare gains that stem from increased access to federal loans for financing. These gains arise because federal loans have a lower uptake cost compared to private loans.[55]

A comparison of Subfigures 5a and 5b highlights the additional insight one gains from incorporating over-optimism about likelihood of college graduation into the model environment. With

[55] The rest of the population experiences small gains from the loan limit expansion. See Supplementary Appendix M for details.

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 18-year-olds 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 probabilities of college graduation.



(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 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. Subfigures 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 young adults without other forms of financing. Such young adults are primarily from low-income families. In Figure 6, we plot welfare implications by family income quantile as well as skill. Subfigures 6a and 6b show that 18-year-olds from low-income families in the lowest skill quantile experience large welfare losses when loan limits are expanded, whereas 18-year-olds from low-income families in the highest skill quantile experience large welfare gains. Thus, among young adults raised by poor families, there are heterogeneous effects of the increased access to credit for financing college. These effects depend on skill endowment level, which is correlated (but not perfectly) with parent education and thus parent income. At the same time, the impact of the loan limit expansion on the welfare of 18-year-olds from high-income families is small. This is because 18-year-olds from high-income families received large inter vivos transfers from their parents before the policy change, and a higher federal student loan limit simply crowds out family transfers without changing enrollment decisions.

To summarize, an expansion in the federal loan limit will not be welfare improving for all young adults. In particular, the impact of the loan limit expansion is felt the most by 18-year-olds in low-income families: in this income group, those with low skill see welfare losses, whereas those with high skill see welfare gains. This heterogeneity in welfare changes is driven by the presence of over-optimism about the likelihood of college graduation.

7 Conclusion

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

Our analyses lead to two main findings. First, although over-optimism leads 18-year-olds to over-enroll in college, it also benefits these young adults once we consider the impact of general equilibrium adjustments in the average income tax rate, as well as changes in parental transfers and intergenerational effects on skill. Second, in the presence of over-optimism, increasing financial aid through an expansion in the federal student loan limit leads to welfare losses for low-skill young adults from poor families. This happens because access to more federal student loans worsens over-enrollment in college for these consumers.

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 this 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 (Bureau of Labor Statistics, U.S. Department of Labor, 2019). This survey collected data annually from 1997 to 2011 and biannually from 2011 to the present (rounds 1 through 19).

This section proceeds as follows. Subsection A.1 extends the main text's analysis of over-optimism. Subsection A.2 reports estimates of over-enrollment in college using results from regressions predicting enrollment. Subsection A.3 explains the methodology and results for computing inter vivos transfers in the NLSY97.

A.1 Educational attainment outcomes versus expectations

Table 14 reports enrollment rates by age 25 and by age 30 in the NLSY97 for each skill quantile (skill is measured with the high school GPA tercile assigned using the distribution of skill among 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 because this aligns with the wording of the expectations question in the NLSY97 questionnaire. For the enrollment rates used as calibration targets in the model, however, enrollment by age 30 is not an intuitive mapping to the one-time enrollment choice consumers make at age 18 in the model. Since the model allows this choice to be made once immediately after high school graduation, but in reality young people may wait a few years after high school before enrolling in college, using enrollment by age 18 in the data is not satisfactory either. We therefore use enrollment by age 25, between these two ages, as the calibration target for enrollment in the quantitative model. Table 15 shows enrollment rates by age 25 broken down by family income quantile in addition to skill quantile. Family income quantiles are assigned using the distribution of high school graduates; note that the sample with valid family income observations is smaller than the main high school graduates sample. These enrollment rates are used to calibrate a sensitivity analysis in Subsection N, where the college enrollment option shock, q, depends on skill.

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 16 reports the difference

Table 14: Bachelor's degree program enrollment rates by skill quantile

Skill	Group obs	Enrolled by age 25	Enrolled by age 30
1	807	22.92	27.51
2	812	45.57	48.65
3	748	77.01	78.48
Obs	2,367		

Notes: Table 14 shows enrollment rates in a 4-year degree program by age 25 and by age 30, for each skill quantile. Skill quantiles are assigned using the distribution among high school graduates. Enrollment rates computed for the same sample. Source: NLSY97.

Table 15: Bachelor's degree program enrollment rates by skill and family income quantile

Income:	1		2		3	
Skill	Enr. rate	Obs	Enr. rate	Obs	Enr. rate	Obs
1	19	242	22	190	32	148
2	27	204	48	198	66	173
3	64	116	72	196	88	248
Obs	1,715					

Notes: enrollment rate in 4-year program by age 25, by skill (rows) and family income (columns) quantile. Enrollment rates are in percentages. Sample is high school graduates for whom family income is also observed. Source: NLSY97.

between student and parent expected probabilities of obtaining a BA, within the same family, when both expectations are reported. This means the sample is greatly reduced relative to just student expectations because parent beliefs are only reported with valid responses for a subset of the student beliefs sample. As is evident in Table 16, on average the beliefs of parents and children agree within a few percentage points of each other within each skill bin. The median difference in expected probabilities is 0. Percentiles of the distribution of differences other than the median (p50) are also reported in the table and indicate the the distribution is largely symmetric around 0. These results support our modeling assumption that parents are overly optimisc to the same extent as their children.

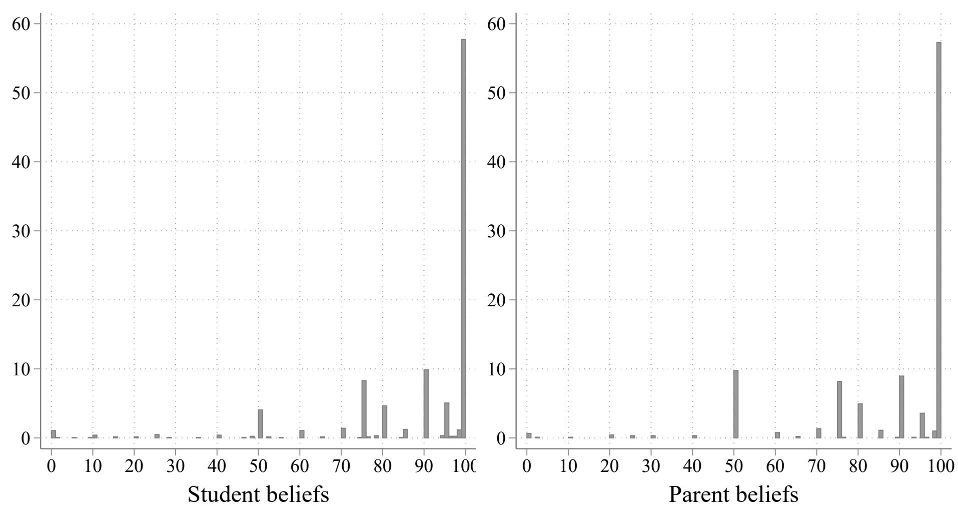
Table 16: Moments of the distribution of within-family difference in beliefs

Skill	Group obs	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: Table 16 shows statistics on the distribution of within-family differences between parent and child expected probabilities of the child earning a BA. Sample: students who enrolled in a BA program before age 30, whose parents responded to the beliefs question. Source: NLSY97.

Figure 7 shows a histogram of reported expected probabilities from the focal respondents and their parents, regarding the respondent's 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 it apparent that many college students, as well as 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 four-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 17 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).[56] In Panel A, we see that 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 or more 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, we see more similarity across education categories than across skill bins within

[56]Note that, as in the main text, we assume throughout that the expected probability of enrollment is 1, so that reported probabilities are interpreted as the conditional probability of graduating once enrolled. Relaxing this assumption would raise measured over-optimism with respect to college persistence probability.

an education category.

Table 17: Over-optimism about BA attainment: breakdowns

Panel A: by student gender and skill	Gender	Skill	Obs	Earned BA by age 30	Exp. prob. BA by 30	Extent of 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	Obs	Earned BA by age 30	Exp. prob. BA by 30	Extent of 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: Table 17 compares expectations and outcomes across skill quantiles by student gender and parental education level. Panel A is students who enrolled in a BA program before age 30, and Panel B is students who enrolled in a BA program before age 30 and for whom parental education is observed. Source: NLSY97.

In Table 2 of the main text, we have shown that beliefs about the likelihood of BA completion predict college enrollment. This means that, in the NLSY97, those who do not enroll in college have lower expected probabilities of completion compared to those who do enroll. We also computed our main empirical findings on over-optimism using those who eventually enroll in a 4-year BA program before age 30. In our model framework, we then assume that those who do not enroll in the baseline economy have the same extent of over-optimism as those who do enroll, conditioning on skill quantile. This model assumption abstracts from belief heterogeneity within skill quantiles, while our parallel empirical analysis on how beliefs are related to actions (i.e., enrollment) indicates that beliefs do partially predict selection into college enrollment in the data, so that on average those who do not enroll have lower expected probabilities of earning a BA. This model abstraction is not relevant for our results on the role of over-optimism in the economy, but could be relevant for the experiment where we expand borrowing limits and observe large changes in enrollment choices among those in the lowest skill quantile.

Motivated by this logic, we perform robustness exercises for our estimates of over-optimism by changing the estimation sample used to produce those statistics. Table 18 compares the realized graduation rates of those who enroll in each skill quantile with the average expected probabilities of those who never enroll (Panel A) and all high school graduates (Panel B), using data from the NSLY97. In each of these panels, the implied extent of over-optimism could be seen as a lower bound for the over-optimism of the population as a whole. For Panel A, this is because those who enroll tend to have higher expected probabilities of earning a BA, relative to those who do not enroll (Table 1). For both Panel A and Panel B, it is also the case that the graduation rate conditional on enrollment would likely have been lower for those who do not enroll, but we impute these rates using rates for those who enroll. Comparing Table 18 with Table 1, it is evident that in the NSLY97 over-optimism is present and sizable for the lowest levels of skill regardless of which sample we focus on. To examine the consequences of the change in over-optimism's magnitude, in Subsection N we use the over-optimism estimated in Panel A as an alternative target for the calibrated framework and examine how it affects the effects of federal loan limit expansion. Although both panels of Table 18 are candidates for the over-optimism lower bound, we choose Panel A rather than Panel B for the calibration targest of this robustness exercise because Panel A shows less over-optimism than Panel B does.

Note that, in Table 18, the data indicates that among non-enrollees with high skill there is actually slight pessimism about the probability of earning a BA, relative to completion rates among those who enroll in the top quantile (Panel A), although on average in the population of high school graduates over-optimism is prevalent (Panel B). This finding speaks to a target population for previous information interventions in studies by Hoxby and Avery (2013), Hoxby and Turner (2015), and Dynarski, Libassi, Michelmore, and Owen (2021). In those studies, high-skill students who face challenges (like isolated location or low family income) are provided with information about the costs and benefits of college, thereby improving their enrollment rates or the quality of the institution they enroll in. Panel A of Table 18 indicates that, in our NSLY97 sample, for this narrow group of high-skill students (who are possibly geographically isolated, or possibly from low-income families), we find evidence for potential benefits of a highly targeted information intervention like those implemented in previous studies.[57] In this paper, however, we are concerned more with aggregate consequences of biases in beliefs—biases which tend to exhibit over-optimism, rather than pessimism, not only on average but especially among those with low skill.

Table 19 contains summary statistics of the NLSY97 samples used in the tables of the main manuscript and in this appendix.

[57] Accounting for geographic location and resulting differences in access to information or credit is outside the scope of this paper.

Table 18: Over-optimism about BA attainment: robustness for selection into enrollment

Panel A: Beliefs of non-enrollees	**Skill**	**Enr. obs**	**Beliefs obs**	**Earned BA by 30 (enr)**	**Exp. prob. BA by 30**	**Extent of over-optimism**
	1	222	585	31.98	64.72	32.74
	2	395	417	55.95	69.31	13.36
	3	587	161	78.19	72.17	-6.02
	Obs	1,204	1,163			
Panel B: Beliefs of all high school graduates	**Skill**	**Enr. obs**	**Beliefs obs**	**Earned BA by 30 (enr)**	**Exp. prob. BA by 30**	**Extent of over-optimism**
	1	222	807	31.98	69.41	37.43
	2	395	812	55.95	78.12	22.17
	3	587	748	78.19	88.95	10.76
	Obs	1,204	2,367			

Notes: Table 18 reports over-optimism among high school graduates who do not enroll in a 4-year BA program (Panel A) and all high school graduates regardless of college enrollment status (Panel B). Source: NLSY97.

Table 19: Overconfidence about BA attainment sample summary statistics

Sample:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Sample description/ Variables	**Cleaned sample**	**(1) + student beliefs**	**(2) + family attr.**	**(2) + BA enr by 30**	**(4) + parent beliefs**	**Learning sample**
HS GPA	2.90	2.89	2.90	3.13	3.12	3.22
Age 1997	14.40	15.25	15.22	15.21	15.75	15.83
Pr. BA by 30 (parent)	76.67	76.69	76.18	88.03	88.03	90.16
Pr. BA by 30 (student)	78.57	78.57	79.20	89.37	89.06	92.07
Enr BA by 25	49.22	47.78	49.09	93.94	93.50	100.00
Enr BA by 30	52.32	50.87	52.42	100.00	100.00	100.00
BA by 30	33.25	31.73	32.67	62.38	62.00	69.62
Obs	4,673	2,367	1,656	1,204	892	316

Notes: Table 19 reports summary statistics for cleaned sample, cleaned sample additionally imposing observed student beliefs, cleaned sample additionally imposing observed student beliefs and family attributes, cleaned sample 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 BA program by 2001 used to compute the findings in Panel B of Table 1 of the main text. Data is at the individual level. Source: NLSY97.

A.2 Over-enrollment

To estimate the share of college students that are over-enrolled in the data, we use the predicted college enrollment as a function of beliefs from model (1) of Table 2 in the main text. First, we use the coefficients of that estimation result to estimate the enrollment rate using reported beliefs; next, we evaluate at the realized graduation likelihoods for those enrolled in a 4-year BA before age 30 as shown in Panel A of Table 1 in the main text. The difference between the enrollment rate predicted using reported sample member beliefs and the enrollment rate predicted using realized graduation likelihoods is the over-enrollment estimated in the data, and the percentage of college students who are over-enrolled for each skill quantile in the NLSY97 is reported in Table 20. Empirical moments from Table 20 are compared with their model counterparts in columns (5) and

(6) of Table 9 in the main text.

Table 20: Over-enrollment as a percentage of enrollees by skill quantile

Skill	Percentage over-enrolled
1	69.40
2	28.45
3	10.09
Obs	1,204

Notes: Table 20 reports the percentage of college enrollees who would not have enrolled with correct beliefs, by skill quantile. Sample is those who enroll in a 4-year bachelor's degree program by age 30. Source: NLSY97.

A.3 Inter vivos transfers

In order to estimate average inter vivos transfers from parents to their college-aged children 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 post-secondary education, which broadens the sample relative to the earnings estimation in any given year. Next, we restrict attention to observations where sample members were independents between the ages of 18 and 23 during the years from 1997 to 2003 .[58] 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, and in the same year, to account for 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 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 transfers received to per capita income for each individual while they are young adults of college age. We then average this ratio across invididuals and years to find the ratio reported in the first row of Table 21. 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 21 reports additional summary statistics for the inter vivos transfer estimation sample.

[58]For independence criteria see National Longitudinal Surveys, https://www.nlsinfo.org/content/cohorts/nlsy97/topical-guide/Income. The NLS criteria for dependency status are not the same as those used in the FAFSA (FSA, 2022b).

Table 21: 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 21 reports average transfers (Panel A) and other summary statistics (Panel B) for the sample used to estimate inter vivos transfers. Sample: independents between 18 and 23 observed during 1997-2003. Units for transfer amounts: 2000 $'s. Data are at the individual-year level. Source: NLSY97.

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, $\epsilon_{j,e,s}$, and a stochastic component, η_j. The deterministic component depends on the consumer's age, j, their education, e, and their skill endowment (high school GPA), s:

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

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

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

To estimate the earnings process for each education category e, we implement a modification of the approach described in Abbott, Gallipoli, Meghir, and Violante (2019).[59] 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, $e = \ell$ (HS or some college) or $e = h$ (BA or

[59] That paper includes gender as a type, while we do not have that kind of heterogeneity. This necessitated re-estimating the earnings profiles so that they are compatible with our model specification.

higher). This identifies $\beta^A_{e,1}$, $\beta^A_{e,2}$, and $\beta^A_{e,3}$ for each education group e. We use the PSID rather than the NLSY97 to estimate the age polynomial because it allows us to see a more complete life cycle of earnings than is visible in the NLSY97 due to the latter survey's shorter panel dimension. 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 s for a given education e, $\beta^s_{e,s}$. Finally, using the residuals from the NLSY97 regression, we jointly estimate $\rho_{\eta,e}$ and $\sigma_{\nu,e}$ 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 (Survey Research Center, Institute for Social Research, 2021). 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 the labor component of business income when necessary) by total hours worked for the individual.[60] We correct all income and wage variables for inflation using the CPI and thereafter use real dollar values in our analysis. We then 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 eight 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 education; those with a college education are individuals with 16 years or more of education. These definitions mean that those with only an associate's degree, and those who drop out of a 4–year bachelor's program, would both be assigned to the high school graduates group in our estimation procedure. 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

[60]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.

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

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

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

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

where u is the i.i.d. residual. The coefficients of interest for estimating the age profile of education category e are $\beta_{e,1}$, $\beta_{e,2}$, and $\beta_{e,3}$. Because the average rejected wage offer is likely lower than the average accepted wage offer, the expected sign of the inverse Mills ratio coefficient in the second stage, $\gamma_{e,IM}$, is positive. In our estimation, this coefficient has the expected sign for both education groups. Table 22 presents the second-stage regression results. The sample summary statistics for the first- and second-stage regressions are presented in Table 23. 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, $\mathbb{I}_{\text{SC}}$, with the age polynomial. Results for this estimation are presented in Table 24. The coefficients on the interaction terms are statistically insignificant.

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" of Table 26 in Subsection C.4, with no age restrictions or post-secondary non-enrollment requirements. For this sample, 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

Table 22: Wages as a function of age

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

Notes: Table 22 reports regression results. The effect of age on earnings by education level $e = \ell$ (HS or some college) and $e = h$ (BA or higher). Not shown in table but included in regression: state and year FE, married indicator, inverse Mills ratio, constant. Source: PSID.

Table 23: Age profile of earnings: summary statistics

Panel	Sample	Variable	High school + some college	BA or higher
A	First stage: 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	Second stage: 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 23 reports summary statistics by education category for the first-stage regression (Panel A) and second-stage regression (Panel B). Data are at the individual-year level. Source: PSID.

above 4 percent or below -2 percent. For the "Regression sample" in Table 36, we drop those with either some high school or with a GED, and those currently enrolled in a BA program. 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 degree 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.

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 that include indicators for the year, a set of

Table 24: Log wages as a function of age: robustness on pooling assumption

Controls	$\log(wage)$
$\mathbb{I}_{SC}\times$ 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 24 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.

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

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

where u is the i.i.d. residual. Table 25 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 26 contains summary statistics for the cleaned sample, the regression sample, and regression samples for two subgroups: those with high school or some college and those with a BA degree or more.

B.3 Estimating the stochastic component of earnings

After estimating the skill loadings in the NLSY97, we use the residuals of that regression 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

Table 25: Age-free wages as a function of skill

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

Notes: Table 25 reports regression results. Model (1) is for high school or some college ($e = \ell$); model (2) is for BA degree or higher ($e = h$). Here, the baseline skill quantile is the top quantile ($s = 3$). Not shown in table but included as controls are: year FE, number of children (top-coded at 4) indicators, married indicator. Source: NLSY97.

Table 26: Earnings process estimation sample summary statistics at individual-year level

Variable	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 26 reports summary statistics highlighting the effects of restrictions on sample composition for the 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 across different years, but not within a given year). Source: NLSY97.

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 $\nu_{e,j}$ has a similar variance across the two education groups, although it is slightly lower for the $e = h$ group. Specific point estimates are reported in Table 27.

B.4 Summary of results

Table 27 presents the results of the age profile from the PSID, the loadings on skill from the NLSY97, and the results from the residual process estimation.

Table 27: Earnings process estimation results

Parameter	Description	Value
Life cycle productivity: high school or some college ($\epsilon_{j,e=\ell,s}$)		
$\rho_{\eta\|\ell}$	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
$\beta^s_{\ell,1}$	Skill endowment shifter	-0.0426
$\beta^s_{\ell,2}$		-0.0362
Life cycle productivity: college graduate ($\epsilon_{j,e=h,s}$)		
$\rho_{\eta\|h}$	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
$\beta^s_{h,1}$	Skill endowment shifter	-0.180
$\beta^s_{h,2}$		-0.132

Notes: Table 27 summarizes the results from the earnings process estimation. Sources: PSID and NLSY97.

B.5 College wage premium

Table 28 reports the median wage within each skill quantile for two education categories: those with at least a high school education, but less than a bachelor's degree, and those with a bachelor's degree or more. In the last column of the table is the college wage premium within each skill quantile, which is the ratio of the two medians. The sample used in Table 28 is at the individual-year level and is the same as what is used at in the earnings estimation procedure described above. The sample only includes observations for years in which individual's are not enrolled in an education program.

The wage premia reported in Table 28 are compared with their untargeted model counterparts in Table 39 of Subsection K of this appendix.

Table 28: BA wage premium: ratio of median wages

	High school		Bachelor's degree		
Skill	Wage	Obs	Wage	Obs	Wage premium
1	10.64	6,902	14.18	880	1.33
2	11.06	5,382	15.56	2,369	1.41
3	11.23	2,677	17.58	5,296	1.57

Notes: Table 28 tabulates the median wage within each high school GPA quantile for those with a high school degree but less than a bachelor's degree ("High school") and those with a bachelor's degree or higher ("Bachelor's degree"), for those not currently enrolled in post-secondary education. The last column is the ratio of the wages in the two educational attainment categories. 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 (U.S. Department of Education, 2020a). The survey collection occured 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. We use the public version of the HSLS:09, where this information is reported up to and including the 2015-2016 academic year (Duprey et al., 2020).

Table 29 presents an outline of the structure of the HSLS:09.[61] 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" during the 2013 Update collection 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 the spring of 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 four-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 in the spring of their third year of college. Additionally, post-secondary education transcripts and student records are collected until up to summer of 2016, after potentially three full years of academic enrollment in post-secondary education.

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 slightly after the second follow-up. Our estimation methodology uses variables based on student record information, when available, over student recollection in the student questionnaire. Even if sample members enroll but do not persist in college, we are able to see information on student debt, grant receipt amounts, and other characteristics for those individuals.

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

[61] Questionnaires are available here: National Center for Education Statistics, https://nces.ed.gov/surveys/hsls09/questionnaires.asp.

Table 29: Structure of the Public-Use HSLS:09

Wave	**Base Year**	**1^{st} Follow-up**	**2013 Update**	**HS Transcripts**	**2^{nd} Follow-up**	**PS Transcripts + SR**
Calendar Year(s)	**2009 (Fall)**	**2012 (Spring)**	**2013 (Summer)**	**2013-2014**	**2016**	**2015-2016**
Academic Year (if enrolled)	**1st year HS (Fall)**	**3rd year HS (Spring)**	**Graduated HS**	**Graduated HS**	**3rd year PS (Spring)**	**Summer after 3rd year PS**
Questionnaire						
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 29 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 submitted to that row's type of recipient at that column's point in time. Calendar years and academic years are distinguished in the table's column headings 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 Transcripts collections when this information 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.

attainment and their parents' expectations 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 NLSY97. 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 HSLS:09 data moments are weighted using survey weights. 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 what would be the spring of the sample member's junior year of high school if they have not left school, the HSLS:09 asks interviewees about their expected educational attainment. Subsequently, we are able to verify whether the sample members enroll in a four-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. This is especially true for 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 probabilistically, unlike the phrasing of a similar question in the NSLY97. 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 posed 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 of the student’s parent about their child’s prospects. The possible answers to this question are reported in Table 30. 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 four-year program, an indicator is created that is set to 0 for valid responses and replaced with a 1 if the response x is such that $8 \leq x < 13$. An indicator for those who expect to earn at least a master’s degree is constructed the same way, but with the lower bound starting at 10.

Table 30: 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 31 shows educational attainment expectations and outcomes for several samples of students who enrolled in a four-year bachelor’s degree program. This table presents, by high school GPA quantile, the percentage of each skill bin that expected to complete college and the percentage of the bin that persisted in college to complete their third academic year. Note that, since in the public HSLS:09 we observe the student up to three full 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 such as “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 particular, Panel A of Table 31 demonstrates that the sample of students who enroll in a four-year program in 2013 tend to overestimate their educational attainment, given their skill. This is especially the case for those in the lowest skill quantile.

One concern with the findings reported in Panel A of Table 31 is that perhaps restricting to only those who enroll in a four-year program right after college (in the fall of 2013) leads to a distorted sample of students. Hypothetically, these students could be the most overly optimistic of high school graduates, whereas those who take a gap year (or several years) could be more realistic. In Panel B of Table 31, we present the results of a robustness exercise where we broaden the sample to include those who enroll in a four-year program at any point between the 2013-2014 academic year and the 2015-2016 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 2015-2016 academic year automatically counts as a student who persists. This is a much more relaxed criterion for persistence to compare with expected educational attainment than the one used in Panel A. In Panel B, both the persistence rate and the percentage that expected to earn a BA decrease, but students still tend to overestimate their probability of persisting given their level of skill.

Another concern is that when students answer that they expect to earn a bachelor's degree program (or a higher degree program) they are simply responding in this way because admitting they will probably stop after high school is embarrassing and generates a stigma cost. This in turn may generate what often referred to as a "social desirability bias" in the survey responses provided by these individuals. Such respondents would be 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 to earn 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 percentage who persist in each quantile still remains well below the expected graduation rate from college.

Finally, what do parents expect their child's educational attainment to be? In Panel D of Table 31, we tabulate the parent responses to what they expect their child's educational attainment will be, with the response choice set shown in Table 30.[62] Panel D shows that, for the sample of students who enrolled in a BA program in the fall of 2013, parents of this group tend to overestimate the likelihood of college graduation for their children. 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, for both 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 not possible to construct in the HSLS:09. One would need to observe the survey respondent until the end of their life in order to truly check whether expectations, as solicited by the HSLS:09

[62]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 percent of families in the sample.

questionnaire, were accurate or not.

Table 31: Educational attainment outcomes versus expectations

Panel	Sample	Skill	Sample obs	Group obs	% Persisted BA	% Expect BA	Over-optimism
A	Fall 2013 enrollees	1	2,356	155	48	76	29
		2		659	71	80	9
		3		1,542	83	93	10
B	Ever enrolled	1	3,531	404	21	62	41
		2		1,080	51	76	25
		3		2,047	74	91	16
C	Expect MA+	1	1,356	57	44	100	56
		2		310	70	100	30
		3		989	83	100	17
D	Parent expectations	1	1,021	62	38	76	38
		2		277	71	92	21
		3		682	81	94	13

Notes: Table 31 compares realized and expected bachelor's degree attainment. Samples vary across panels. Weights are PETS-SR student records longitudinal weights. Source: HSLS:09.

C.2 Grant aid

Table 32 reports statistics on grant aid receipt in dollar amounts and uptake rates across persistence statuses. Grants are cumulative as of the summer of 2016 (three academic years after enrollment). Overall, 20 percent dollars allocated in grants go to non-persisters, a sizable amount (Panel A). Like student loan balances, the average grant aid received is slightly lower among non-persisters who received any grants because they received the aid for fewer years than students who persisted in college. Relative to persisters, non-persisters tend to receive less in merit and 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 slightly more likely to receive merit-based grants, and slightly less likely to receive need-based grants, relative to persisters.

Table 32: Grant aid by persistence status

Panel A: dollar amounts	**Persistence status**	**Group obs**	**Total**	**Need**	**Merit**	**Share of $**
	Did not persist	501	7,790	3,373	4,417	0.20
	Persisted	1,855	9,889	4,463	5,427	0.80
Panel B: uptake rates	**Persistence status**	**Group obs**	**Either**	**Need**	**Merit**	**Both**
	Did not persist	501	0.78	0.18	0.32	0.29
	Persisted	1,855	0.75	0.21	0.28	0.27

Notes: Table 32 reports grant aid by persistence status 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 by persistence status, on average. Sample: students who enrolled in a four-year program in the fall of 2013. Weights are PETS-SR student records longitudinal weights. Source: HSLS:09.

C.3 Calibration targets and model primitives

Table 33 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. The table includes three categories of moments, indexed with roman numerals: 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 quantile of college students in the HSLS:09 (here, college students means those who enroll in the fall of 2013, immediately after high school graduation). 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 (we relax this assumption in the robustness exercises of Subsection N and find that the results are unchanged). 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 reported in Table 7 of the main text, along with findings from Krueger and Ludwig (2016). Finally, Category III in Table 33, persistence rates, is used to discipline the true probability of persistence for those enrolled in college. From left to right, these persistence rates are for those enrolled in their first year (the percentage completing their third academic year) and those enrolled in their second year (again, the percentage completing their third academic year).

Table 33: Statistics by skill quantile

	Category:	**(I) Child skill by parental education**		**(II) Tuition and grant aid**		**(III) Persistence rates**	
	Sample:	**High school graduates**		**Enrolled fall 2013 (Y1)**		**Enr Y1**	**Enr Y2**
fa	**Statistic:**	$\pi(s\|e=\ell)$	$\pi(s\|e=h)$	**Tuition + Fees**	**Agg Merit + Need Grants / Agg Tuition + Fees**	**% Enr. Y3**	**% Enr. Y3**
	1	42.64	17.63	17,139	0.407	47.57	77.40
Skill	2	34.08	31.12	17,694	0.462	71.08	86.26
	3	23.28	51.24	19,959	0.520	82.90	91.26

Notes: Table 33 shows statistics by skill quantile for three categories of variables. Category I reports the conditional distribution over high school GPA quantile, given parental education (where $s = h$ denotes at least one parent with BA or more); Category II reports tuition and fees in dollar amounts and total grants as a fraction of tuition and fees; Category III reports conditional persistence probabilities. Samples vary across categories and are explained in the table. Weights are Second Follow-up longitudinal weights for Category I and PETS-SR longitudinal weights for Categories II and III. Source: HSLS:09.

Table 34 reports moments describing average labor supply among enrollees (Panel A) and reasons for not enrolling in post-secondary education (Panel B). Panel A reports the fraction of the time endowment spent working, on average, among fall 2013 enrollees who are enrolled during their third year of college. In Panel B, 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 survey question, unlike in the main text and this appendix generally, "college" refers to *any* post-secondary education). Respondents are only asked this question if they say that they never enrolled in post-secondary education, so those who never enroll in a four-year degree program are frequently not asked this question because they may have enrolled in another type of post-secondary program instead. 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 such as academics, family, or other reasons that do not include financial or work factors led to them not enrolling in college.

Table 34: Labor supply and dependency status, and reasons for never enrolling

Panel	**Category**	**Variable**	**Mean value**	**Panel sample obs**
A	Labor supply junior year	$\frac{\text{Average weekly hours worked}}{40}$	0.347	1,855
B	Reason never enrolled in post-secondary ed. (answered "yes" for a given reason)	Academic, personal/family, other	0.244	5,393
		Financial	0.193	
		Work, military, career	0.150	

Notes: Table 34 reports labor supply and reasons for never enrolling in a post-secondary program. Samples: Panel A: students who enrolled in a 4-year program in the fall of 2013 and persisted through their third academic year; Panel B: sample members who graduated from high school in 2013 and either did not enroll or enrolled in a 4-year degree in the fall of 2013; enrollees are counted as answering 'No' for each possible reason. Weights are PETS-SR longitudinal weights in Panels A and B and 2013 Update longitudinal weights for Panel C. Source: HSLS:09.

Finally, in Table 35, 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 Ordinary Least Squares (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) and from year 2 to year 3 (model 2). The results indicate that high school GPA plays a statistically significant role in predicting persistence early in one's college career, reinforcing our model specification linking the probability of dropping out of college to student skill and year of enrollment.

C.4 Summary statistics

Table 36 reports summary statistics for the samples used to compute the HSLS:09 findings reported in the main text and in this appendix.

Table 35: Predicting enrollment persistence

	Persistence	
Controls	**Y2	Y1**	**Y3	Y2**
High school GPA	0.09823	0.06340
	(0.02540)	(0.02173)
Log(HH income)	-0.00854	-0.00089
	(0.02110)	(0.01595)
Log(SL debt)	0.01660	0.05432
	(0.05156)	(0.03679)
Hours worked	-0.00390	-0.00388
	(0.00290)	(0.00172)
Log(tuition and fees Y1)	0.01877	-0.00339
	(0.02212)	(0.02170)
Flag: no SL debt	0.17742	0.52024
	(0.44641)	(0.33658)
Flag: no work hours	-0.06370	-0.07192
	(0.05271)	(0.03355)
Flag: parents BA+	0.05046	0.04093
	(0.02895)	(0.02758)
Flag: female	-0.00249	0.03212
	(0.02521)	(0.02488)
Constant	0.32938	0.21391
	(0.50824)	(0.42853)
R^2	0.068	0.040
Obs	2,356	2,097

Notes: Table 35 reports results from regressing an indicator for persisting to the next academic year on various controls measured in the current academic year using an OLS estimator. Sample: students who enrolled in a four-year program in the fall of 2013 (Y1); the second column additionally conditions on being enrolled in the 2014-2015 academic year (Y2). Bootstrap standard errors are in parentheses; weights are replicate PETS-SR student records longitudinal weights. Source: HSLS:09.

Table 36: Financial aid and robustness exercises sample summary statistics

Sample: Description/ Variables	**(1) High school graduates**	**(2) (1) + enr. 2013 (Y1)**	**(3) (2) + completed Y3**	**(4) (2) + parents' exp.**
Family income	77,481	105,897	111,230	111,642
High school GPA	2.93	3.50	3.59	3.53
Flag: Parent BA+	0.366	0.596	0.636	0.637
Flag: Student exp. BA	0.664	0.874	0.885	0.880
Flag: Persisted Y3*	0.132	0.763	1.000	0.752
Flag: Parent exp. BA	0.680	0.924	0.932	0.924
Flag: Any SL Y3*)		0.683	0.653	0.664
SL $ if SL>0*		22,116	24,648	22,329
T+F $ if BA*		18,997	19,323	19,656
Obs	11,444	2,356	1,855	1,021

Notes: Table 36 shows summary statistics for estimation samples in the HSLS:09. Continuous variables report means (dollar values are current U.S. dollars); flag variables report fraction of total where the flag takes a value of 1. Variables with * are drawn from the post-secondary transcript and student records information collection. Weights are Second Follow-Up weights for the HS Grads sample and PETS-SR longitudinal weights for the other samples. Source: HSLS:09.

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 (Board of Governors of the Federal Reserve System, 2019). Table 37 contains SCF codebook variable codes corresponding to variables discussed in the text.

Table 37: Mapping from variables to 2019 Survey of Consumer Finances codebook codes

Category	Variable	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 37 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: Board of Governors of the Federal Reserve System, "Codebook for the 2019 Survey of Consumer Finances,", September 2020, https://www.federalreserve.gov/econres/files/codebk2019.txt.

Part II

Model Appendix

E Private loan payment functions

The full payment function for private student loans is given by

$$\rho_R^{pr}(j,x) = \begin{cases} \dfrac{r_{SL}^{pr}}{1-(1+r_{SL}^{pr})^{-(T_{SL}+5-j)}}x & \text{if } x>0 \text{ and } 4<j\leq T_{SL}+4 \\ (1+r_{SL}^{pr})x & \text{if } x>0 \text{ and } j>T_{SL}+4 \\ 0 & \text{otherwise } (x=0) \end{cases} \tag{16}$$

Similar to the repayment function for federal student loans given in equation (2) of the main text, the payment amount for private student debt is determined by the age of the borrower and the stock of private debt. In particular, $\rho_R^{pr}(j,x)$ depends on whether the student has a positive private student loan balance and whether they are still within the repayment period.

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

$$\rho_D^{pr}(j,x,y) = \min[\tau_g \max[y - T(y) - \bar{y}, 0], \rho_R^{pr}(j,x)] \tag{17}$$

F Value functions

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

$$\begin{aligned}
&\hat{V}(j,h,s,\eta,a,x) = \max_{\hat{c}\geq 0,\hat{a}',\hat{x}'} U(c,j,h) - \xi_L \mathbb{I}_{a\geq 0 \text{ and } x=0 \text{ and } (\hat{a}'<0 \text{ or } \hat{x}'>0)} - \xi_L^{pr} \mathbb{I}_{x=0 \text{ and } \hat{x}'>0} \qquad (18)\\
&+ \beta\psi_j \Big[\hat{p}(s) E_{\eta'|h,\eta} V(j+1,h,s,\eta',\hat{a}',\hat{x}') + (1-\hat{p}(s)) E_{\eta'|\ell,\eta} V(j+1,\ell,s,\eta',\hat{a}',\hat{x}')\Big]\\
&s.t.\\
&(1+\tau_c)\hat{c} + \hat{a}' + (1-\theta(s)-\theta^{pr}(s))\kappa = y_{j,h,s,\eta,a} + a + Tr_j - T(y_{j,h,s,\eta,a}) + (\hat{x}' - x)\\
&\hat{a}' \geq -\frac{\bar{A}[(1-\theta(s)-\theta^{pr}(s))\kappa + \bar{c}]j}{4}\\
&\hat{a}' \leq a \ \text{ if } \ a \leq 0\\
&\hat{x}' - x \in \Big[0, [(1-\theta(s)-\theta^{pr}(s))\kappa + \bar{c}] - [\max(-\hat{a}',0) - \max(-a,0)]\Big]
\end{aligned}$$

The idiosyncratic state of a consumer while $j > 4$ and $j \neq j_f + j_a$ is given by the tuple (j,e,s,η,a,x). Their value function is given by

$$\begin{aligned}
&V(j,e,s,\eta,a,x) = \max_{d_f\in\{0,1\},d_x\in\{0,1\}} (1-d_f)(1-d_x)V^R(j,e,s,\eta,a,x) + \qquad (19)\\
&d_f(1-d_x)V^{D_f}(j,e,s,\eta,a,x) + (1-d_f)d_x V^{D_x}(j,e,s,\eta,a,x) + d_f d_x V^D(j,e,s,\eta,a,x)
\end{aligned}$$

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

$$
\begin{aligned}
&V^R(j,e,s,\eta,a,x) = \max_{c \geq 0, a'} U(c,j,e) + \beta\psi_j E_{\eta'|e,\eta} V(j+1,e,s,\eta',a',x') \qquad (20)\\
&s.t.\\
&(1+\tau_c)c + a' = y_{j,e,s,\eta,a} + a + \mathbb{I}_{\{a<0\}} r_{SL} a + Tr_j - T(y_{j,e,s,\eta,a}) - \rho_R^{pr}(j,x)\\
&a' \begin{cases} = (1+r_{SL})a + \rho_R(j,a) & \text{if } \ a < 0\\ \geq 0 & \text{if } \ a \geq 0 \ \text{ and } \ x = 0\\ = 0 & \text{otherwise } (a \geq 0 \ \text{ and } \ x > 0)\end{cases}\\
&x' = x(1+r_{SL}^{pr}) - \rho_R^{pr}(j,x)
\end{aligned}
$$

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 $\rho_R^{pr}(j,x)$. 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

$$
\begin{aligned}
&V^{D_f}(j,e,s,\eta,a,x) = U(c,j,e) - \xi_D + \beta\psi_j E_{\eta'|e,\eta} V(j+1,e,s,\eta',a',x') \qquad (21)\\
&s.t.\\
&(1+\tau_c)c = y_{j,e,s,\eta,a} + Tr_j - T(y_{j,e,s,\eta,a}) - \rho_D(j,a,y_{j,e,s,\eta,a}) - \rho_R^{pr}(j,x)\\
&a' = (1+r_{SL})a + \rho_D(j,a,y_{j,e,s,\eta,a}) - \phi_D[\rho_R(j,a) - \rho_D(j,a,y_{j,e,s,\eta,a})]\\
&x' = x(1+r_{SL}^{pr}) - \rho_R^{pr}(j,,x)
\end{aligned}
$$

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 $\rho_D(j,a,y_{j,e,s,\eta,a})$. 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

$$V^{D_x}(j,e,s,\eta,a,x) = U(c,j,e) - \xi_D^{pr} + \beta\psi_j E_{\eta'|e,\eta} V(j+1,e,s,\eta',a',x') \tag{22}$$
$$s.t.$$
$$(1+\tau_c)c + a' = y_{j,e,s,\eta,a} + a + \mathbb{I}_{\{a<0\}} r_{SL} a + Tr_j - T(y_{j,e,s,\eta,a}) - \rho_D^{pr}(j,x,y_{j,e,s,\eta,a})$$
$$a' = \mathbb{I}_{a<0}(1+r_{SL})a + \rho_R(j,a)$$
$$x' = (1+r_{SL}^{pr})x - \rho_D^{pr}(j,x,y_{j,e,s,\eta,a}) + \phi_D[\rho_R^{pr}(j,x) - \rho_D^{pr}(j,x,y_{j,e,s,\eta,a})]$$

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 because of delinquency on private loans. The garnishment amount is denoted by $\rho_D^{pr}(j,x,y_{j,e,s,\eta,a})$, 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

$$V^{D}(j,e,s,\eta,a,x) = U(c,j,e) - \xi_D - \xi_D^{pr} + \beta\psi_j E_{\eta'|e,\eta} V(j+1,e,s,\eta',a',x') \tag{23}$$
$$s.t.$$
$$(1+\tau_c)c = y_{j,e,s,\eta,a} + Tr_j - T(y_{j,e,s,\eta,a}) - \rho_D(j,a,y_{j,e,s,\eta,a}) - \rho_D^{pr}(j,x,y_{j,e,s,\eta,a})$$
$$a' = (1+r_{SL})a + \rho_D(j,a,y_{j,e,s,\eta,a}) - \phi_D[\rho_R(j,a) - \rho_D(j,a,y_{j,e,s,\eta,a})]$$
$$x' = (1+r_{SL}^{pr})x - \rho_D^{pr}(j,x,y_{j,e,s,\eta,a}) + \phi_D[\rho_R^{pr}(j,x) - \rho_D^{pr}(j,e,x,y_{j,e,s,\eta,a})]$$

A consumer who chooses this outcome is subject to stigma cost, wage garnishment, and a collection fee (analogous to the previous two cases) from both 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.

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 save until they have paid off their student loans. Therefore, the value functions for delinquency are largely the same as in equations (21)-(23), with the difference that the parent has a term reflecting altruistic utility toward their child, represented by the addition of $\beta_c E_{\eta'|l} \hat{W}(s_c,\eta',b=0)$ to the objective function.

G 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:

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

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 (8) and (9), 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

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

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

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

Definition Given an initial level of capital stock K_0 and an initial distribution over idiosyncratic states $\Omega_0\left(\overrightarrow{\omega}\right)$, a competitive equilibrium consists 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 $\{\hat{d}_{e,t}(\overrightarrow{\omega}),\ \hat{d}_{d,t}(\overrightarrow{\omega}), d_{d,t}(\overrightarrow{\omega})\}$, 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 $\{Y_t, K_t, L_t\}$, tax policies $\{\gamma_t\}$, prices $\{r_t, w_t, r^{pr}_{SL,t}\}$, Social Security transfers $\{ss_{t,e,s}\}$, accidental bequests $\{Tr_{t,j}\}$, and measures $\{\Omega_t\left(\overrightarrow{\omega}\right)\}$ such that:

(i) Given prices, transfers, and policies, the value functions and household policy functions solve the consumer problems in equations (6)-(11) and (18)-(23);

(ii) The saving interest rate and wage rate satisfy equations (14) and (15), 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[63]

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

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

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

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

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

[63] In our baseline calibration and in 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:

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

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

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

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.

H 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 $ss_{e,s,\text{guess}}$).

2. Use backward induction to solve the consumer's problem from $j = j_f + j_a + 1, \ldots, J$ (equations (19)-(23)).

3. Guess overly optimistic value function before college, $\hat{W}_{\text{guess}}(s, \eta, a)$ (equation (6)).

4. Use backward induction to solve for the consumer's problem from $j = 1, \ldots, j_f + j_a$ (equations (6)-(11) and (18)).

   - In solving the consumer's problem at $j = j_f + j_a$, the guess $\hat{W}_{\text{guess}}(s, \eta, a)$ 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, $(j \leq 4, e = \ell, a \geq 0, x = 0)$, 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. We take this approach 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 $(j \leq 4, e = h$ 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. We use this method because the delinquency decision could lead to discontinuities in the objective functions.

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

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

7. Given policy functions, exogenous processes, and $\Omega(j = 1, s, \eta, a)_{\text{guess}}$, 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 initial 18-year-old consumers $\Omega(j = 1, s, \eta, a)$.

9. Update $\Omega(j = 1, s, \eta, a)_{\text{guess}}$ 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 (14) and (15)).
    - 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 $ss_{t,e,s,\text{guess}}$) 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 $\hat{W}_t(s, \eta, a)$. 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 initial

18-year-old consumers $\Omega_t(j=1,s,\eta,a)$.

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.

I 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."

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., $\tilde{V}(\overrightarrow{\omega}) = V(\overrightarrow{\omega})$). They are equal because over-optimism about likelihood of college continuation only affects the college enrollment decision, the inter vivos transfer decision, and the decisions leading up to and including the age at which the inter vivos transfer decision is made ($j_f + j_a$). After that, the consumers' over-optimism about likelihood of college continuation no longer affects their decision rules, and they then 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

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

In computing $\tilde{V}(j,e,s,\eta,a,x,s_c)$, the planner takes as given the delinquency decisions $d_f(j,e,s,\eta,a,x,s_c)$ and $d_x(j,e,s,\eta,a,x,s_c)$, which solve equation (10). Note that there is no optimization problem for the planner (i.e., no $\max$ operator). The values for $\tilde{V}^R(j,e,s,\eta,a,x,s_c)$, $\tilde{V}^{D_f}(j,e,s,\eta,a,x,s_c)$,

$\tilde{V}^{D_x}(j,e,s,\eta,a,x,s_c)$, and $\tilde{V}^{D}(j,e,s,\eta,a,e,x,s_c)$ are given by

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

where $\tilde{W}(s_c,\eta',b)$ is the value before college computed by the planner (given below) and policy functions $\{c(j,e,s,\eta,a,x,s_c), a'(j,e,s,\eta,a,x,s_c), b(j,e,s,\eta,a,x,s_c)\}$, taken as given, solve equation (11) 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 $\tilde{W}(s_c,\eta',b)$, whereas the overly-optimistic consumer uses $\hat{W}(s_c,\eta',b)$.

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

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

where the planner takes as given $d_f(j,e,s,\eta,a,x)$ and $d_x(j,e,s,\eta,a,x)$, which solve equation (19). The values for $\tilde{V}^{R}(j,e,s,\eta,a,x)$, $\tilde{V}^{D_f}(j,e,s,\eta,a,x)$, $\tilde{V}^{D_x}(j,e,s,\eta,a,x)$, and $\tilde{V}^{D}(j,e,s,\eta,a,x)$ are given by

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

where policy functions $\{c(j,e,s,\eta,a,x), a'(j,e,s,\eta,a,x)\}$, taken as given, solve equations (20)-(23).

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

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

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

$$\tilde{V}(j,h,s,\eta,a,x) = U(c,j,h) - \xi_L \mathbb{I}_{a\geq 0 \text{ and } x=0 \text{ and } (a'<0 \text{ or } x'>0)} - \xi_L^{pr} \mathbb{I}_{x=0 \text{ and } x'>0} \tag{32}$$
$$+ \beta\psi_j E_{\eta'|\ell,\eta}\bigg[p_c(j,s)[(1-d_d)\tilde{V}(j+1,h,s,\eta',a',x') + d_d\tilde{V}(j+1,\ell,s,\eta',a',x')]$$
$$+ (1-p_c(j,s))\tilde{V}(j+1,\ell,s,\eta',a',x')\bigg]$$

where policy functions $\{c(j,h,s,\eta,a,x), a'(j,h,s,\eta,a,x), x'(j,h,s,\eta,a,x), d_d(j,h,s,\eta,a,x)\}$, taken as given, solve equation (9) 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

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

where policy functions $\{c(j,\ell,s,\eta,a,x), a'(j,\ell,s,\eta,a,x)\}$, taken as given, solve equation (7).

The planner's value before college is given by

$$\tilde{W}(s,\eta,a) = q\Big[(1-\hat{d}_e)\tilde{V}(1,\ell,s,\eta,a,x=0) + \hat{d}_e\tilde{V}(1,h,s,\eta,a,x=0)\Big] \tag{34}$$
$$+ (1-q)\tilde{V}(1,\ell,s,\eta,a,x=0)$$

where the planner takes as given the enrollment decision $\hat{d}_e(s,\eta,a)$, which solves equation (6). 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 $\tilde{V}(1,h,s,\eta,a,x=0)$, which uses the true probability $p_c(j,s)$ for likelihood of continuation, whereas the over-optimistic consumer uses $\hat{V}(1,h,s,\eta,a,x=0)$, which uses the over-optimistic probability $\hat{p}(s)$ for likelihood of college continuation.

To measure welfare for the 18-year-old consumer, we use the 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

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

where on 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 $\tilde{W}_t(s,\eta,a)$ but also in 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 right-hand side of equation (35).

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 from 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.

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

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

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

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

Part III

Parameterization Appendix

J Externally calibrated parameters not related to education

Table 38 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 that 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 the possibility of there being children without parents in the model, and it 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 (Bell and Miller, 2020). Specific values for ψ_j are not reported in Table 38 because there is one value for each age j.

Panel B of Table 38 reports parameters that 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 adult equivalence scale, ζ, is set to 0.3 based on estimates from the Organization for Economic Co-operation and Development (OECD) modified scale. 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).[64] The depreciation rate of capital, δ, is set to 0.076, as in Krueger and Ludwig (2016). To discipline the life cycle productivities $\epsilon_{j,e,s}$, which depend on age, j, education, e, and skill endowment, s, 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 PSID and the NLSY97; it is described in detail in Supplementary Appendix B, with results summarized in Table 27. Table 39 in Supplementary Appendix K shows that within-skill level college wage premiums in the model align well with their empirical counterparts, although those moments were not targeted directly in the calibration.

[64] 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.

Table 38: 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	Bell and Miller (2020)	-
Panel B: Preferences & technology			
σ	Risk aversion	Standard value, see Table 1, Panel D, in Chetty (2006)	2
ζ	Adult equivalence scale	OECD modified scale	0.3
α	Capital share	Kydland and Prescott (1982)	0.360
δ	Depreciation rate	Krueger and Ludwig (2016)	0.076
$\epsilon_{j,e,s}$	Earnings life cycle profile	PSID and NLSY97, Table 27	See Table 27
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 that 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.

Panel C, the last panel of Table 38, contains values for parameters related to government policy. 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).

Part IV

Results Appendix

K Baseline initial steady state: college wage premium by skill

Table 39 reports the college wage premium by skill in the data and the baseline model. Data moments are from the NLSY97, as reported in Table 28 of Appendix B.2. To compute the model moment, we compute the college wage premium as the median earnings for an individual with a four year college degree divided by the median earnings for an individual without a four year college degree for workers in the age group from 25 to 39 given their skill level. We focus on the age group from 25 to 39 to directly compare with the age group observed in the NLSY97. The model does remarkably well in explaining these untargeted college wage premiums.

Table 39: College wage premium by skill quantile

Skill	Data	Model
1	1.33	1.31
2	1.41	1.44
3	1.57	1.59

Notes: Table 39 reports the college wage premium in the data and in the baseline model, by skill endowment level. Data is as reported in Table 28 of Subsection B.2. Model moments are computed as described in the text. Source: NLSY97.

L Elimination of over-optimism: enrollment and tax analysis

In Panel A of Table 40, columns (1) and (2) report changes in over-enrollment and college enrollment rates by skill from the initial to the final steady state when over-optimism is eliminated in the baseline model. As the two columns indicate, the fall in college enrollment is larger than the fall in over-enrollment. This subsection discusses why that happens and its implication for the income tax rate. To provide economic intuition, we analyze the elimination of over-optimism in the following two cases: (a) prices, the income tax rate parameter, bequests, and Social Security transfers are fixed at their initial steady state values, but the 18-year-old distribution is allowed to change (column (3)), and (b) the 18-year-old distribution is fixed at its initial steady state level, but prices, the income tax rate parameter, bequests, and Social Security transfers are allowed to adjust to satisfy their respective equations (column (4)).

As column (3) of Panel A indicates, when the 18-year-old distribution is allowed to change, but other general equilibrium objects are held fixed at their initial steady state values, college enrollment rates fall as much as they do in the baseline. This suggests that enrollment rate changes are driven mainly by either 18-year-olds correcting their beliefs or because their distribution over initial assets or skill changes. Column (4) in Panel A shows that when the 18-year-old distribution is fixed, but other general equilibrium objects are allowed to adjust, the drop in college enrollment rates match the drop in over-enrollment in the baseline. We conclude that changes in the 18-year-old distribution contribute to the larger fall in college enrollment compared to over-enrollment.

When over-optimism is eliminated, the 18-year-old distribution changes for several reasons: parents reduce transfers as they update their beliefs, the economy becomes poorer leading to lower transfers, and children become lower skilled. We use Panel B to establish that the primary driver of the fall in college enrollment beyond the fall in over-enrollment is parents reducing their transfers with updated beliefs. Panel B reports statistics analogous to that of Panel A, but from the initial

Table 40: Elimination of over-optimism: changes from initial steady state ...

Panel A: ... to final steady state	**Over-enrollment**	**College enrollment rate**		
	(1)	**(2)**	**(3)**	**(4)**
Skill	**Baseline**	**Baseline**	**Endogenous** Ω_{18}	**Exogenous** Ω_{18}
1	-15.77	-20.25	-20.21	-15.77
2	-5.57	-23.58	-23.49	-5.57
3	0.00	0.00	0.00	0.00
Panel B: ... to first transition period	**Over-enrollment**	**College enrollment rate**		
	(1)	**(2)**	**(3)**	**(4)**
Skill	**Baseline**	**Baseline**	**Endogenous** Ω_{18}	**Exogenous** Ω_{18}
1	-15.77	-19.13	-19.22	-15.77
2	-5.57	-20.53	-20.55	-5.57
3	0.00	0.00	0.00	0.00
Panel C: ... to final steady state		**Income tax rate | Initial steady state mean income**		
		(2)	**(3)**	**(4)**
		Baseline	**Endogenous** Ω_{18}	**Exogenous** Ω_{18}
		0.57	0.00	0.20

Notes: Panels A and B report changes in enrollment statistics by skill resulting from an elimination of over-optimism from the initial steady to the final steady state and the first period of the transition, respectively. Columns (1) and (2) report changes in over-enrollment and college enrollment rates from the baseline model. Column (3), "Endogenous Ω_{18}", reports changes in the college enrollment rates when prices, the income tax rate, bequests, and Social Security transfers are fixed at their initial steady state values, but the 18-year-old distribution (over skill, productivity, and assets) is allowed to change. Column (4), "Exogenous Ω_{18}", reports changes in the college enrollment rates when the 18-year-old distribution is fixed at its initial steady state level, but prices, the income tax rate, bequests, and Social Security transfers are allowed to adjust to satisfy their respective equations. Panel C reports changes in the income tax rate given the initial steady mean income from the initial steady state to the final steady under each model variation. All units are in percentage points.

steady state to the first transition period rather than the final steady state. We see that the changes in Panel B are nearly the same as those in Panel A. Therefore, parents reducing transfers due to adjustments in beliefs must drive the lower college enrollment because the other distributional reasons would not have kicked in the first period of the transition.

In Panel C, we show that the mechanism highlighted above also matters for the increase in the income tax rate. In our baseline framework with progressive income taxation, a college education has a positive fiscal externality because college graduates pay higher marginal income taxes. In the baseline model, the fall in college enrollment leads to an increase in the income tax rate of 0.57 percentage points for an individual with the initial steady state mean income. In the baseline, as discussed above, college enrollment falls because 18-year-olds no longer over-enroll and also because parents update their beliefs and reduce transfers. The effect of the latter on the income tax rate is significant. In column (4), when we consider the case where the 18-year-old distribution is fixed, but other general equilibrium objects are allowed to adjust, we see that the income tax rate increases by 0.20 percentage points. This suggests that adjustments in the 18-year-old distribution explains the remainder of the increase in the income tax rate of 0.37 percentage points.

M Main experiments: additional welfare change statistics

Table 41 reports additional welfare change statistics for the two main experiments from Section 6: (1) elimination of over-optimism and (2) federal loan limit expansion. These statistics are computed in the period of the transition for two populations: for those 19 and over and for parents at the age at which they make the inter vivos transfer decision $(j = j_f + j_a)$. We report welfare in both general and partial equilibrium.

In the case of eliminating over-optimism, shown in column (1) of Table 41, 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 both general and partial equilibrium. General equilibrium effects amplify the gains.

Table 41: Main experiments: additional welfare change statistics

			(1) Elimination of over-optimism		(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	0.03	0.03
		Parents at $j = j_f + j_a$	0.07	0.07	0.06	0.06
B	General	Population 19 and over	-0.15	-0.15	0.06	0.06
		Parents at $j = j_f + j_a$	-0.15	-0.15	0.17	0.17

Notes: Table 41 provides welfare implications for the population 19 and over and parents at age $j_f + j_a$ in the period of the transition under the following two exercises: (1) elimination of over-optimism, and (2) federal loan limit expansion to fund four years of college net tuition plus room and board. Panels A and B report 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.

N Main experiments: sensitivity analyses

In this section, we perform several sensitivity analyses by considering alternative variations of the baseline model. In each case, the model variation is re-calibrated to target the same set of moments as the baseline calibration to the extent possible. The welfare implications under each variation for the two main experiments are shown in Figures 8 and 9, where the same panel in each figure corresponds to a given sensitivity exercise.

No learning about over-optimism The baseline model assumed that students learn their true continuation probabilities in the first year of college, which in principle is a conservative assumption about the extent of over-optimism. In this sensitivity analysis, we consider the case in which students never learn their true continuation probabilities and continue to be over-optimistic for the whole duration of college. A comparison of Subfigure 8a to Subfigure 8b and Subfigure 9a to Subfigure 9b shows that the welfare implications of the two main experiments barely change. The assumption about learning does not matter because most drop outs happen between the first and second year of college.

Higher add-on for federal student loans 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 sensitivity analysis, we consider the case in which students pay a higher add-on to the federal student loan interest rate by increasing τ_{SL} from 0.0205 to 0.0305. Subfigures 8c and 9c show that the welfare implications barely change in this case as well. These results suggest that our baseline model is not sensitive to the abstraction from unsubsidized loans and loan fees. The lack of impact from a higher add-on to the federal interest rate suggests that students are interest inelastic to small perturbations in the parameter space for the cost of borrowing implied by the baseline model.

Non-enrollees' beliefs as targets In the baseline model, we calibrated the expected continuation probabilities, $\hat{p}(s)$, to target the expected likelihood of college graduation for college enrollees, estimated from the NLSY97. In this sensitivity analysis, we consider an extremely conservative calibration where we target the expected likelihood of BA attainment of those who do not enroll in college by age 30. The beliefs estimates are reported in Panel A of Table 18 in Subsection A.1. This is an extremely conservative calibration for two reasons. First, by using beliefs about the likelihood of BA attainment, we implicitly assume that the individual's expectation about likelihood of enrollment is one, which provides a lower bound for the expected likelihood of college graduation conditional on enrollment —the key statistic we care about that is not directly observed in the data. Second, in our model framework, within a skill bin, all 18-year-olds have the same beliefs about the likelihood of college graduation. Therefore, we assume that given a skill bin, all 18-year-olds have the same beliefs as those who do not enroll in college. Subfigures 8d and 9d show the welfare implications from the two main experiments. Even with this extremely conservative calibration (although magnitudes are smaller) the elimination of over-optimism leads to welfare losses and an expansion in the federal student loan limits hurts low skill 18-year-olds.

Flat income taxation In our baseline model, income taxation is progressive. In the presence of flat income taxation (with government consumption still set as a constant fraction of output), a college education does not have a fiscal externality because high income college graduates do not pay a higher marginal tax rate. To demonstrate this, in this sensitivity analysis we analyze a variation with flat income taxation ($\tau_p = 0$). Subfigure 8e shows that the costs of eliminating over-optimism are dampened compared to the baseline. In fact, some 18-year-olds in the early periods of the transition experience significant gains while the low skill 18-year-olds experience gains in all periods. As Subfigure 9e shows, the key welfare takeaways from a federal loan limit expansion do not change.

College tuition that depends on skill In our baseline calibration, college tuition κ does not depend on skill. In reality, high skill students are more likely to attend higher quality colleges that cost more.[65] In this sensitivity analysis, we consider the case where college tuition κ depends on skill. We use average tuition estimates by skill reported in Table 33 as target moments. Subfigures 8f and 9f show that the key welfare insights from the two main experiments do not change.

Lower private loan uptake cost In the baseline model, we calibrated the private loan uptake cost, ξ_L^{pr}, to target the total loan uptake of private students loans. This cost generates a pecking order in the model consistent with the data, where students borrow from the federal student loan program before turning to private lenders. The first two rows of Table 42 compare the student loan portfolio composition between data and the baseline model. While the baseline model does remarkably well in explaining the student portfolio composition observed in the data, one could argue that in the data, the uptake of "Only private" loans is 2 percent, whereas that statistic in the baseline model is 0. In this sensitivity analysis, we calibrate the private loan uptake cost to target the "Only private" loan uptake of 2 percent instead of the "Any private" loan uptake of 22 percent. In this calibration, ξ_L^{pr} is equal to 0.570, as opposed to 2.713 in the baseline calibration, so the cost is almost 80 percent lower.[66] As Subfigure 8g shows, although the magnitudes are different, the elimination of over-optimism leads to welfare losses in the long run. Subfigure 9g shows that a federal student loan limit expansion leads to gains for the high skill and losses for the low skill, although the magnitudes are smaller. This is because, with a lower ξ_L^{pr}, the substitutability between federal and private students loans is higher. Although this calibration accounts for uptake of "Only

[65] The higher benefits of college for higher skill students is captured through the higher college wage premium in our model.

[66] A lower cost for ξ_L^{pr} generates a positive "Any private" loan uptake for the following reason. In our baseline model framework, the only benefit of private student loans over federal student loans is that college enrollees can save when they borrow from private lenders, but cannot save when they borrow from the federal student loan program. This captures a mechanism similar to the Expected Family Contribution (EFC), where students from richer families face lower federal student loan limits due to higher EFCs, and so turn to private lenders for borrowing.

private" loans, as Table 42 shows, it significantly understates the uptake of "Only federal" student loans and overstates the uptake of "Any private" student loans. Therefore, the baseline calibration is our preferred calibration.

Table 42: Student loan portfolio composition in data and model

Case	**Either**	**Only federal**	**Only private**	**Both**	**Any private**
Data	65	44	2	20	22
Model: baseline	56	34	0	22	22
Model: lower private loan uptake cost	58	10	2	46	48

Notes: Table 42 reports the share of students who owe money for either, only federal, only private, both types, or any private student loans three years after enrollment in the data, the baseline model, and a variation of the model that is re-calibrated with a lower private loan uptake cost. Numbers in italics in the model rows are calibration targets to discipline the loan uptake costs. Percentages are rounded to the nearest percentage point, so the sum of the last three columns may not exactly equal the value in the first column. Weights are PETS-SR student records longitudinal weights. Source: HSLS:09.

College enrollment option shock that depends on skill In our baseline calibration, the college enrollment option shock, q, does not depend on skill and was calibrated so that the model matches the enrollment rate for those in the highest skill quantile. In this sensitivity analysis, we consider the case where the q shock depends on skill. We calibrate the shock by targeting enrollment rates for high school graduates in the highest family income quantile for each skill bin instead of the overall enrollment rate for the highest skill quantile. The empirical estimates for enrollment rates by skill quantile in the highest family income quantile are given in Table 15. As shown in Subfigures 8h and 9h, the key welfare insights from the two main experiments do not change.

Skill does not depend on parental education In our baseline calibration, the child's skill depends on parental education. Our calibrated estimates imply that high education parents are more likely to have children with higher skill (see Table 33). In this sensitivity analysis, we relax this assumption and consider the case where the child's skill does not depend on parental education. We do this by setting $\pi(s_c|e) = 1/3$ for all s_c and e. Subfigures 8i and 9i show that the key takeaways from the main two experiments do not change.

O Additional experiment: public grant expansion

Section 6.2 compared the welfare implications of an expansion in the federal student loan limit in the baseline model with over-optimism to a model without over-optimism. Recall that the latter was re-calibrated to match the same set of target moments as the baseline after dropping moments related to beliefs about the likelihood of college graduation. In this section, we consider an expan-

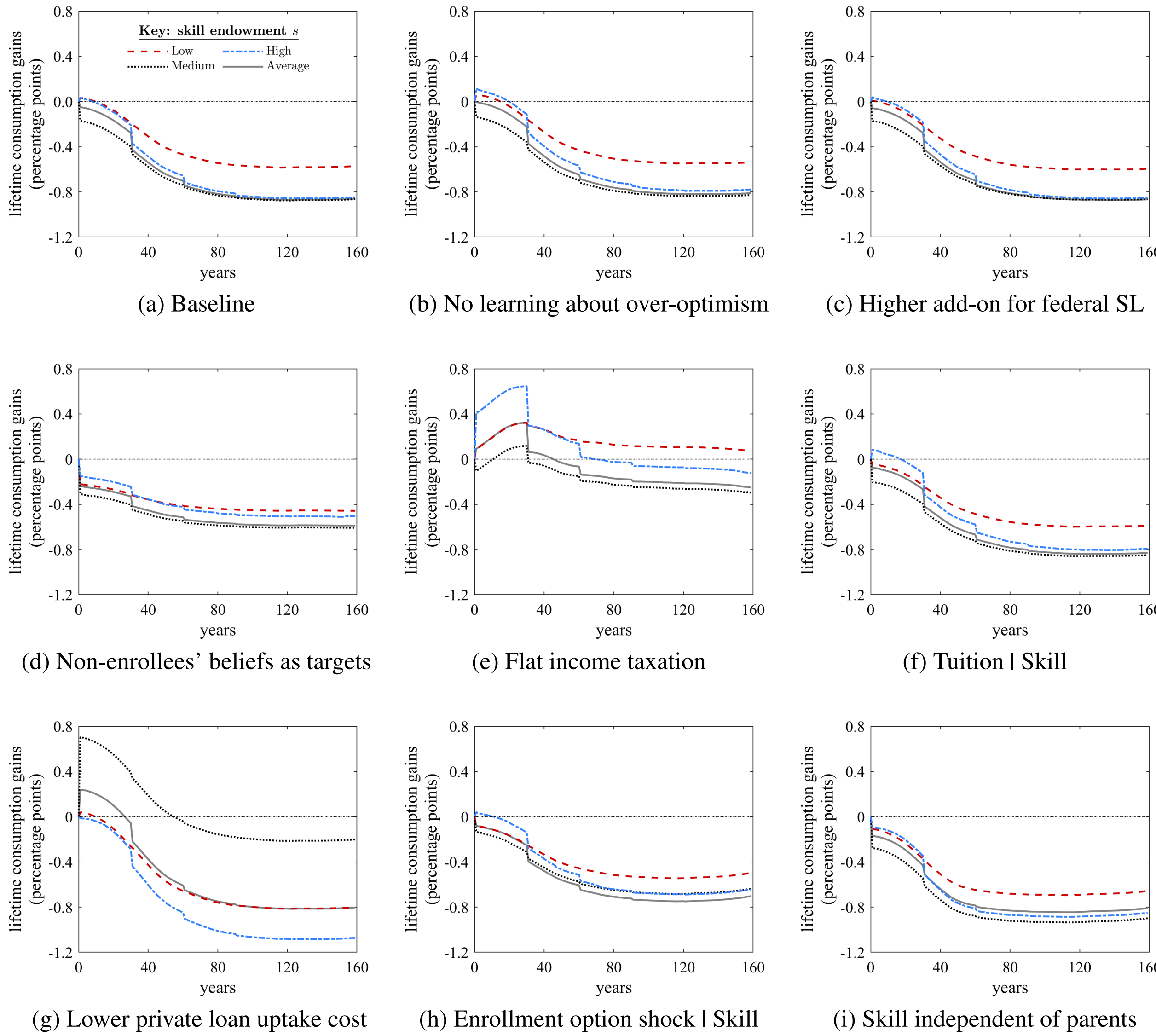
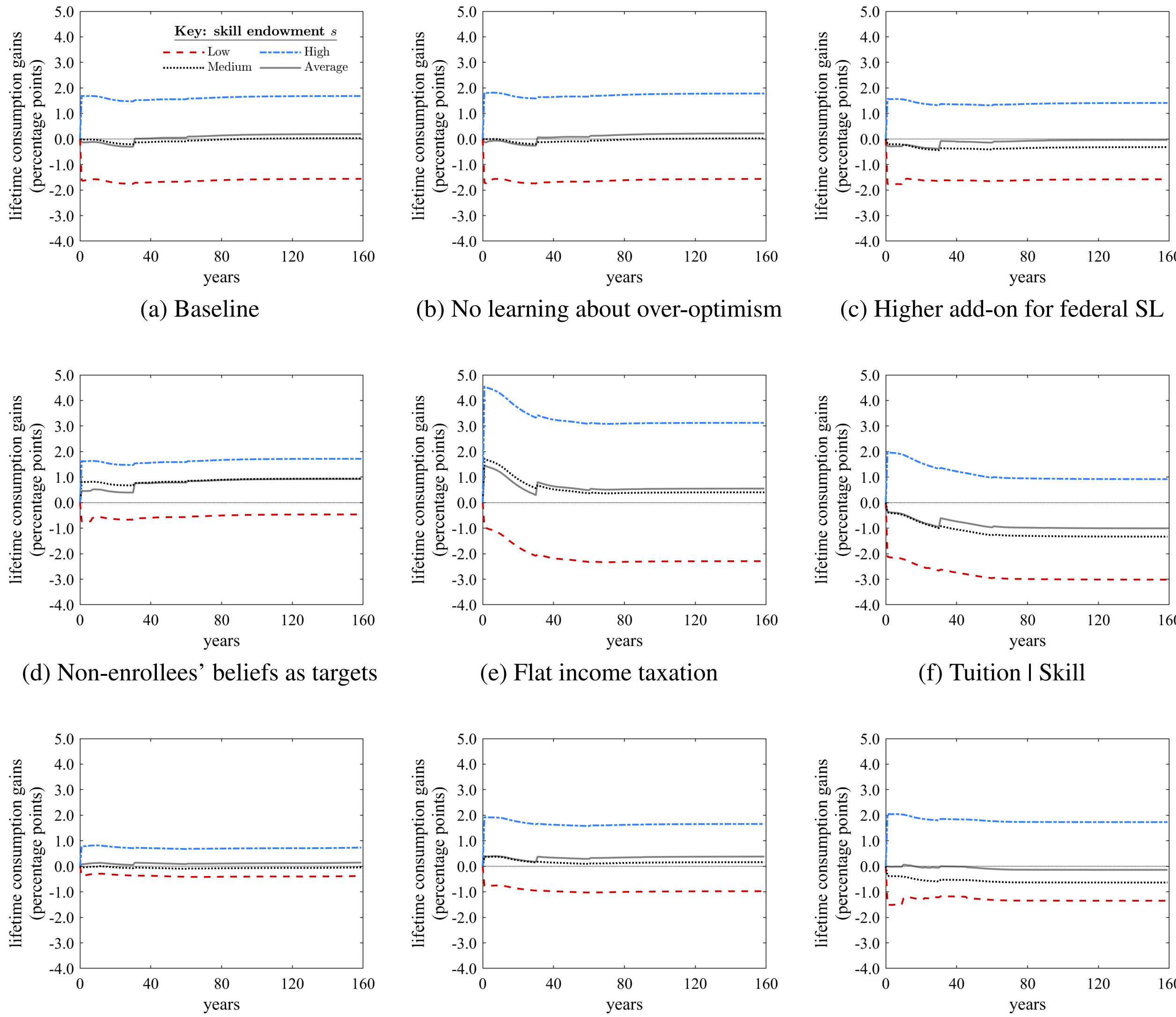


Figure 8: Sensitivity analyses for elimination of over-optimism: welfare

Notes: Figure 8 plots welfare implications of eliminating over-optimism under the following cases: (a) baseline, (b) students do not learn about over-optimism for the whole duration of college, (c) higher add-on for the federal student loan interest rate, (d) non-enrollees' expected likelihood of BA attainment used as beliefs targets, (e) flat income taxation, (f) college tuition depends on skill, (g) lower uptake cost for private loans, (h) college enrollment option shock depends on skill, and (i) skill does not depend on parental education. Each variation of the baseline model is re-calibrated.

sion in federal grants, another important source of college financial aid. We analyze a transition where the public grant parameter $\theta(s)$ increases to $1-\theta^{pr}(s)$, so that public grants fully fund four years of college tuition net of private grants.

Figure 10, divided into two subfigures, provides a welfare analysis of the public grant expansion



(a) Baseline (b) No learning about over-optimism (c) Higher add-on for federal SL

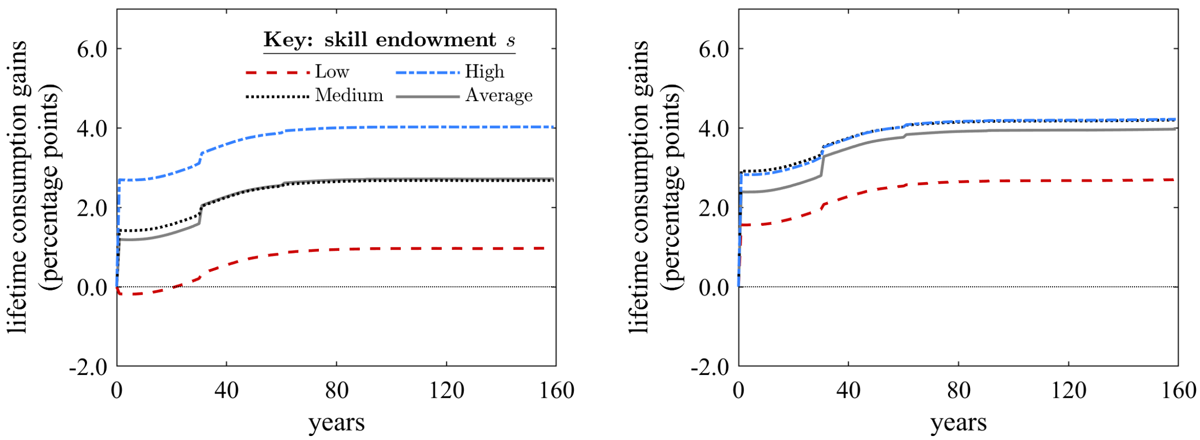
(d) Non-enrollees' beliefs as targets (e) Flat income taxation (f) Tuition | Skill

(g) Lower private loan uptake cost (h) Enrollment option shock | Skill (i) Skill independent of parents

Figure 9: Sensitivity analyses for federal loan limit expansion: welfare

Notes: Figure 9 plots welfare implications of a federal student loan limit expansion under the following cases: (a) baseline, (b) students do not learn about over-optimism for the whole duration of college, (c) higher add-on for the federal student loan interest rate, (d) non-enrollees' expected likelihood of BA attainment used as beliefs targets, (e) flat income taxation, (f) college tuition depends on skill, (g) lower uptake cost for private loans, (h) college enrollment option shock depends on skill, and (i) skill does not depend on parental education. Each variation of the baseline model is re-calibrated.

in our baseline economy and the economy without over-optimism. Both subfigures show welfare changes by skill quantile and on average for 18-year-old consumers. This analysis leads to two new insights. First, in the presence of over-optimism, the gains for the low- and medium-skill are



(a) Baseline

(b) No over-optimism

Figure 10: Public grant expansion welfare analysis: baseline versus no over-optimism

Notes: Figure 10 provides a welfare analysis of an expansion in the public grant to fund four years of college tuition net of private grants in the baseline economy (Subfigure 10a) and an economy without over-optimism (Subfigure 10b). 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.

smaller compared to the case without over-optimism.[67] Second, while a limit expansion leads to large losses for the low-skill in the presence of over-optimism, as highlighted in Figure 5, a grant expansion leads to small losses in the initial periods of the transition, but significant gains in the later periods.

[67]In fact, low skill 18-year-olds in the early periods of the transition experience small welfare losses. This is because although the grant expansion eliminates the pecuniary cost of college, there are still other costs such as college effort and foregone earnings.