Better Late Than Never: Delayed Undergraduate Enrollment and Financial Aid*

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Abstract

We study delayed undergraduate enrollment as a margin for overcoming college financing constraints and its interaction with financial aid. Using data on the United States, we provide new evidence that a quarter of those who enroll in a bachelor's degree delay it by at least a year after high school completion, and that delay is more common among enrollees from poor families or with low skill. We build a model of delayed enrollment with financing constraints that rationalizes these facts. An experiment in which we expand the loan limit reveals that the resulting increase in immediate enrollment stems mostly from those shifting out of delayed enrollment rather than non-enrollees switching into enrollment.

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1 Introduction

Existing studies that have pioneered the development of college enrollment choice models assume that enrollment is a once in a lifetime decision.[1] In this paper, we show that this assumption is highly at odds with the data and that relaxing it improves our understanding of financial aid policy. Specifically, we document new empirical facts on the *delayed enrollment* margin—that is, enrollment in college at least a year after high school completion. We then incorporate the option to delay college enrollment into a quantitative model of college enrollment choice with financing constraints, examine its economic tradeoffs, and illustrate how the option to delay enrollment matters for policy analysis by analyzing a counterfactual loan limit expansion.

Our main empirical insights into the magnitude and cross-sectional patterns of delayed college enrollment are based on the 1997 National Longitudinal Survey of Youth (NLSY97). We show that it is common to delay enrollment by at least one year after high school graduation: more than 25 percent of those who eventually enroll in a bachelor's degree (BA) delay their enrollment. In addition, many delay by a significant amount of time: 12 percent of all enrollees delayed enrollment by at least five years.[2] Furthermore, among college enrollees, those who are poor or have lower skill are more likely to delay enrollment in comparison to their peers. Taken together, the magnitude and cross-sectional patterns of delayed enrollment indicate that delay is aligned with economic incentives.[3]

Motivated by this empirical evidence, we extend a quantitative college enrollment choice model to allow for delayed enrollment with financing constraints. Our framework also includes rich details of college financing incorporated into other frontier models in this literature, such as a federal student loan program with subsidized and unsubsidized loans, Pell grants, and endogenous family transfers. Furthermore, lifetime returns to education are skill-specific: in the model, skill affects both college graduation likelihood and the wage premium for a college degree in an empirically disciplined way.

The model is calibrated to the U.S. economy so that it matches key patterns related to delayed enrollment by year since high school completion. First, we use our calibrated model to gain insight into the economics of delayed enrollment, and validate the model by showing that the option to delay enrollment leads to equilibrium outcomes consistent with the data. Second, we use the model to illustrate the relevance of delayed enrollment for financial aid policy analysis via a counterfactual

[1] For the early papers, see Caucutt and Kumar (2003) and Ionescu (2009); for the more recent ones, see Abbott, Gallipoli, Meghir, and Violante (2019) and Krueger, Ludwig, and Popova (2024).

[2] Unless otherwise stated, in this paper, delayed enrollment refers to enrollment delayed by at least one year since high school completion.

[3] We also use the High School Longitudinal Survey of 2009, a nationally representative sample of 2009 9th graders, to document a similar pattern. The NLSY97 is our main data source because it has a longer panel dimension.

federal student loan limit expansion in which the status quo limit is expanded by one hundred percent.

In our model, high school graduates differ in their initial assets (determined largely based on parental income), skill endowment, earnings potential, and eligibility for need-based federal aid. We show that high school graduates from low income families or with low skill are more likely to delay enrollment. The reason is financing constraints. Those from low-income families will experience a larger consumption loss by enrolling in college immediately in comparison to their peers from high-income families. Those with low skill have lower returns to education in comparison to their high-skill peers, which interacts with financing constraints. As a result, in our model, financing constraints provide an incentive for high school graduates from low-income families or with low skill to not enroll immediately. Instead, this population accumulates assets over their early years of adulthood to overcome the costs of financing constraints, resulting in delayed enrollment.[4]

We validate the economics of our baseline calibration by showing that the resulting equilibrium can account for empirical enrollment patterns observed in the cross-section by skill and parental income. The financing constraints in our model result in immediate enrollment rates that are increasing in parental income controlling for skill. This pattern of immediate enrollment is consistent with that observed in the NLSY97. The option to delay enrollment results in delayed enrollment that decreases in income controlling for skill and in skill controlling for income for the population of enrollees in a cohort of high school graduates. This pattern is also consistent with that observed in the NLSY97.

Before proceeding into the loan limit expansion counterfactual experiment, we perform two model validation exercises that lend credibility to the model's implications for changes in enrollment and welfare from the counterfactual experiment. First, we test the enrollment rate's responsiveness to changes in financial aid policy: for a \$1,000 subsidy, the model produces a response in the enrollment rate comparable in magnitude to that observed in the data.[5] Second, we show that the model generates a college wage premium that is increasing in skill, which is consistent with the data. We view this as affirming that the calibrated model produces credible skill-specific returns to education.

In our main experiment, we double the federal student loan limit. This policy change generates a

[4] In the current version of the paper, there is only one kind of postsecondary education: a bachelor's degree. Apart from financing constraints, however, sub-baccalaureate programs also seem to be important in the context of delayed enrollment: as shown in Table A5 of Appendix A.1, roughly 75 percent of delayed enrollees had previously enrolled in a sub-baccalaureate program. The next revision will explore this channel both empirically and theoretically.

[5] We do not consider a model validation exercise in which the loan limit is changed because there are no widely accepted empirical estimates from such a quasi-experiment.

large increase in the immediate enrollment rate among high school graduates of 13.83 percentage points. However, more than 75 percent of this increase is accounted for by delayed enrollees in the initial equilibrium substituting towards immediate enrollment, as opposed to inflows from those who would have never enrolled in the initial equilibrium. Our model framework thereby uncovers nuance in the impact of a financial aid policy expansion on college enrollment.

Our policy analysis is able to offer new insights by relaxing a common assumption made in related studies. Specifically, in the macroeconomic literature that analyzes college financial aid policies, a key variable for analysis is the college enrollment decision because the welfare impact of policy changes depends in large part on how enrollment responds. The existing literature models the college enrollment decision as a once-in-a-lifetime decision made by a young adult immediately after high school graduation. Examples include Caucutt and Kumar (2003), Ionescu (2009), Chatterjee and Ionescu (2012), Krueger and Ludwig (2016), Ionescu and Simpson (2016), Abbott, Gallipoli, Meghir, and Violante (2019), Matsuda (2020, 2022), Colas, Findeisen, and Sachs (2021), Kim and Kim (2023), Luo and Mongey (2024), Moschini, Raveendranathan, and Xu (2024), Vardishvili (2024), Krueger, Ludwig, and Popova (2024), Hendricks, Koreshkova, and Leukhina (2024), and Moschini and Raveendranathan (2024). Building on these studies, we allow consumers to delay college enrollment in a model with financing constraints, and quantify the importance of this margin for the analysis of college financial aid policy.

Our empirical analysis of delayed enrollment contributes to a growing body of evidence that financing constraints for post-secondary education are binding. In particular, Lochner and Monge-Naranjo (2011) document that enrollment in post-secondary education is increasing in income controlling for skill for the NLSY79 and NLSY97 cohorts; this enrollment pattern is viewed as consistent with the presence of financing constraints, although it is not direct evidence. Moschini and Raveendranathan (2024) document a similar pattern for a third and more recent cohort of high school graduates using the High School Longitudinal Study of 2009 (HSLS:09). For evidence that is somewhat more direct, Wei and Berkner (2008) find that roughly 73 percent of dependent Stafford loan borrowers took out the maximum federal loan in 2003-04, and Moschini, Raveendranathan, and Xu (2024) show that roughly 30 percent of juniors in a BA fully utilized their federal student loan limit in 2016.

More broadly, our paper contributes to the literature highlighting novel margins of adjustment. For example, Kehoe and Ruhl (2013) show that a key margin of adjustment during trade growth comes from least traded products. Herreno and Ocampo (2023) analyze the margin of subsistence self-employment in the context of credit constraints in emerging economies. Another example is Brüggemann, Mahone, and Palmer (2024), who emphasize the importance of firm resale as a margin of adjustment as opposed to firm exit. Our study makes a parallel contribution by highlighting the significance of the delayed enrollment margin for the post-secondary education literature.

This paper proceeds as follows. In Section 2 we present our main empirical findings from the NSLY97. Section 3 presents our model framework, and Section 4 the model parameterization. Section 5 reports the results from the model parameterized to the U.S. economy, and Section 6 concludes.

2 Data

Our main source of data is the 1997 National Longitudinal Survey of Youth (Bureau of Labor Statistics, U.S. Department of Labor, 2019). We use cleaned data from 1997 to 2019 on respondents who receive a high school diploma between the ages of 17 and 19, and are observed in each wave until they turn 30. We also require that the Armed Services Vocational Aptitute Battery score (ASVAB), our preferred measure of skill, and parental income in 1997 be observed. Using this sample, we construct a variable that records the years between receiving a high school diploma and bachelor's degree (BA) enrollment. This variable also records whether the respondent is never observed as having enrolled in a BA.

Summary statistics and the magnitude of delayed enrollment Table 1 reports summary statistics of the cleaned sample, both overall (column 1) and by parental income tercile (columns 2 to 4). For each group, the first four rows of the table report the average ASVAB score, real parental income in 1997, the share female, and the age in 1997. The last three rows report the share who ever enroll in a BA, followed by the share who immediately enroll (within 1 year of completing high school), and, conditional on ever enrolling in a BA, the share who delay their BA enrollment by enrolling one year or more after high school completion.

The pooled sample ("All") of Table 1 shows that the delayed BA enrollment margin is sizable. In the cohort of high school graduates, 45 percent enroll immediately within a year since high completion, whereas 17 percent delay enrollment by at least a year. As a result, delayed enrollment accounts for more than 25 percent of total inflows into enrollment.[6] Figure A1 of Appendix A.1.2 shows that many delay undergraduate enrollment for a significant amount of time.

How do those who enroll in a BA immediately after high school compare with those who delay enrollment? The last two columns of Table 1 report descriptive statistics for the subgroup of

[6]Typically, the National Center for Education and Statistics (NCES) reports college enrollment rates for 18 to 24 year olds. This variable measures the share of 18 to 24 year olds that are enrolled at a given point in time. As a result, this statistic is not informative about the extent of delayed enrollment. We report inflow rates into enrollment for a given cohort of high school gradates, overall and by year since high school completion, so that we can document the magnitudes of delayed enrollment.

those enroll immediately and the subgroup of those who delay enrollment. Comparing these two columns, it is evident that those who delay have lower skill and lower average family income, compared to their peers who enroll immediately after high school.

Table 1: Summary statistics overall and by subgroups

		BA enrollment timing	
	All	Immediate	Delayed
Skill (ASVAB)	54.19	69.59	53.35
Real parental income in 1997	135,891	95,162	67,724
Female	0.55	0.56	0.57
Age in 1997	14.19	14.13	14.23
Ever enroll	0.62	1.00	1.00
Immediately enroll	0.45	1.00	0.00
Delayed enroll	0.17	0.00	1.00
Delayed enr | Ever enr	0.27	0.00	1.00
Observations	2,589	1,170	430

Notes: This table reports summary statistics for high school graduates overall (column 1) and for BA enrollees by enrollment timing (columns 2 and 3). Source: NLSY97.

Delayed enrollment, parental income, and skill Among high school graduates, skill, BA enrollment, and BA enrollment timing are related to parental income. Do parental income or sample member skill predict ever enrolling in a BA, or delayed enrollment among those who ever enroll, holding the other attribute fixed? To examine this relationship, Table 2 presents Average Marginal Effects (AMEs) for three probit regressions, with regression coefficients presented in Table A1 of Appendix A.1.1.

Model (1) predicts ever enrolling in a BA as a function of parental income tercile and skill tercile, where for each variable the AMEs are computed relative to the top tercile. The AMEs indicate that, on average and holding other attributes fixed, relative to the top tercile of parental income the likelihood of ever enrolling in a BA is 15.2 percentage points lower for those in the lowest parental income tercile. Similarly, relative to the top skill tercile, the likelihood of enrolling in a BA is 48.4 percentage points lower for those in the lowest skill tercile. These AMEs are statistically significant at the one percent level.

Model (2) reports AMEs for a similar regression on the same sample of high school graduates, where the dependent variable is an indicator for delayed enrollment. The AMEs indicate that, relative to the top income tercile, delayed enrollment is more likely for those with lower income among high school graduates, although the second tercile is not statistically significant. As for skill, relative to the top skill tercile, the lowest skill tercile has an AME that is not statistically different from zero, while the second skill tercile has a statistically significant 7.2 percent higher probability of delaying enrollment.

Conditioning on ever enrolling in a BA, as we do for the sample of Model (3), clarifies the relationship between income, skill, and delayed enrollment. The results indicate that, among those who eventually enroll in a BA, those in the lowest parental income bin are 15.6 percentage points more likely to delay BA enrollment compared to sample members from the top parental income tercile. In regards to skill, those in the lowest skill tercile are 23.9 percentage points more likely to delay BA enrollment compared to sample members from the top skill tercile. Both AMEs are also statistically significant at the 1 percent level.

Table 2: Average Marginal Effects: Predicting Ever Enrolling and Delay Among Enrollees

	(1) Ever	(2) Delayed	(3) Delayed
Flag: Income tercile 1	-0.152 (0.0230)	0.0483 (0.0189)	0.156 (0.0293)
Flag: Income tercile 2	-0.102 (0.0214)	0.0272 (0.0172)	0.0777 (0.0245)
Flag: Skill tercile 1	-0.484 (0.0229)	-0.0141 (0.0176)	0.239 (0.0360)
Flag: Skill tercile 2	-0.220 (0.0207)	0.0717 (0.0183)	0.173 (0.0249)
Observations	2,589	2,589	1,600
Sample	HS graduates	HS graduates	Ever enrolled

Notes: This table reports probit regression AMEs for (1) the likelihood of ever enrolling in a BA, conditional on receiving a high school diploma, (2) the likelihood of delayed BA enrollment conditional on receiving a high school diploma, and (3) the likelihood of delayed enrollment in a BA (at least one year after high school completion) conditional on ever enrolling. Standard errors in parentheses. Source: NLSY97.

In Appendix A.2.2, we use the High School Longitudinal Survey of 2009 (National Center for Education Statistics, U.S. Department of Education, 2020), a nationally representative sample of 2009 9th graders, to document a similar pattern more than 10 years after the NLSY97's main enrollment window. In particular, we find that in the HSLS:09 being from a lower parental income tercile or having lower skill is associated with a lower likelihood of enrolling in a BA. We also find that, conditional on ever enrolling, being from a lower parental income tercile is associated with a higher likelihood of delaying enrollment. Additionally, skill's AMEs (where skill in the HSLS:09 is measured with high school GPA rather than ASVAB) exhibit patterns similar to the analogous results from the NLSY97.

Overall, the results discussed here show that high school graduates from poorer families or with lower skill delay enrollment as a means to achieve a bachelor's degree education. In the next section, we build a model of college enrollment with financing constraints in which enrollment timing is endogenized.

3 Model

Building on our empirical findings, we extend the overlapping generations model of Moschini and Raveendranathan (2024) to incorporate a delayed college enrollment option for high school graduates. In our model, high school graduates may delay enrollment to overcome financial constraints. We abstract from college financial aid application frictions, the focus of Moschini and Raveendranathan (2024).

This section is organized as follows. Section 3.1 provides an overview of the agent problems. Section 3.2 presents consumer value functions before and while enrolled in college; value functions after the highest level of education is completed are in Appendix B.1. Appendix B.2 presents additional functional forms and the equilibrium definition. Appendix B.3 presents the computational algorithm.

3.1 Overview

Time is discrete and runs forever; each period lasts one year. The economy contains heterogeneous overlapping generations of consumers, a government, and a final goods firm.

3.1.1 Consumers

Consumers start making decisions when they turn 18 at model age $j = 1$. Adults survive each period with probability ψ_j, and live for a maximum of J periods.

At the start of adulthood, the consumer is indexed by their skill endowment, s, stochastic idiosyncratic earnings productivity, η, initial net assets, a, and Expected Family Contribution, f. The skill endowment of a new adult is drawn once from a uniform distribution. Skill indexes the college enrollment option shock, $q(s)$, which is a permanent one-time draw.[7] It also indexes the exogenous probability of being allowed to continue in each year of college for enrollees, $p(s)$, grants from privates sources, $\theta^{pr}(s)$, grants from public sources other than Pell, $\theta^{other}(s)$, the deterministic life cycle component of earnings, $\epsilon_{j,e,s}$, and Social Security transfers, $ss_{e,s}$. The idiosyncratic stochastic component of earnings follows an AR(1) process that depends on completed education, e. Net assets at the start of adulthood are determined by a one-time inter vivos transfer from the consumer's parent, and are recorded with $a \geq 0$. The Expected Family Contribution (EFC), depends on the income and assets of each 18-year-old's parents, as well as on whether the enrollee qualifies for a professional judgment by the aid administrator, as described in more detail in Section 3.1.2.

[7] The shock captures unmodelled reasons that lead a consumer to not go to college such as personal preference and lack of acceptance by a college they would like to enroll in.

A consumer who receives the college enrollment option shock may enroll in the current period or in a future period. While enrolled, college students incur a non-pecuniary effort cost, λ, but also benefit from an age-specific non-pecuniary consumption value of college, $CV(j)$. Non-discretionary college expenses include only tuition and fees, κ; these expenses can be financed with federal student loans (the only form of debt in the model) where the stock of debt is recorded with $a < 0$, inter vivos transfers from parents, earnings from work while enrolled, Pell grants (described in Section 3.1.2), other public grants, and private grants. Completed education recorded with $e = h$ indicates a college graduate with a high level of education, whereas $e = \ell$ indicates a consumer with a low level of education either because they never enrolled in, are currently enrolled in, or have dropped out of college. Completed education indexes the return to labor supply, w_e, the deterministic component of life cycle earnings, $\epsilon_{j,e,s}$, the parameters for the AR(1) process for earnings, that is, the persistence, ρ_e, and the variance, σ_e^2, and Social Security transfers, $ss_{e,s}$.

Repayment of federal student loans begins after an agent leaves college (as a dropout or graduate); subsidized federal loan balances have interest assessed starting at this stage, whereas interest accrues on unsubsidized federal loan balances during college as well. During the repayment phase, consumers choose between making a full payment, $d_f = 0$, and delinquency, $d_f = 1$. A full payment implies that the consumer must make a payment of at least $\rho_R(j, a)$, whereas delinquency leads to a partial payment, $\rho_D(j, a, y)$, due to garnishment of disposable income above the amount $\bar{y}$ at a rate τ_g; additional costs of delinquency are a collection fee that is proportional to the missed payment, ϕ, and a utility cost, ξ_D. The payment functions are provided in Appendix B.2.

Upon paying off student loans, consumers solve a standard consumption-savings problem, which at certain ages is affected by the presence of a child. Specifically, all consumers have a child at age j_f. At the beginning of age $j_f + j_a$, the family draws the child's skill endowment, s_c. The parent then makes an inter vivos asset transfer to their child, altruistically taking into account the child's skill.

Consumers retire at age j_r and receive Social Security transfers until they die.

Preferences The consumer's flow utility function is given by, $U(c, x, j, d_e, d_f)$, in which the inputs are household consumption, c, hours worked, x, adult age, j, indicator for enrollment in college, $d_e \in \{0, 1\}$, and indicator for student loan delinquency, $d_f \in \{0, 1\}$. The utility function is given by

$$U(c, x, j, d_e, d_f) = \frac{\left[\left(\frac{c}{\zeta_j}\right)^{\upsilon}\left(1 - x - d_e\lambda\right)^{1-\upsilon}\right]^{1-\sigma}}{1-\sigma} + d_e CV(j) - d_f \xi_D \tag{1}$$

where ζ_j is an adult equivalence parameter that determines child consumption, 1 is time endowment (normalized), λ is college effort cost, υ is consumption share, σ determines the relative risk aversion, $CV(j)$ is a utility shifter for the consumption value of college that depends on age, and ξ_D is a stigma cost associated with student loan delinquency. The consumption value of college depends on age and is governed by the parameters cv_1, cv_2, and cv_3 according to the function

$$CV(j) = cv_1 * \exp(-cv_2(j-1)) + cv_3 \tag{2}$$

Pretax income function Pretax income $y_{j,e,s,\eta,a,x}$ is determined by age, completed education, skill, stochastic earnings productivity, net assets, and hours worked, as summarized by the tuple (j, e, s, η, a, x), and is given by

$$y_{j,e,s,\eta,a,x} = w_e \epsilon_{j,e,s} \eta x \mathbb{I}_{j<j_r} + ss_{e,s} \mathbb{I}_{j \geq j_r} + r \left[a \mathbb{I}_{j>1} \mathbb{I}_{a>0} + Tr_j \right] \tag{3}$$

where w_e is the completed education specific wage rate, $\epsilon_{j,e,s}$ is a deterministic life cycle component, j_r is retirement age, $ss_{e,s}$ is the Social Security transfer defined in equation (23) in Appendix B.2, r is the risk-free savings rate, and Tr_j is accidental bequests of the deceased.[8]

3.1.2 Government

The government provides grants for college education, which include Pell grants, runs the federal student loan program, funds Social Security, and faces an exogenous government consumption set as a fraction g of gross domestic product (GDP).

Pell grants provide an amount that is based on the EFC, f, and the cost of attendance, $\kappa + \bar{c}$, where κ denotes tuition and fees (which are non-discretionary) and $\bar{c}$ denotes an amount for room and board (which is discretionary). The Pell grant has a maximum value of θ^{Pell}_{max}, and is decreasing in the EFC, with a function given by

$$\theta^{Pell}(f) = \max[\min[\kappa + \bar{c} - f, \theta^{Pell}_{max} - f], 0] \tag{4}$$

The federal student loan program is characterized by a cumulative student loan limit for subsidized and unsubsidized loans, $\bar{A}$, a cumulative student loan limit for subsidized loans, $\bar{A}_s$, 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 an add-on set by the government. Let j_c denote the year of college. The subsidized loan amount is determined by the year of college, EFC, cost of attendance, and the cumulative limit. The

[8]The indicator $\mathbb{I}_{j>1}\mathbb{I}_{a>0}$ implies that interest income on the inter vivos transfer accrues to the parents and not the newly emancipated child who has age $j = 1$.

subsidized loan function is given by

$$a_s(j_c, a', f) = -\mathbb{I}_{a'<0} \min[-a', \tfrac{j_c}{4}\bar{A}_s, j_c \max[\kappa + \bar{c} - f - \theta^{Pell}(f), 0]] \tag{5}$$

This function computes the amount of federal loans taken out by the student that are treated as subsidized. In this function, the term $\frac{j_c}{4}$ scales the cumulative limit with each year of college. The function implies that, subject to the borrowing limit $\frac{j_c}{4}A_s$, subsidized loans can be used to pay for at most the cost of attendance net of the EFC and the Pell grant.

The EFC is determined by the formula $EFC(y, a, d_{pj})$, which depends on parental income, parental net assets, and whether the applicant qualifies for a professional judgment by the financial aid administrator. Qualification for professional judgment is an indicator variable where $d_{pj} = 0$ represents the case in which the applicant does not qualify for a professional judgment and $d_{pj} = 1$ represents the case in which the applicant qualifies for a professional judgment. In the latter case, the income used to determine the EFC is scaled down by $\tau_{AAI} < 1$. This professional judgment feature captures unmodeled special circumstances (e.g., recent unemployment of a family member, tuition expenses at an elementary or secondary school, and medical expenses not covered by insurance) in which the aid administrator may lower the income used to determine the EFC. The probability that $d_{pj} = 0$, so that the income used to determine EFC remains unchanged, depends on income and is given by $\pi_{AAI}(y)$. The functional form for $\pi_{AAI}(y)$ is chosen so that the probability of not qualifying for a professional judgment increases with income (see equation (17) in Appendix B.2).[9] The formula that determines the EFC is provided in equation (19) in Appendix B.2. The EFC formula is such that families with low income and assets will have a low EFC, and therefore be eligible for more need-based aid (that is, Pell grants and subsidized loans).

Government expenditure is financed with tax revenue collected from a flat consumption tax, τ_c, and a progressive income tax and transfer function, $T(y)$, which is levied on pretax income, y. The income tax and transfer function follows the specification of Heathcote, Storesletten, and Violante (2017), and is given by

$$T(y) = y - \gamma y^{1-\tau_p} \tag{6}$$

where τ_p governs the tax progressivity and γ is used to balance the government budget constraint in every period as shown in equation (25) in Appendix B.2.

[9] Incorporating the professional judgment feature allows our model to account for the positive Pell grant uptake rates observed among students from families in middle or high income terciles, as documented in Moschini and Raveendranathan (2024). For more details about special circumstances and professional judgment, see Program Communications Division, Federal Student Aid (2013).

3.1.3 Final goods firm

Output is produced by a final goods firm using a production function that combines aggregate capital, K, and aggregate labor, L, is Cobb-Douglas with capital share α. Aggregate labor, in turn, is a constant elasticity of substitution aggregator of efficiency units of labor with low education, L_ℓ, and high education, L_h, with elasticity of substitution $1/(1-\iota)$ and share parameter ν. Specifically, the final goods production function is given by:

$$Y = K^\alpha \left[Z\{(\nu(L_\ell)^\iota + (1-\nu)(L_h)^\iota)^{1/\iota}\}\right]^{1-\alpha} \tag{7}$$

where Z is aggregate labor productivity. The capital stock depreciates at rate δ.

3.2 Consumer value functions before and while enrolled in college

Given their type, (s, η, a, f), the lifetime expected value to an 18-year-old (that is, $j = 1$ in the model) is given by

$$\begin{aligned} W(s,\eta,a,f) =& (1-q(s))V(j,\ell,s,\eta,a)+ \\ &+ q(s)[\max_{d_e\in\{0,1\}}(1-d_e)V^{PFE}(j,\ell,s,\eta,a,f) + d_e V^{BA}(j,j_c=1,\ell,s,\eta,a,f)] \end{aligned} \tag{8}$$

where $V(j,\ell,s,\eta,a)$ is the value of never going to college, $V^{PFE}(j,\ell,s,\eta,a,f)$ is the value of a potential future enrollee who does not enroll in the current period, and $V^{BA}(j,j_c=1,\ell,s,\eta,a,f)$ is the value of enrolling in college. The value of enrolling in college for the first three years of college, $j_c \in \{1,2,3\}$, is given by

$$\begin{aligned} &V^{BA}(j,j_c,\ell,s,\eta,a,f) = \max_{c\geq 0,a',x\in X} U(c,x,j,d_e=1,d_f=0)+ \\ &\beta\psi_j E_{\eta'|\ell,\eta}\big[p(s)\max[V^{BA}(j+1,j_c+1,\ell,s,\eta',a',f), V(j+1,\ell,s,\eta',a')]+ \\ &(1-p(s))V(j+1,\ell,s,\eta',a')\big] \\ &s.t. \\ &(1+\tau_c)c + a' + \kappa = y_{j,\ell,s,\eta,a,x} + a + Tr_j - T(y_{j,\ell,s,\eta,a,x}) + \theta^{other}(s) + \theta^{pr}(s) \\ &+\theta^{Pell}(f) + r_{SL}(\mathbb{I}_{a<0}a - a_s(j_c,a',f)) \\ &a' \geq -\tfrac{j_c}{4}\bar{A} \end{aligned} \tag{9}$$

where β is the discount factor, a' is the stock of assets or federal student loans in the next period, $\theta^{Pell}(f)$ and $a_s(j,a',f)$ are functions that determine Pell grants and subsidized federal student loans, defined in equations (4) and (5), and $\frac{j_c}{4}\bar{A}$ determines the cumulative limit for both subsidized and unsubsidized loans with each year of college, j_c. The continuation value reflects that, apart from exogenously dropping out, consumers may also choose to drop out before the start of the next academic year if given the option to continue. Those who drop out will permanently become a consumer whose highest level of educational attainment is a high school degree.

For a college enroll, the value function at $j_c = 4$ is a slightly modified version of equation (9): as long as the consumer is allowed to continue and graduate, the AR(1) draw in the next period will be made from the distribution for the high-education labor, there will be no endogenous dropout decision, and they will receive the continuation value $V(j+1, h, s, \eta', a')$.

The value of a potential future enrollee for ages $j \in \{1, ..., J_c - 2\}$, where J_c is the maximum age at which a consumer may enroll in college, is given by

$$\begin{aligned}
&V^{PFE}(j, \ell, s, \eta, a, f) = \max_{c \geq 0, a', x \in X} U(c, x, j, d_e = 0, d_f = 0) + \beta \psi_j E_{\eta' | \ell, \eta} \qquad (10)\\
&[\max_{d_e \in \{0,1\}} (1 - d_e) V^{PFE}(j+1, \ell, s, \eta', a', f) + d_e V^{BA}(j+1, j_c = 1, \ell, s, \eta', a', f)]\\
&s.t.\\
&(1 + \tau_c)c + a' = y_{j,\ell,s,\eta,a,x} + a + Tr_j - T(y_{j,\ell,s,\eta,a,x})\\
&a' \geq 0
\end{aligned}$$

For a potential future enrollee, the value function at $j = J_c - 1$ is a slightly modified version of equation (10): the continuation value will reflect the feature that if the agent does not enroll in college at $j = J_c$, their lifetime value will be equal to that of a consumer who never goes to college (see equation (12) in Appendix B.1).

4 Parameterization

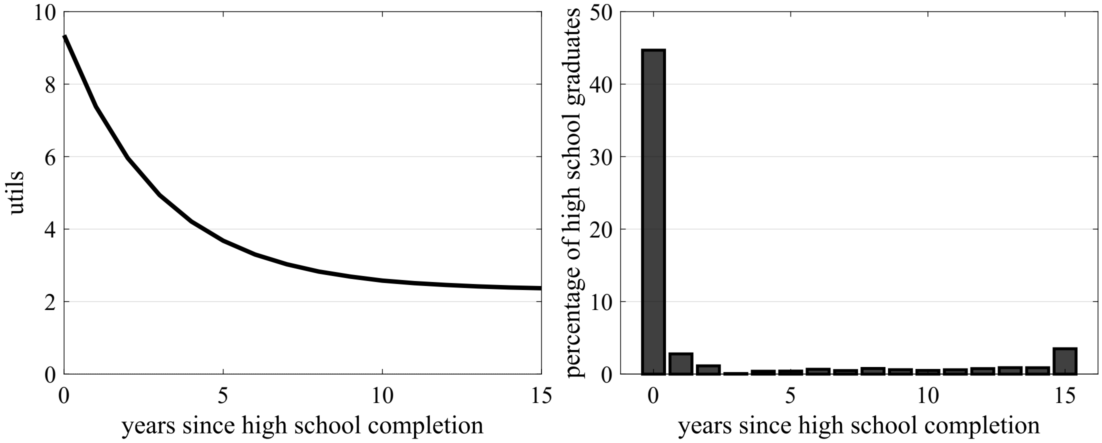
In this section, we present the internally calibrated parameters. The externally estimated parameters are presented in Table 7 of the Appendix.

Table 3 reports internally calibrated parameters. The first column 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 description, the moment in the data, and the moment in the calibrated model, respectively. Although parameters and moments are grouped 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. In several rows within this table, we note that the moment is normalized by GDP per capita for those 18 and over. This value is computed by combining information on GDP from BEA (2022, T1.1.5) with population levels from the US Census Bureau for 2013-2015 (Census Bureau of the United States, 2020).

Table 3: Internally calibrated parameters

Symbol	Parameter description	Parameter value	Moment	Data moment	Model moment
Panel A: Moments from NLSY97					
$p(s)$	Continuation prob. average	(0.898,0.919,0.954)	Graduation rate: immediate enrollees	*(0.549,0.681,0.821)*	*(0.541,0.655,0.822)*
$q(s)$	Enrollment option shock	(0.379,0.661,0.875)	Enr. within 7 years | High income	*(0.381,0.650,0.873)*	*(0.361,0.644,0.872)*
cv_1	Consumption value	7.023	Immediate enrollment	*0.452*	*0.447*
cv_2	Consumption value	0.329	1-year delayed enrollment	*0.031*	*0.028*
cv_3	Consumption value	2.322	Delayed enrollment	*0.166*	*0.145*
β_c	Parent altruism toward child	0.097	Average transfer, normalized	*0.588*	*0.579*
ν	Low-education labor share	0.434	College wage premium | s_2	*1.38*	*1.368*
Panel B: Moments from the HSLS:09					
λ	Net college effort cost	0.492	Average hours in Y3 / Full time hours	*0.349*	*0.366*
$\theta^{other}(s)$	Public grants net of Pell by s	(0.042,0.048,0.065)	Public grants net of Pell to tuition	*(0.197,0.227,0.306)*	*(0.197,0.227,0.306)*
$\theta^{pr}(s)$	Private grants by s	(0.028,0.029,0.033)	Private grants to tuition	*(0.133,0.138,0.158)*	*(0.133,0.138,0.158)*
ϕ_{AAI}	AAI adjustment probability	1.071	Pell extensive margin | Middle income	*0.432*	*0.438*
τ_{AAI}	AAI adjustment scale	0.102	Pell intensive margin, normalized | Middle income	*0.055*	*0.056*
Panel C: Moments from other sources					
$\bar{c}$	College room and board	*0.146*	Room + board, normalized	*0.146*	*0.146*
κ	Annual tuition	*0.212*	Net tuition + fees, normalized	*0.097*	*0.097*
$\bar{y}$	Garnishment-exempt income	*0.152*	Exempt earnings, normalized	*0.152*	*0.152*
ξ_D	Federal delinquency cost	*0.038*	Federal delinquency rate	*0.088*	*0.096*
Z	Aggregate labor productivity	*1.340*	GDP per capita 18+	*1.000*	*0.995*
β	Discount factor	*0.983*	Capital-to-output ratio	*3.000*	*2.994*
χ	SS replacement rate	*0.192*	SS expenditure, fraction of GDP	*0.048*	*0.048*
υ	Consumption share utility	*0.414*	Average work hours = full time	*0.333*	*0.334*

Panel A of Table 3 presents parameters governed by moments from the NLSY97. Additional details on the estimation of the empirical moments including sample selection critetia are reported in Appendix A.1; the first two rows draw on Table A2, rows three to five Table A3, and the last two rows Tables A8 and A7, respectively. The first row of Table 3 reports $p(s)$, which determines the skill-specific probability of being allowed to continue in college; these parameters are chosen to target skill-specific graduation rates of immediate enrollees. The one-time draw of the college enrollment option, $q(s)$, is parameterized to target enrollment rates by skill for the top family income tercile within the first seven years of high school completion. Focusing on enrollment rates of those from high-income families minimizes the role of financial constraints in the enrollment decision while focusing on the longer horizon controls for the permanence of the shock. In this sense, the shock captures unmodeled persistent reasons for non-enrollment such as personal preference and lower likelihood of acceptance into college. The consumption value is a function of age, and its parameters in the next three rows are calibrated to match immediate enrollment as well as delayed enrollment by one year and total delayed enrollment. The resulting age-specific consumption value is depicted in Panel 1a. Panel 1b, which depicts flows into enrollment by year since high school completion in the baseline calibration, shows that the model generates the pattern consistent with that observed in the data in Figure A1. The degree of parental altruism, β_c, is set so that the model matches average parent-to-child transfers in the NLSY97. The parameter that determines the labor share for low-education labor, ν, is set so that the college wage premium for the middle skill tercile matches that observed in the data.



(a) Consumption value of college (b) Enrollment

Figure 1: Age-specific consumption value of college and enrollment

Notes: The figure depicts the age-specific consumption value of college and enrollment flows into college.

Panel B of Table 3 presents parameters governed by moments from the HSLS:09. Additional details on the estimation of the empirical moments including sample selection critetia are reported in Appendix A.2; the first row draws on Table A12, the next two rows Table A13, and the last two rows Table A14. All of these moments are computed for immediate enrollees. The college effort cost, λ, is set to match the average weekly hours worked while in college as a fraction of 40 hours (full-time work) for third-year college students. The next two rows of the panel contain the vectors representing tuition and fees paid with grants and scholarships from public sources other than Pell grants, $\theta^{other}(s)$, and private sources, $\theta^{pr}(s)$, and are set to match the ratios of public grants net of Pell to tuition and private grants to tuition. These ratios are determined using data from the HSLS:09 and incorporating estimates from Krueger and Ludwig (2016). The last two rows contain ϕ_{AAI} and τ_{AAI}. These are the parameters that govern the probability function in equation (17), which determines qualification likelihood for professional judgment, and the proportion by which income is scaled conditional on qualification for professional judgment in equation (18), respectively. These parameters are chosen to match uptake of Pell grants in the middle income tercile in both the extensive and intensive margin.

Panel C of Table 3 reports parameters governed by moments from sources other than the NLSY97 and HSLS:09. The discretionary cost of college (room and board), $\bar{c}$, targets average annual room and board; the non-discretionary cost (annual tuition), κ, targets average annual net tuition and fees. Both empirical moments are computed for bachelor's degree programs from 2013-2015 using data contained in a College Board report (Ma, Pender, and Libassi, 2020), supplemented with information from the National Center for Education Statistics in NCES (2019). The income exempt from garnishment in delinquency, $\bar{y}$, is set to 0.152 based on our calculations using results from Yannelis (2020). The parameter governing the costs of being delinquent on public loans, ξ_D, targets the average cohort delinquency rate 2013-2015 reported by the Federal Student Aid (FSA) report FSA (2021b) (e.g., a delay in payment of 270 days or more). Aggregate labor productivity, Z, is set so that GDP per capita for the population aged 18 and over is one in the model. The discount factor, β, is calibrated to target a capital-to-output ratio of 3, consistent with Jones (2016). The Social Security replacement rate, χ, targets the average ratio of total Social Security expenditure to GDP, estimated using 2013-2015 data from BEA (2022, T2.1) and BEA (2022, T1.1.5). Lastly, the consumption share in the utility function, υ, is calibrated so that the average non-retiree works full time, ft, which is parameterized in Panel A of Table 7 in the Appendix.

5 Results

In Section 5.1, we analyze the economics of delayed enrollment in our calibrated model, with a focus on the college enrollment decision.

In Section 5.2, we validate the model's calibrated baseline with four exercises. In the first two exercises, we compare the model with the data in terms of immediate and delayed enrollment patterns by parental income and skill. These two exercises establish that the economics of delayed enrollment discussed using the college enrollment decision lead to equilibrium outcomes in the baseline calibration that account for patterns observed in the data. In the last two model validation exercises, we show that our calibration accounts for the responsiveness of the enrollment rate to grants and for the increasing college wage premiums by skill. These exercises serve to make our welfare estimates from the loan limit expansion experiment credible. This is because the magnitudes of the welfare changes from such an experiment are strongly associated with the responsiveness of enrollment to policy changes and the skill-specific returns to education.

In Section 5.3, we report changes in immediate, delayed, and total enrollment rates from the federal student loan limit expansion experiment—an exercise motivated by the role of parental income and skill in determining enrollment timing in the data and model. Specifically, we analyze an experiment in which the status quo limit is increased by one hundred percent.

5.1 The economics of delayed enrollment

In this section, we discuss the economics of delayed enrollment—the novel element of our paper—by analyzing the policy function for the college enrollment decision. The three panels in the first row of Figure 2 depict the enrollment decision by years since high school completion across panels in the baseline calibration. An analogous depiction is provided in the panels in the second row after the federal student loan limit expansion. Within each panel, the decision is reported by net assets for those with low skill and high skill. Additional details on assumptions about the consumers' state space are provided in the figure notes.

Panel 2a demonstrates that the immediate enrollees are more likely to have higher skill and higher initial net assets. Although most high school graduates start with a low level of initial net assets (Figure C1 of Appendix C.1), asset accumulation over the life cycle enables those who do not enroll immediately to enroll later. This enrollment option is evident in Panels 2b and 2c, which plot the enrollment decision for the later years after high school completion. The two panels also highlight mitigating forces at play for enrollment in later years in comparison to the initial year. The minimum net assets required to enroll increases with years since high school completion. This is because the benefits of college decrease due to the decline in the consumption value of college (Panel 1a) and the decline in expected lifetime earnings benefits conditional on graduation. In equilibrium, delayed enrollment is observed when the asset accumulation effect outweighs the effect of the reduced consumption value of college and the reduced expected lifetime earnings benefits.[10]

In our model, financing constraints are the reason to delay enrollment. Panel 2d in comparison to Panel 2a shows that those with low net assets who would not have enrolled immediately in the baseline calibration would now choose to do so after a limit expansion. A comparison of Panels 2e and 2f to Panels 2b and 2c also signifies the role of financing constraints: the minimum net assets required for enrollment in college is lower after the limit expansion.

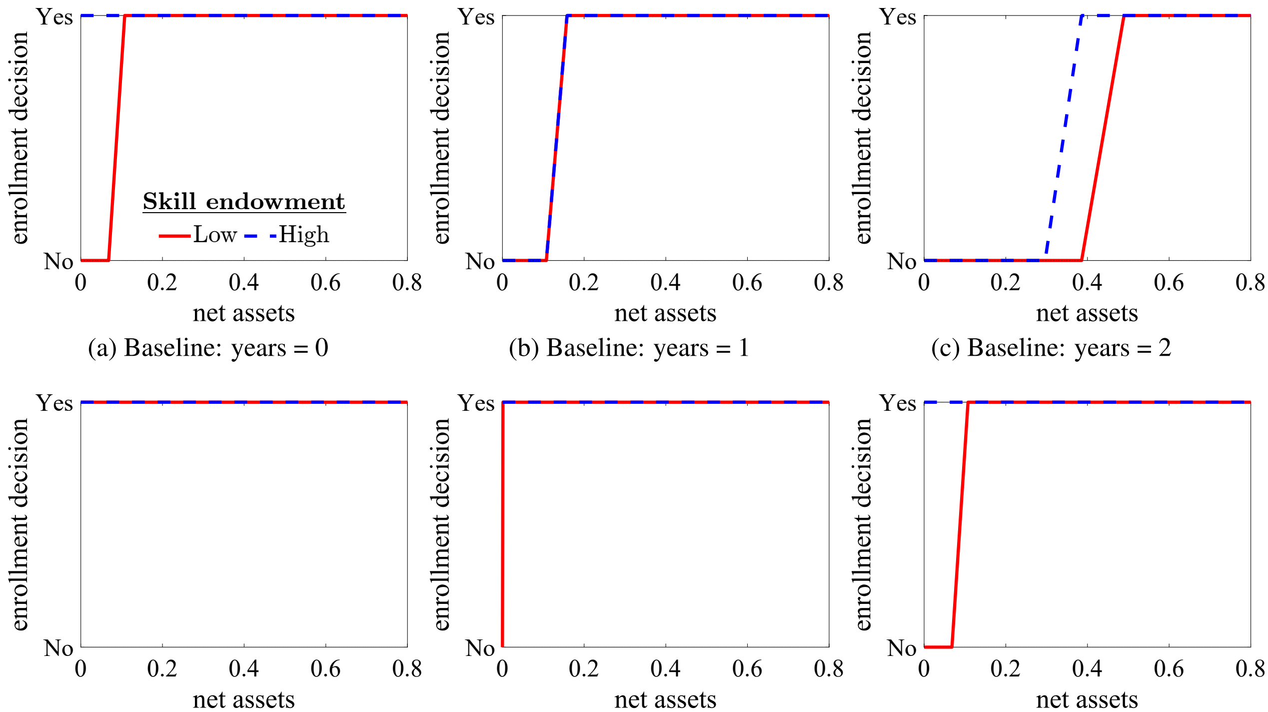
5.2 Model validation of enrollment and skill-specific returns to education

In this section, we present model validation results from the four exercises discussed above.

1. Immediate enrollment by parental income and skill Figure 3 depicts immediate enrollment rates by parental income and skill in the data and in the baseline calibration. The baseline calibration accounts for the pattern observed in the data: the immediate enrollment rate tends to increase in parental income controlling for skill and in skill controlling for parental income.

2. Delayed enrollment (conditional on ever enrolling) by parental income and skill Figure 4 depicts delayed enrollment rates conditional on ever enrolling by parental income and skill in the data and the baseline calibration. The baseline calibration accounts for the pattern observed in the

[10]As discussed in Appendix C.2, waiting for higher realizations of the persistent component of earnings is not a first-order driver of delayed enrollment.



(a) Baseline: years = 0 (b) Baseline: years = 1 (c) Baseline: years = 2

(d) Limit expansion: years = 0 (e) Limit expansion: years = 1 (f) Limit expansion: years = 2

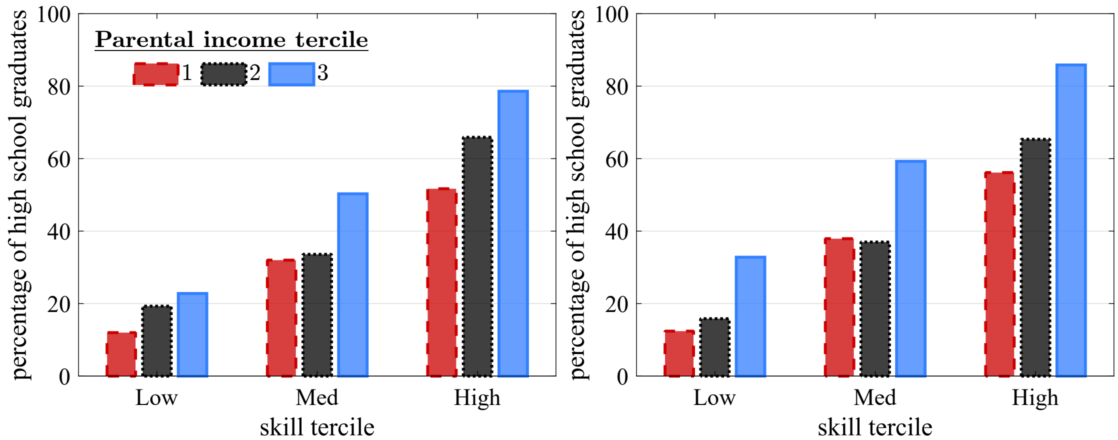
Figure 2: Enrollment decision by years since high school completion and net assets and skill

Notes: This figure depicts the enrollment decision by years since high school completion across panels. The panels in the first row depict enrollment decisions in the baseline calibration, whereas the panels in the second row depict the analogous decisions when the federal student loan limit is expanded by one hundred percent from the status quo value. Within each panel, the decision is reported by net assets for those with low skill and high skill. We restrict our analysis to a consumer whose EFC is zero (that is, they are eligible for the most need-based federal aid) and their realization for the persistent component of earnings is the median. Furthermore, the net assets on the x-axis is restricted to show the enrollment decision for lower levels because for most high school graduates, their initial net asset position is small (Figure C1 of Appendix C.1).

data: the conditional delayed enrollment rate tends to decrease in parental income controlling for skill and in skill controlling for parental income.

3. Enrollment rate response to $1,000 subsidy Table 4 presents enrollment rate response estimates from a quasi-natural experiment in which prospective college students are given a $1,000 subsidy to attend college. The empirical estimate for the enrollment rate response, based on Deming and Dynarski (2009), is 4.00 percentage points. In the model, the analogous non-targeted estimate is 2.35 percentage points.[11]

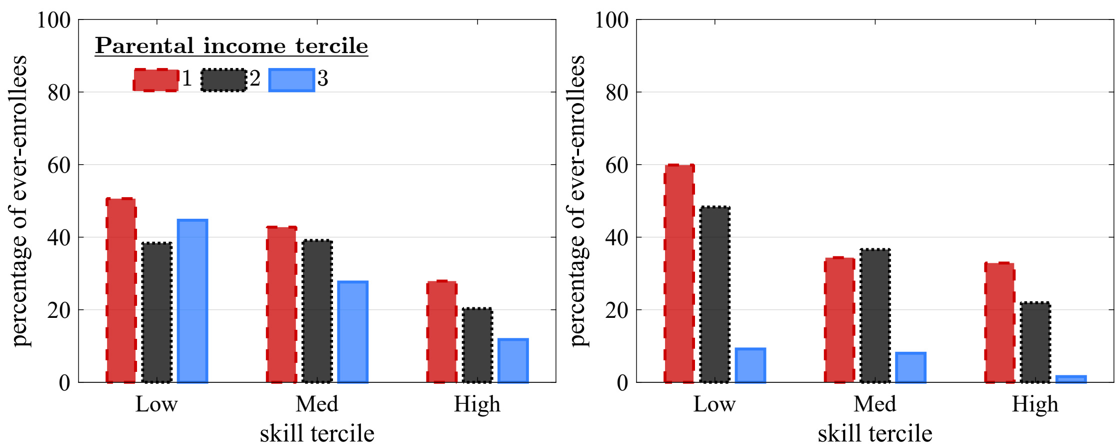
[11] In the model, the change in the immediate enrollment rate is reported.



(a) Data (b) Model

Figure 3: Immediate enrollment rate by parental income and skill

Notes: The figure depicts the immediate enrollment rate by parental income and skill, in the data (Table A4 of Appendix A.1, column 1) and the model. Data source: NLSY97.



(a) Data (b) Model

Figure 4: Delayed enrollment rate conditional on enrolling by parental income and skill

Notes: The figure depicts the delayed enrollment rate conditional on ever enrolling by parental income and skill, in the data (Table A4 of Appendix A.1, column 2 divided by column 3) and the model. Data source: NLSY97.

4. College wage premiums by skill Table 5 presents the college wage premium by skill tercile in the model and the data. In both the model and the data, the college wage premium is computed as the median hourly earnings of individuals with a four-year college degree divided by the median hourly earnings of those without such a degree, for workers aged 25 to 39, within a given respective skill tercile. The age range is chosen to match the available NLSY97 sample used for empirical estimates, which are reported in Appendix A.1.4. The model captures the pattern that the college wage premium increases with skill, although it underestimates the college wage premium for the

Table 4: Enrollment rate response to $1,000 subsidy

Quasi-Natural Experiment	Data	Model
Enrollment change due to additional $1,000 tuition subsidy	4.00	2.35

Notes: The table presents estimates for the enrollment rate response given a subsidy of $1,000, in the data and the model. In the model, the change in the immediate enrollment rate is computed in a partial equilibrium in which the distribution of 18-year-olds and general equilibrium prices, taxes, and transfers are held fixed at their initial steady state values. Data source: Deming and Dynarski (2009).

top skill tercile.

Table 5: College wage premium by skill tercile

Skill tercile	Data	Model
Low	1.35	1.34
Medium	*1.38*	*1.37*
High	1.47	*1.38*

Notes: The table presents the college wage premium by skill tercile, in the data and the model. The middle row estimates are reported in italics because they are targeted in the calibration. Data source: NLSY97.

5.3 Loan limit expansion with delayed enrollment

In this section, we present results from a loan limit expansion experiment in general equilibrium in which the status quo limit is increased by 100 percent. This experiment is motivated by the importance of parental income and skill in determining enrollment timing in the data and model.

Table 6 reports the levels and the changes in immediate, delayed, and ever-enrollment rates among high school graduates across steady states. Delayed enrollment decreases from 14.49 to 3.89 percent, which is evidence that financing constraints are the reason to delay enrollment in our model. Furthermore, the changes reported in the third column of the table quantify the importance of the delayed enrollment margin: most of the increase in the immediate enrollment rate is due to transitions out of delayed enrollment as opposed to transitions out of non-enrollment.

Table 6: Enrollment rates

	Steady state		
Enrollment type	Initial	Final	Change
Immediate	44.69	58.52	13.83
Delayed	14.49	3.89	-10.60
Ever	59.19	62.41	3.22

Notes: The table presents immediate, delayed, and overall enrollment rates (in percentage points) in the initial steady state and the final steady state after a federal loan limit expansion of 100 percent, as well as the change from the initial to final steady state (in percentage points).

Table A18 of Appendix C.3 reports the welfare changes in consumption-leisure equivalent units for high school graduates based on their parental income and skill.[12] The gains to those from a low income family amount to one percent or more of lifetime consumption and leisure regardless of skill. The welfare losses observed among high school graduates with high parental income and high skill are typical of quantitative models of college enrollment: in general equilibrium, the high-education wage rate decreases with an increase in the supply of college graduates. Because this group of high school graduates experiences only a small direct gain from an increase in the intensive margin of access to student loans, on net the wage effect dominates and they are worse off.

6 Conclusion

The main contribution of this paper is to study delaying bachelor's degree enrollment as a margin for overcoming college financing constraints and its interaction with financial aid.

We provide new evidence that over a quarter of high school graduates in the United States who enroll in college at some point in their life delay enrollment by at least a year after graduating from high school. Furthermore, this delay is more common for enrollees from poor families or with low skill.

Based on our new empirical findings, we extend existing quantitative models of college enrollment choice with financing constraints—which treat the college enrollment decision as a once-in-a-lifetime decision—by endogenizing enrollment timing. Our calibrated model accounts for the magnitudes and the cross-sectional patterns of delayed enrollment by years since high school graduation and by parental income and skill.

To illustrate the importance of the delayed enrollment margin, we use the calibrated model to conduct a counterfactual experiment that expands the federal student loan limit. The model reveals that the resulting increase in immediate enrollment stems mostly from those shifting out of delayed enrollment rather than non-enrollees switching into enrollment.

Next, we will extend the paper to incorporate the role of sub-baccalaureate programs. In its current version, the only incentive for high school graduates to delay enrollment are financing constraints. However, Table A5 of Appendix A.1 shows that roughly 75 percent of delayed enrollees had previously enrolled in a sub-baccalaureate program. The next revision will incorporate the potential interaction between sub-baccalaureate programs and delayed BA enrollment both empirically and theoretically.

[12] The details of welfare computation are provided in Appendix B.4.

Appendix

The estimation of the external parameters is the same as in Moschini and Raveendranathan (2024) except in two ways. First, ASVAB instead of high school GPA is used as the measure of skill to estimate the components of the earnings process. Second, this paper includes an additional external parameter, the maximum age for enrolling in college.

Table 7 presents the externally estimated parameters. Panel A governs demographics and hours, which we set by assumption; Panels B uses estimates from the literature to discipline preferences and technologies; Panel C draws on our earnings process estimation using the NLSY97 and PSID, which is explained in more detail in Appendix A.1.4; Panel D uses statutory values for government student aid policy for all parameters except in one case an estimate from the literature; and, finally, Panel E reports parameters related to government spending and tax policy.

In Panel A, the fertility period, j_f, is set to 13 so that consumers have a child when they turn 30; the age adulthood begins, j_a, is set to 18; j_r is chosen so that the retirement age is 65; and, finally, J sets maximum life span to 100 years. The maximum age at which a consumer may enroll in college, J_c, is set to 16 because more than 99 percent of enrollment into college is observed within the first 15 years of high school completion (Figure A1). For $j < j_f + j_a$, we set survival probabilities ψ_j to one to rule out children without parents; ages $j \geq j_f + j_a$ use estimates from the 2010 Social Security Administration Life Tables presented in Bell and Miller (2020). We set full time hours, ft, to 1/3, which is equivalent to 8 hours of work per day, five days a week. The set of hours a consumer could work, X, consists of full time hours scaled by 0, 0.75, 1.00, 1.25, and 1.50.

Panel B reports parameters that govern preferences and the goods production technology. It begins with the parameter that governs the relative risk aversion, σ, which is set to $1/\upsilon + 1$ so that relative risk aversion is equal to 2 based Chetty (2006). The adult equivalence scale, ζ, is set to 0.3 following the Organization for Economic Co-operation and Development (OECD) modified scale. The capital share parameter, α, is set to 0.36 following Kydland and Prescott (1982). The depreciation rate of capital, δ, is set to 0.076, as in Krueger and Ludwig (2016). The parameter that dictates the elasticity of substitution between low- and high-education labor, ι, is set to 0.8, which implies an elasticity of substitution of 5. This value is in the middle of the range (between 4 and 6) reported in Card and Lemieux (2001) after controlling for imperfect substitutability across age groups.

The three rows of Panel C contain objects that determine labor market productivity. First is the deterministic component of the life cycle earnings process, $\epsilon_{j,e,s}$; second, the persistence parameter of the AR(1) productivity shock, ρ_e; and, third, the variance of the AR(1) productivity shock, σ_e^2. These objects are estimated using data from both the PSID and NLSY97, with full results presented

Table 7: Externally estimated parameters

Parameter	Description	Data Target	Value
Panel A: Demographics and hours			
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
J_c	Maximum age of enrolling in college	33 years	16
ψ_j	Survival probability	2010 SSA Life Tables	-
ft	Full time hours	8 hours per day	$1/3$
X	Set of hours	Percent of full time hours	$(0, 0.75, 1, 1.25, 1.5)ft$
Panel B: Preferences and technology			
σ	Risk aversion	Risk aversion $\upsilon = 2$, Chetty (2006)	$\frac{1}{\upsilon} + 1$
α	Capital share	Kydland and Prescott (1982)	0.360
δ	Depreciation rate	Krueger and Ludwig (2016)	0.076
ι	Elasticity of substitution	Card and Lemieux (2001)	0.800
ζ_j	Adult equivalence scale	OECD modified scale	$1 + 0.3\mathbb{I}_{j_f \leq j < j_f + j_a}$
Panel C: Life cycle earnings profile and hours worked in college			
$\epsilon_{j,e,s}$	Deterministic component	PSID and NLSY97	Table A6, App. A.1.4
ρ_e	AR(1) persistence for $e = (\ell, h)$		$(0.903, 0.885)$
σ_e^2	AR(1) variance for $e = (\ell, h)$		$(0.052, 0.072)$
Panel D: Government student aid policy and grants			
$y_{EFC=0}$	Income threshold 0 EFC, normalized	Statutory	0.345
$y_{f,i}$	AAI thresholds for EFC, normalized		(-∞,-0.049,0.220,0.276,0.332,0.389,0.445,∞)
f_i	Lower-bound for EFC, normalized		(0,0,0.048,0.062,0.079,0.098,0.120)
$y_{f,i}$	Lower income bound for EFC marginal rate, normalized		(0,0,0.220,0.276,0.332,0.389,0.445)
a_{prot}	Asset protection allowance, normalized		0.521
$\bar{A}$	Subsidized and unsubsidized loan limit, normalized		0.377
$\bar{A}_s$	Subsidized loan limit, normalized		0.265
θ^{Pell}_{max}	Pell maximum, normalized		0.079
$\tau_{f,i}$	Marginal rate for EFC		(0,0.22,0.25,0.29,0.34,0.40,0.47)
τ_a	Asset conversion rate		0.120
τ_{SL}	Interest rate add-on		0.021
T_{SL}	Maximum years to repay		24
τ_g	Federal SL garnishment rate		0.150
ϕ_D	Student loan collection fee	Luo and Mongey (2024)	0.185
Panel E: Government spending and tax policy			
g	Government consumption	BEA	0.147
τ_p	Income tax progressivity	CBO	0.177
τ_c	Consumption tax rate	OECD	0.044

and explained in the discussion surrounding Table A6 of Appendix A.1.4.

Panel D reports government policy parameters related to student aid, as well as subsidy rates for grants other than Pell grants. The first eight rows of this panel are normalized by GDP per capita for those 18 and over, which is computed by combining information on GDP from BEA (2022, T1.1.5) with population levels from the US Census Bureau (Census Bureau of the United States, 2020) for 2013-2015. In rows 1-5 and 9-10 we report parameters that govern the EFC in the model, which are drawn from the EFC formula guide for 2013-2014 prepared by the Federal Student Aid Office, U.S. Department of Education (2014). The first row reports the income threshold below which households are assigned an automatic zero EFC, $y_{EFC=0}$, which is set to 0.345. If the household does not qualify for an automatic zero EFC, then the EFC is computed after computing the adjusted available income using equation (18), an input into the EFC schedule provided in case 2 of equation (19). The various parameters of the adjusted available income function and the schedule are reported in rows 2-5 and rows 9-10. Rows 6, 7, and 8 report limits for federal aid: $\bar{A}$ is the net borrowing limit for any federal student loans which is set to 0.377, $\bar{A}_s$ is the net borrowing limit for subsidized loans which is set to 0.265, both determined using the limits for four years of college reported by the CRS (Smole, 2019), and θ^{Pell}_{max} is the maximum Pell amount an individual can be awarded, set to 0.079 using the amount from the Office of Postsecondary Education, Federal Student Aid (2013). The eleventh row contains τ_{SL}, the interest rate add-on, set to 0.021 as reported by the Chief Operating Officer for FSA (2021). Row 12 contains the number of years for repayment on a student loan, T_{SL}, which is set to 24. This implies that for an immediate enrollee who graduates the maximum repayment period is 20 years.[13] The next row is the garnishment rate conditional on delinquency on student loans, τ_g, which is set as established by the 2005 Deficit Reduction Act (109th Congress of the United States of America, 2006). The last row contains the student loan collection fee, ϕ_D, which is set to 0.185 following Luo and Mongey (2024).

Panel E reports parameters related to government spending and tax policy. Government consumption as a share of GDP, g, is set to 0.147 using estimates of the numerator and denominator from the Bureau of Economic Analysis (BEA) in BEA (2022, T1.1.5) and BEA (2022, T3.1). The income tax progressivity, τ_p, is set to 0.177 following our estimation results using data from the Congressional Budget Office (CBO) provided in U.S. Congressional Budget Office (2018a,b), with the estimation procedure described in Appendix A.3 and point estimates presented in Table A16. Finally, we estimate the consumption tax rate, τ_c, to be 0.044 by applying the method of Mendoza, Razin, and Tesar (1994) to OECD data for the period 2013-2015 (OECD, 2024a,b,c); estimation results are presented in Table A17 of Appendix A.4.

[13] This is within the term range for the Standard Repayment Plan (10 years) and the Extended Repayment Plan (25 years).

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Online Appendix for:
"Better Late Than Never: Delayed Undergraduate Enrollment and Financial Aid"

by Emily G. Moschini and Gajendran Raveendranathan

Contents

A Data Appendix

A.1 The 1997 National Longitudinal Survey of Youth

We use the NLSY97 for both motivating evidence (presented in the main text) and parameterization moments. Our main sample consists of respondents who we observe up to at least age 30, and who complete high school between the ages of 17 and 19. We also require that we observe our preferred measure of skill (ASVAB) for each respondent, as well as their parent's income in 1997, and that the variable recording enrollment status (which also records educational attainment) provided in each wave of the survey not imply contradictory information. This leaves us with a total of 2,589 individuals.

When we refer to skill and parental income terciles, we are referring to equal-sized bins assigned using the distribution of skill and parental income among high school graduates. We do not condition on observing educational attainment or on being in the sample until age 30 when we assign these bins.

A.1.1 Probit regression coefficients

Table A1 reports regression coefficients for the AMEs reported in Table 2 of the main text.

Table A1: Regression Coefficients: Predicting Ever Enrolling and Delay Among Enrollees

	(1) Ever	(2) Delayed	(3) Delayed
Flag: Income tercile 1	-0.471 (0.0701)	0.197 (0.0767)	0.493 (0.0894)
Flag: Income tercile 2	-0.323 (0.0676)	0.115 (0.0732)	0.262 (0.0821)
Flag: Skill tercile 1	-1.376 (0.0712)	-0.0635 (0.0796)	0.729 (0.101)
Flag: Skill tercile 2	-0.685 (0.0657)	0.273 (0.0695)	0.552 (0.0775)
Constant	1.227 (0.0598)	-1.153 (0.0608)	-1.145 (0.0652)
Observations	2,589	2,589	1,600
Sample	HS graduates	HS graduates	Ever enrolled

Notes: This table presents probit regression AMEs for (1) the likelihood of ever enrolling in a BA, conditional on receiving a high school diploma, (2) the likelihood of delayed BA enrollment conditional on receiving a high school diploma, and (3) the likelihood of delayed enrollment in a BA (at least one year after high school completion) conditional on ever enrolling. Standard errors in parentheses. Source: NLSY97.

A.1.2 Distribution of enrollment timing

Figure A1 plots percentage of high school graduates who enroll at each year after college graduation. The figure illustrates that the timing of delayed enrollment is not clumped at a particular threshold, but rather declines gradually as the enrollment horizon rises.

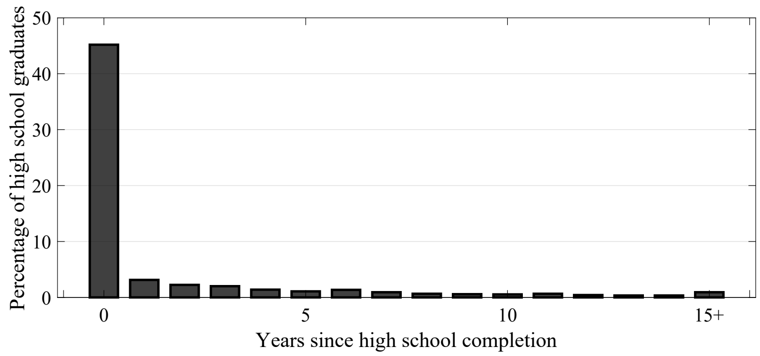


Figure A1: Distribution of enrollment timing

Notes: This figure illustrates the distribution of enrollment timing among high school graduates. Source: NLSY97.

A.1.3 Estimation moments for internally calibrated parameters

Table A2 reports various enrollment rates by skill bin and overall. The first column of Table A2 reports immediate enrollment rates (within 1 year of high school graduation); the second column contains immediate enrollment rates for those with parents in the top income tercile. The third column reports BA completion rates by age 30 for those who immediately enroll in a BA after completing high school. The fourth column reports enrollment in a BA within 7 years of completing high school, conditional on having parents in the top income tercile.

Table A2: Enrollment and BA attainment among enrollees, by skill and overall

Skill	Immediate enr	Immediate enr | Rich	BA grad | Imm Enr	Within 7 years enr | Rich
1	0.166	0.238	0.549	0.381
2	0.393	0.512	0.681	0.650
3	0.704	0.787	0.821	0.873
Total	0.452	0.632	0.754	0.742

Notes: The first column of this table presents immediate enrollment rates by skill and overall for high school graduates. The second column reports analogous statistics for respondents with parents in the top income tercile. The third column reports the BA completion rate for those who immediate enroll; the fourth column reports enrollment rates within 7 years of completing high school for respondents with parents in the top income tercile. Sample: varies across columns. Source: NLSY97.

Table A3 reports BA enrollment rates within 1 year of high school graduation (immediate), 1 year after high school graduation (1 year delay) and at some point over the sample (ever), for the population of high school graduates.

Table A3: BA enrollment rates (immediate, 1 year delay, ever)

Immediate	1 year delay	Ever
0.452	0.031	0.618

Notes: This table presents enrollment rates by timing categories. Sample: high school graduates. Source: NLSY97.

Table A4 reports immediate, delayed, and overall enrollment rates by skill tercile and parental income tercile.

Table A4: Enrollment in BA by income and skill

		BA enrollment timing		
Skill	Income	Immediately	Delayed	Ever
1	1	0.124	0.134	0.259
	2	0.207	0.128	0.335
	3	0.238	0.200	0.438
2	1	0.313	0.254	0.567
	2	0.339	0.214	0.554
	3	0.512	0.192	0.704
3	1	0.534	0.207	0.741
	2	0.669	0.161	0.831
	3	0.787	0.104	0.892
Total		0.452	0.166	0.618
Observations	2,589			

Notes: This table immediate, delayed, and overall ("ever") enrollment rates by skill tercile and parental income tercile. Sample: high school graduates. Source: NLSY97.

Table A5 tabulates the share of those who ever enroll in a BA who previously enrolled in another type of postsecondary education (PSE). Most of enrollees (almost 75 percent) who delay enrollment by at least one year previously enrolled in a sub-baccalaureate program.

Table A5: Share of delayed BA enrollees who enrolled in other PSE beforehand

	Delayed BA enrollee
Previously enrolled in sub-baccalaureate program	0.749
Observations	430

Notes: This table presents the share of delayed BA enrollees who enroll in a sub-baccalaureate program before enrolling. Sample: high school graduates who enroll in a BA at least 1 year after high school graduation. Source: NLSY97.

A.1.4 Life cycle earnings profile estimation

The model of the main text incorporates life cycle earnings profiles that vary with age, skill endowment, and education level. This quantity of efficiency units a worker has at age j has a deterministic component, $\epsilon_{j,e,s}$, and a stochastic component, η. Besides age, the deterministic component depends on education, e, and skill, s:

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

The stochastic component follows an AR(1) process with a persistence parameter, ρ_e, and a variance, σ^2_e, of the Normal distribution from which the error term ν_e is drawn which are both indexed by education, e.

$$\eta' = \rho_e \eta + \nu_e, \quad \nu_e \sim \mathbb{N}\left(0, \sigma^2_e\right)$$

To estimate the parameters of the earnings profile (following Abbott et al. (2019) and Moschini et al. (2024)), we use the Panel Study of Income Dynamics or PSID in combination with the NLSY97 to discipline the deterministic component of the life cycle profile of earnings and the distribution of shocks. Our sample selection procedure is the same as Moschini et al. (2024), except that we convert to 2012 dollars. Because we then continue to drop observations with wages above 400 dollars and below 1 dollar, comparing 2012 dollars to this threshold yields a slightly different sample count.

Note also that we use both the PSID and NLSY97 because the longer panel dimension of the PSID allows us to observe more ages than the NLSY97 and to estimate a more complete life cycle profile, while the skill measure ASVAB reported in the NLSY97 allows us to account for a college degree having a potentially different effect on labor earnings for different skill terciles. We estimate the stochastic component of the earnings process on the residuals from the NLSY97 skill-shifter estimation, which uses age-free wages cleaned by applying the age profiles estimated using the PSID.

Table A6 reports the college wage premium by skill tercile in the NLSY97. Here, we compute median wages for each education grouping and take their ratio, presented in the last column, to compute the college wage premium within each skill tercile. In Table A7 we report computed college wage premia by skill tercile using the same sample as the NLSY97 estimations in Table A6.

A.1.5 Inter vivos transfers

Table A8 reports summary statistics related to inter-vivos transfers on a subset of the life cycle earnings profile estimation sample used in Appendix A.1.4. In addition to the requirements, to estimate inter-vivos transfers we require that we observe the respondent when they are between 18 and 23 years of age, that this happen between 1997 and 2003, that the child be an independent (according to the definition of the NLSY97) and that parental income be nonmissing. With this

Table A6: Life cycle earnings process parameter estimates

Category	Data source	Parameter	Value
Age profile of earnings	PSID	$\beta^A_{e,1}$	$0.0958, 0.187$
		$\beta^A_{e,2}$	$-0.00151, -0.00328$
		$\beta^A_{e,3}$	$0.00000691, 0.0000187$
Skill shifters	NLSY97	$\beta^s_{e,s=1}$	$-0.179, -0.247$
		$\beta^s_{e,s=2}$	$-0.0644, -0.105$
Stochastic components	PSID + NLSY97	ρ_e	$0.903280, 0.884949$
		σ^2_e	$0.052023, 0.071802$

Notes: This table presents parameters of the life cycle earnings profile's deterministic and stochastic components. Sample: high school graduates. Source: PSID and NLSY97.

Table A7: BA wage premium: ratio of median wages

Skill	Wage HS	Obs(wage HS)	Wage BA	Obs(wage BA)	BA wage premium
1	13.12	7,404	17.75	1,013	1.35
2	15.29	5,764	21.10	2,706	1.38
3	16.43	3,185	24.18	5,657	1.47

Notes: This table presents the skill-specific wage premium in the NLSY97.

sample, we compute inter-vivos transfers as described in Moschini et al. (2024). Note that because the sample for the life cycle profile estimation is affected by our choice of base year for dollar values, and the inter-vivos transfer sample is a subset of life cycle profile estimation sample, the moments in Table A8 differ slightly from the analogous table in Moschini et al. (2024).

Table A8: Inter-vivos transfers: average transfers + sample summary statistics

Variable	Mean
Transfer ratio	0.588
Transfers	6,389
Transfers not allowance	663
Allowance	169
Imputed rent	6,467
Observations	8,894

Notes: This table reports statistics related to inter vivos transfers in the NLSY97. Sample: independents aged 18-23 from 1997 to 2003. Dollars are in real values. Observations are at individual-year level. Source: NLSY97.

A.2 The High School Longitudinal Study of 2009

The High School Longitudinal Study of 2009 (HSLS:09) is a panel survey conducted by the United States Department of Education that is representative of 9th graders in the US in 2009. The panel collects information in the base year of 2009 (BY), in a first follow-up in 2011 (F1), an update in the summer of 2013 (2013 Update), in a second follow-up in 2016 (F2) and via postsecondary transcripts and student records (PETS-SR). The BY and F1 rounds of data collection implement several questionnaires to sample members, their parents, and school administrators. In the 2013 Update either the student or the parent completes a questionnaire; in F2, only the student completes a questionnaire. PETS-SR contains information collected directly from postsecondary institutions and administrative records (e.g., federal student loan balances).

We use the HSLS:09 for two main purposes: first, to provide supporting evidence for the points made using the NLSY97 in the main text; and, second, to discipline parameterization moments related to financial aid and labor supply during college enrollment.

Our HSLS:09 estimation sample requires that students earn a high school diploma in 2013 and have valid observations for honors-weighted high school GPA, parental education, and parental income. A valid parental income observations means we can see discretized parent income at least once before high school completion; if we observe it twice, we use the average value after correcting for inflation. We also require that the respondent live with at least one parent at some point in the first two waves of data collection. In addition, we require that we have sufficient information to construct the respondent's postsecondary education outcome and that this outcome satisfy basic consistency conditions. This amounts to requiring that, for those who we flag as enrollees, the PETS/SR data collection have variables reflecting the first year of postsecondary enrollment populated and consistent with one another. Those we flag as not enrolling in postsecondary education are not required to have PETS/SR records (which are only collected for those with an institutional postsecondary education record).

A.2.1 Imputing income values from the CPS ASEC

We use the Current Population Survey's Annual Socioeconomic Supplement (CPS ASEC) in 2009 and 2012 to compute within-bin average incomes that we impute to income bins in the base year and first follow-up waves of the HSLS:09 to assign income a real dollar value. Table A9 reports these dollar values for each income bin. Income bin thresholds are drawn from the HSLS:09. These moments are computed for total income at the tax unit level. For the 2008 income values the sample is observations with a child between 13 and 14 and adults between 35 and 70 in 2009, while for the 2011 income values the sample is households with a child between 16 and 17 and adults between 35 and 70 in 2012. The ages of the child in these sample selection criteria reflect the ages of sample members in the base year and first follow up waves of the HSLS:09.

Table A9: Median income and federal tax liability (CPS ASEC) by income bin

Income bin	Income (2008)	Income (2011)
1	9,093	8,590
2	26,665	25,547
3	47,996	45,459
4	69,274	66,329
5	89,642	85,814
6	110,462	105,764
7	131,864	126,571
8	154,134	148,174
9	175,026	167,808
10	195,559	187,339
11	217,222	207,419
12	237,512	228,722
13	419,805	315,814
Observations	89,925	87,475

Notes: This table reports the within-bin median income used to impute dollar values to the HSLS:09 family income variable. These imputation moments from the CPS ASEC in real dollars, rounded to the nearest dollar. Source: 2009 and 2012 CPS ASEC

A.2.2 The relationship of BA enrollment to skill and income

Table A10 reports Average Marginal Effects (AMEs) from a probit regression analogous to that of Table 2 of the main text, which is run on the NLSY97. Coefficients are presented in Table A11. The HSLS:09 is a different cohort than the NLSY97 (finishing high school between 10 and 15 years later), and the former survey has a shorter panel dimension. Nevertheless, enrolling within three years after completing high school is less likely for lower income and lower skill respondents in the HSLS:09 (model 1 of Table A10), just as in the NLSY97. It is also true that, in the HSLS:09, those who enroll in a BA at some point 3 years after completing high school are more likely to delay enrollment (model 3 of Table A10). AMEs in model (3) are slighly decreasing with respect to income, and it is still true compared to poorer BA enrollees the top income tercile is relatively less likely to have delayed enrollment by at least one year.

Table A10: AMEs: BA enrollment as a function of attributes

	(1) Ever	(2) Delayed	(3) Delayed
Flag: Income tercile 1	-0.290	-0.0154	0.0607
	(0.0259)	(0.0132)	(0.0265)
Flag: Income tercile 2	-0.170	0.0128	0.0598
	(0.0216)	(0.0120)	(0.0177)
Flag: Skill tercile 1	-0.557	-0.00932	0.192
	(0.0218)	(0.0130)	(0.0349)
Flag: Skill tercile 2	-0.253	0.0183	0.0707
	(0.0216)	(0.0142)	(0.0199)
Observations	7,193	7,193	4,392
Sample	HS grads	HS grads	Ever enrolled

Notes: This table reports probit AMEs for an analogous exercise to the NLSY97 probit of the main text. Sample descriptions details are in provided in the text. Weights: Second follow up student longitudinal weights. Source: HSLS:09.

Table A11: Regression coefficients: BA enrollment as a function of attributes

	(1) Ever	(2) Delayed	(3) Delayed
Flag: Income tercile 1	-0.963	-0.109	0.286
	(0.0843)	(0.0949)	(0.115)
Flag: Income tercile 2	-0.589	0.0790	0.282
	(0.0746)	(0.0739)	(0.0783)
Flag: Skill tercile 1	-1.695	-0.0656	0.752
	(0.0706)	(0.0922)	(0.115)
Flag: Skill tercile 2	-0.839	0.114	0.341
	(0.0696)	(0.0881)	(0.0920)
Constant	1.518	-1.406	-1.445
	(0.0650)	(0.0638)	(0.0660)
Observations	7,193	7,193	4,392
Sample	HS grads	HS grads	Ever enrolled

Notes: This table reports regression coefficients for the AMEs of Table A11. Weights: Second follow up student longitudinal weights. Source: HSLS:09.

A.2.3 Estimation moments for externally estimated parameters

Tables A12, A13, and A14 report tabulations used for parameterizing the model framework computed with the HSLS:09. Specifically, Table A12 reports the average hours worked in the third year of college for all enrollees. Table A13 reports grants received as a shre of tuition and fees by skill tercile. Lastly, focusing on Pell grants, Table A14 reports Pell grant receipt and conditional amounts by skill tercile for those who enroll in college immediately after completing high school.

Table A12: Hours worked in Y3

Hours | enrollee Y3	13.95

Notes: This table reports average hours worked per week for third-year college students. Weights: Second follow up student longitudinal weights. Source: HSLS:09.

Table A13: Grants subsidy rate by skill bin

Skill tercile	Grants/TF	Prv Grants/TF	Pub Grants/TF	Pell grants/TF	Pub Grants net Pell/TF
1	0.444	0.133	0.311	0.114	0.197
2	0.460	0.138	0.322	0.094	0.227
3	0.528	0.158	0.370	0.064	0.306

Notes: This table reports grant subsidy rates broken down by skill tercile, for several grant categories. Weights: PETS-SR longitudinal weights. Source: HSLS:09.

A.3 Income tax progressivity τ_p

To estimate the income tax progressivity parameter τ_p we apply the estimation method of the robustness exercise described in Heathcote, Storesletten, and Violante (2017) to aggregate data published in "The Distribution of Household Income" by the Congressional Budget Office (CBO)

Table A14: Pell grant receipt and conditional amounts by income tercile

Skill tercile	Share Pell>0	Pell | Pell>0
1	79.73	4,925
2	43.20	3,855
3	7.85	4,105
Total	32.45	4,361
Observations	2,638	

Notes: This table reports Pell grant rates of receipt and conditional means among first-year college enrollees. Sample: Fall 2013 BA enrollees. Weights: Second follow up student longitudinal weights. Source: HSLS:09.

for 2014 and 2015 (U.S. Congressional Budget Office, 2018a,b). Table A15 reports the baseline federal tax rate in column (1), and transfer rates from Temporary Assistance to Needy Families (TANF), Supplemental Nutrition Assistance Program (SNAP), and Supplemental Security Income (SSI) in columns (2), (3), and (4), respectively. The net tax rate in column (5) is measured the federal tax rate (which includes refundable credits) net of the transfer rates from TANF, SNAP, and SSI. Pretax income and its log are in columns (6) and (7); the log of after-tax income is in column (8), computed as $\log\left((6) \times (1-(5))\right)$.

Table A15: Income and tax data from CBO reports

	Percentiles		**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Year	Min	Max	Fed. tax	TANF	SNAP	SSI	Net tax	Ave. Y	$\log(Y)$	$\log(Y_{AT})$
2014	99	100	33.6				33.6	1.77	0.25	0.07
	96	99	26.7				26.7	0.34	-0.47	-0.60
	91	95	23.4				23.4	0.21	-0.69	-0.80
	81	90	21.2				21.2	0.15	-0.82	-0.92
	60	80	17.8				17.8	0.10	-0.98	-1.07
	40	60	14.0				14.0	0.07	-1.16	-1.23
	20	40	9.1	1.6	1.6	1.1	4.8	0.04	-1.38	-1.40
	0	20	1.9	6.6	9.7	7.0	-21.4	0.02	-1.72	-1.63
2015	99	100	33.4				33.3	1.86	0.27	0.09
	96	99	26.7				26.7	0.36	-0.45	-0.58
	91	95	23.6				23.6	0.21	-0.67	-0.79
	81	90	21.3				21.3	0.16	-0.80	-0.91
	60	80	17.9				17.9	0.11	-0.97	-1.05
	40	60	14.0	0.5			13.5	0.07	-1.15	-1.21
	20	40	9.2	1.6	1.4	0.9	5.4	0.04	-1.36	-1.38
	0	20	1.5	6.5	9.0	6.7	-20.7	0.02	-1.79	-1.62

Notes: This table reports data used to estimate τ_p. Data is from 2014 and 2015, and dollar values in column (6) are in millions of current USD. After-tax income is defined as $Y_{AT} \equiv \left(1 - \frac{\text{Net tax}}{100}\right) Y$, where the net tax rate is defined as $(5) \equiv (1) - (2) - (3) - (4)$.

The estimation equation uses the relationship between after-tax income and pretax income in logs: $\log(Y_{AT}) = \log(\lambda) + (1-\tau_p)\log(Y)$. The estimation equation is $\log(Y_{AT}) = \beta_0 + \beta_1 \log(Y)$, where $\beta_1 = 1 - \tau_p$. The dependent variable is column (8) from , and the independent variable is column (7), in Table A15. We use an Ordinary Least Squares or OLS estimator, and weight each row's observation using population shares for each row, implied by the row's percentiles. Table

A16 presents estimation results. The annual estimated value for τ_p over this time period is on average 0.177.

Table A16: Estimation results: τ_p

Coefficient	**2014**		**2015**	
β_1	0.822	(0.0250)	0.824	(0.0244)
β_0	-0.251	(0.0309)	-0.246	(0.0298)
Annual: $\hat{\tau}_{p,t}$	0.178		0.176	
Average: $\hat{\bar{\tau}}_p$	0.177			

Notes: This table reports estimation results. Standard errors in parentheses.

A.4 Consumption tax rate τ_c

We apply equation (5) of Mendoza, Razin, and Tesar (1994) to OECD data for the 2013-2015 period (OECD, 2024a,b,c). This equation is:

$$\tau_{c,t} = 100 \times \frac{5110_t + 5121_t}{C_t + G_t - GW_t - 5110_t - 5121_t} \tag{11}$$

Table A17 summarizes estimation data (Panels A, B, and C) and estimation results (Panel D). We parameterize τ_c as the average of annual estimated values from 2013 to 2015: 0.044.

Table A17: OECD data and τ_c estimation results

Variable	**Description**	**2013**	**2014**	**2015**	**Source**
Panel A: Total tax revenue (all levels of government)					
5110	General taxes on goods and services	343,853	361,685	374,173	OECD (2024c)
5121	Excises	154,390	155,976	156,902	
Panel B: Final consumption expenditure					
C	Private	11,040,849	11,521,194	11,933,651	OECD (2024b)
G	Government	2,530,745	2,562,276	2,603,988	OECD (2024a)
Panel C: Compensation of employees by source					
GW	Paid by producers of gov't services	1,665,524	1,706,888	1,758,064	OECD (2024a)
Panel D: Estimation results for τ_c					
$\hat{\tau}_{c,t}$	Annual rate (share)	0.044	0.044	0.043	
$\hat{\bar{\tau}}_c$	Average rate (share)	0.044			

Notes: This table reports OECD data used in the consumption tax rate estimation and the estimation results. Dollar values are in millions of current USD for that year, rounded to the nearest dollar.

B Model Appendix

B.1 Consumer value functions after highest educational attainment

This section presents the value functions after the highest level of educational attainment is permanently determined.

Consumers are required to begin student loan payments the year after they are no longer enrolled in college regardless of whether or not they completed college. The idiosyncratic state of a consumer when $j \neq j_f + j_a$ is given by the tuple (j, e, s, η, a). The consumer's value function is given by

$$V(j, e, s, \eta, a) = \max_{d_f \in \{0,1\}} (1 - d_f) V^R(j, e, s, \eta, a) + d_f V^D(j, e, s, \eta, a) \tag{12}$$

where d_f denotes the student loan delinquency decision. The objects $V^R(\cdot)$ and $V^D(\cdot)$ denote the value of repayment and the value of delinquency, respectively. The value of repayment for $j \neq j_f + j_a$ is given by

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

$$s.t.$$

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

$$a' \geq \min[(1 + r_{SL})a + \rho_R(j, a), 0]$$

The constraint on a' is the loan repayment constraint, which requires that if the consumer has outstanding federal loans, then the consumer must repay at least $\rho_R(j, a)$ of the outstanding principal plus interest.

Alternatively, these consumers can choose delinquency. The value function for $j \neq j_f + j_a$ is given by

$$V^D(j, e, s, \eta, a) = \max_{c \geq 0, x \in X} U(c, x, j, d_e = 0, d_f = 1) + \beta \psi_j E_{\eta'|e,\eta} V(j + 1, e, s, \eta', a') \tag{14}$$

$$s.t.$$

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

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

In the case of delinquency, consumers do not make a consumption-savings decision. Instead, they have their wage garnished to make a partial payment $\rho_D(j, a, y_{j,e,s,\eta,a,x})$. Therefore, they consume whatever remains from their disposable income, plus accidental bequests, after making the partial payment. The parameter ϕ_D is the fraction of the missed payment, the 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). During delinquency the consumer also faces a stigma cost, which is represented in the utility function in equation (1) by ξ_D.

When $j = j_f + j_a$, in addition to the choices described above, the parent chooses an inter vivos transfer to their child, who will become an independent agent in that period. At the start of age $j_f + j_a$, the parent draws their child's skill type and then chooses whether or not to be delinquent on any student debt payments; the EFC of the child, f, is determined based on parental income, parental net assets, and the respective probabilities of qualifying for a professional judgment. The value function before the draw of child skill type is given by

$$V(j,e,s,\eta,a) = \sum_{s_c} \pi_{s_c}(s_c)\,\big[\max_{d_f\in\{0,1\}}(1-d_f)V^R(j,e,s,\eta,a,s_c) + d_f V^D(j,e,s,\eta,a,s_c)\big] \quad (15)$$

where $\pi_{s_c}(s_c)$ is the probability over child skill. The value of repayment for $j = j_f + j_a$ is given by

$$\begin{aligned}
V^R(j,e,s,\eta,a,s_c) = &\max_{c\geq 0,a',x\in X,a_c} U(c,x,j,d_e=0,d_f=0) + \beta\psi_j E_{\eta'|e,\eta}V(j+1,e,s,\eta',a') + \quad (16)\\
&\beta_c E_{\eta'|\ell}\big[\pi_{AAI}(\tilde{y})W(s_c,\eta',a_c,EFC(\tilde{y},a,0)) + (1-\pi_{AAI}(\tilde{y}))W(s_c,\eta',a_c,EFC(\tilde{y},a,1))\big]\\
&s.t.\\
&(1+\tau_c)c + a' + a_c = y_{j,e,s,\eta,a,x} + a + r_{SL}a\mathbb{I}_{a<0} + Tr_j - T(y_{j,e,s,\eta,a,x})\\
&a' \geq \min[(1+r_{SL})a + \rho_R(j,a), 0]\\
&a_c \geq 0\\
&\tilde{y} = y_{j,e,s,\eta,a,x=ft}
\end{aligned}$$

where $EFC(\cdot)$ is the EFC formula defined in equation (19), a_c is the inter vivos transfer to the child, $W(\cdot)$ is the child's value function, β_c disciplines the intensity of parental altruism toward the child, $\pi_{AAI}(\cdot)$ is the probability with which the child does not qualify for a professional judgment by the aid administrator, and $\tilde{y}$ is income at full time work hours, $x = ft$. When computing the EFC, parental income assuming full time work hours is used to avoid moral hazard incentives with respect to hours worked; otherwise, the parent may have an incentive to work fewer hours to lower the EFC so that the child qualifies for more need-based aid.[14]

[14]In reality, this moral hazard incentive is most likely not big because the EFC is updated for every academic year of college. In our model, for the purposes of tractability, the EFC is determined in the year that the child leaves the

When $j = j_f + j_a$ and the consumer chooses delinquency, we assume for simplicity that those consumers cannot make an inter vivos transfer to their child. Therefore, the value functions for delinquency are the same as in equation (14), with the difference that the parent has a term reflecting altruistic utility toward their child in their objective function.

B.2 Additional functional forms and equilibrium definition

This section presents functional forms not provided in the main text in Section 3.1 and the equilibrium definition.

Professional judgment probability function. With probability $\pi_{AAI}(y)$, an 18-year-old does not qualify for a professional judgment by the aid administrator. This probability function is given by

$$\pi_{AAI}(y) = 1 - \exp(-\phi_{AAI} y) \tag{17}$$

where ϕ_{AAI} governs the rate at which the probability function is increasing in y.

Adjusted available income function. When the applicant does not qualify for an automatic zero EFC, the EFC is determined using a schedule provided in the second case of the EFC formula in equation (19). The input into the schedule is adjusted available income, which is computed using the function given by

$$y_{adj}(y, a, d_{pj}) = [(1 - d_{pj}) + d_{pj}\tau_{AAI}][y - T(y) + \tau_a \max(-a - a_{prot}, 0)] \tag{18}$$

where τ_a and a_{prot} denote the asset conversion rate and the asset protection allowance, respectively.

Expected family contribution function. The function to determine the EFC is given by

$$EFC(y, a, d_{pj}) = \begin{cases} 0 & \text{if } y \leq y_{EFC=0} \text{ or } T(y) \leq 0 \\ \bar{f}_i + \tau_{f,i}[y_{adj}(y, a, d_{pj}) - \underline{y}_{f,i}] & \text{else, } y_{f,i} < y_{adj} \leq y_{f,i+1} \end{cases} \tag{19}$$

for $i = 1, ..., n_f$. If parental income is less than or equal to the zero EFC income threshold, $y_{EFC=0}$, or income tax is less than 0 (i.e., positive transfers), then the expected family contribution is an automatic 0. Otherwise, the EFC is determined using the EFC schedule after computing the adjusted available income using equation (18).

Full payment function. Federal student loan repayment leads to a full payment given by the

household and stays constant thereafter.

function

$$\rho_R(j,a) = \begin{cases} -\left[\frac{r_{SL}}{1-(1+r_{SL})^{-(T_{SL}+1-j)}}\mathbb{I}_{j\leq T_{SL}} + (1+r_{SL})\mathbb{I}_{j>T_{SL}}\right]a & \text{if } a<0 \\ 0 & \text{otherwise} \end{cases} \tag{20}$$

If there is an outstanding balance and j is still within T_{SL} periods of repayment, then the loan is amortized with an interest rate of r_{SL}; otherwise, the outstanding principal plus interest is due. If there is no outstanding loan balance, the payment amount is zero.

Partial payment function. Federal student loan delinquency leads to a partial payment given by the function

$$\rho_D(j,a,y) = \min[\tau_g \max[y - T(y) - \bar{y}, 0], \rho_R(j,a)] \tag{21}$$

To present the function for Social Security transfers and then define the equilibrium, we must first discuss notation. Let $\overrightarrow{\omega}$ denote the idiosyncratic state of a consumer. This state depends on age and enrollment status in the following way:

$$\overrightarrow{\omega} = \begin{cases} (s,\eta,a,f) & \text{for 18-year-olds, before realization of college enrollment option shock} \\ (j,\ell,s,\eta,a,f) & \text{for potential future enrollees} \\ (j,j_c,\ell,s,\eta,a,f) & \text{for consumers in college} \\ (j,e,s,\eta,a) & \text{for consumers who will never enroll, dropouts, or graduates, if } j\neq j_f+j_a \\ (j,e,s,\eta,a,s_c) & \text{if } j=j_f+j_a \end{cases} \tag{22}$$

Furthermore, let $d_{d,t}(\overrightarrow{\omega})$ denote the dropout decisions that solve the endogenous discrete dropout problems in the continuation values of equation (9).

Social Security transfer function. Social Security transfers are set equal to 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

$$ss_{e,s} = \frac{\chi}{2}\left[\frac{\int w_e\eta\epsilon_{j,e,s}x(\overrightarrow{\omega})\Omega_t d(\overrightarrow{\omega}|18\leq j<j_r,e,s)}{\int \Omega_t d(\overrightarrow{\omega}|18\leq j<j_r,e,s)} + \frac{\int w_e\eta\epsilon_{j,e,s}x(\overrightarrow{\omega})\Omega_t d(\overrightarrow{\omega}|18\leq j<j_r)}{\int \Omega_t d(\overrightarrow{\omega}|18\leq j<j_r)}\right] \tag{23}$$

Although we compute the transition path in our analysis, thus far we omitted time subscripts for the ease of exposition. For the definition of equilibrium, we include a time subscript, t, to indicate which variables may change along a transition path.

Equilibrium definition. Given an initial level of capital stock K_0 and an initial distribution over idiosyncratic states $\Omega_0(\overrightarrow{\omega})$, a competitive equilibrium consists sequences of household value functions $\{W_t(\overrightarrow{\omega}), V^{PFE}{}_t(\overrightarrow{\omega}), V^{BA}{}_t(\overrightarrow{\omega}), V_t(\overrightarrow{\omega}), V_t^R(\overrightarrow{\omega}), V_t^D(\overrightarrow{\omega})\}$, household college entrance and dropout policy functions $\{d_{e,t}(\overrightarrow{\omega}),\ d_{d,t}(\overrightarrow{\omega})\}$, household consumption, hours worked, and next period asset policy functions $\{c_t(\overrightarrow{\omega}),\ x_t(\overrightarrow{\omega}), a_t'(\overrightarrow{\omega})\}$, household delinquency policy functions $\{d_{f,t}(\overrightarrow{\omega})\}$, household inter vivos transfer policy function $\{a_{c,t}(\overrightarrow{\omega})\}$, production plans $\{Y_t, K_t, L_t, L_{\ell,t}, L_{h,t}\}$, tax policies $\{\gamma_t\}$, prices $\{r_t, w_{\ell,t}, w_{h,t}\}$, Social Security transfers $\{ss_{t,e,s}\}$, accidental bequests $\{Tr_{t,j}\}$, and measures $\{\Omega_t(\overrightarrow{\omega})\}$ such that:

(i) Given prices, transfers, and policies, the value functions and household policy functions solve the consumer problems in equations (8)-(10) and (12)-(16);

(ii) The saving interest rate and wage rates satisfy firm first order conditions;

(iii) Social Security transfers satisfy equation (23);

(iv) Accidental bequests are transferred to households between ages 50 and 60 $(33 \leq j \leq 43)$ after deducting expenditure on private education subsidies[15]

$$Tr_{t+1,j} = \frac{\int (1-\psi_j) a_t'(\overrightarrow{\omega}) \Omega_t d(\overrightarrow{\omega}) - \int \theta^{pr}(s) \mathbb{I}_{e=h \text{ and } j\in\{1,2,3,4\}} \Omega_{t+1} d(\overrightarrow{\omega})}{\sum_{j=33}^{43} N_{t+1,j}} \tag{24}$$

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

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

$$\int [\tau_c c_t(\overrightarrow{\omega}) + T(y_{t,j,e,s,\eta,a})] \Omega_t d(\overrightarrow{\omega}) = G_t + E_t + D_t + SS_t \tag{25}$$

where G_t, E_t, D_t, and SS_t are government consumption, total public education subsidy, federal student loan program expenditure, and Social Security expenditure;

(vi) Labor, capital, and goods markets clear in every period t; and

(vii) $\Omega_{t+1} = \Pi_t\Big(\Omega_t\Big)$, 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 the probabilities of being allowed to continue college.

Note that in the stationary equilibrium, the the equilibrium distribution will be stationary, and all aggregates, prices, taxes, and transfers will be constant, and all value functions and policy functions

[15] 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.

will be time invariant.

B.3 Computational algorithm

This section presents the computational algorithm to solve for the stationary equilibrium. The algorithm for the transition path is analogous except that the value functions, policy functions, prices, taxes, transfers, and distributions are indexed by a time subscript.

1. Guess interest rate, r_{guess}, wage rates, $w_{\ell,\text{guess}}$ and $w_{h,\text{guess}}$, the level parameter for the income tax rate, γ_{guess}, Social Security transfers, $ss_{e,s,\text{guess}}$, and accidental bequests, $Tr_{j,\text{guess}}$
2. Use backward induction to solve consumer problems during the empty nester and retirement phases from $j = j_f + j_a + 1, \ldots, J$ (equations (12)-(14))
3. Guess value function before college, $W_{\text{guess}}(s, \eta, a, f)$ (equation (8))
4. Use backward induction to solve consumer problem from $j = 1, \ldots, j_f + j_a$ (equations (8)-(16). In solving the consumer problem at $j = j_f + j_a$, use $W_{\text{guess}}(s, \eta, a, f)$ for the altruism term.
5. Use new value before college to update $W_{\text{guess}}(s, \eta, a, f)$; repeat 4.-5. until convergence
6. Guess initial distribution of 18-year-old consumers $\Omega(j = 1, s, \eta, a, f)_{\text{guess}}$
7. Simulate and solve for distribution of Ω for $j = 2, \ldots, J$
8. Use distribution of Ω for $j = j_f + j_a$, exogenous processes for college enrollment option shock, child skill, productivity, and qualification for professional judgment, and inter vivos transfers policy function to compute new estimates for distribution of initial 18-year-old consumers $\Omega(j = 1, s, \eta, a, f)$
9. Update $\Omega(j = 1, s, \eta, a, f)_{\text{guess}}$ and repeat 7.-9. until convergence
10. Given the stationary distribution of Ω for $j = 1, \ldots, J$, solve for new guesses:
    - Compute interest and wage rates from the firm's first order conditions
    - Compute the level parameter for the income tax rate using the government budget constraint (equation (25))
    - Compute Social Security transfers and accidental bequests (equations (23) and (24))
11. Update guesses in 1., and repeat steps 2.-11. until convergence

B.4 Welfare computation

To measure welfare changes for the 18-year-old consumer, we use consumption-leisure equivalent variation. We measure consumption-leisure 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 fixed costs or benefits. This approach is similar to that of Abbott, Gallipoli, Meghir, and Violante (2019), Moschini, Raveendranathan, and Xu (2024), and Moschini and Raveendranathan (2024). For the average 18-year-old in period t of the transition to the new stationary steady state, the consumption-leisure equivalent variation, $g_{cx,t}$, is computed using the following equation

$$(1+g_{cx,t})^{1-\sigma}\int V_{\text{initial}}(1,\ell,s,\eta,a)\Omega_{\text{initial}}d(\overrightarrow{\omega})=\int W_t(s,\eta,a,f)\Omega_t d(\overrightarrow{\omega}) \tag{26}$$

where on the left-hand side of the equation, “initial" refers to the initial stationary equilibrium. To compute the resulting gains or losses from a policy change in consumption-leisure equivalent units, we report the difference between period t and the initial stationary equilibrium: $100\times(g_{cx,t}-g_{cx,\text{initial}})$. When measuring welfare holding the distribution of 18-year-old consumers fixed to that from the initial stationary equilibrium, we use the distribution Ω_{initial} instead of Ω_{t} for the right-hand side of equation (26).

C Results Appendix

C.1 Initial distribution of assets among high school graduates

Figure C1 depicts the initial distribution of assets among high school graduates in the baseline calibration. The initial assets are determined by inter vivos transfers received from the parents.

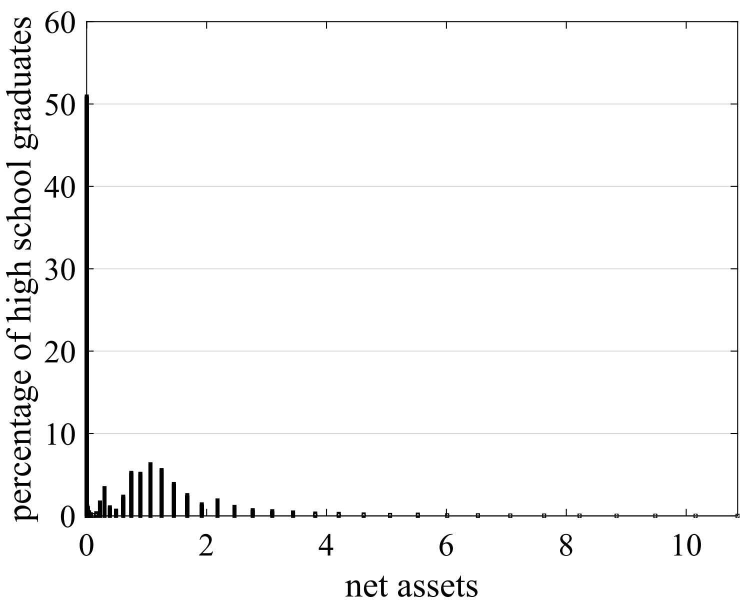


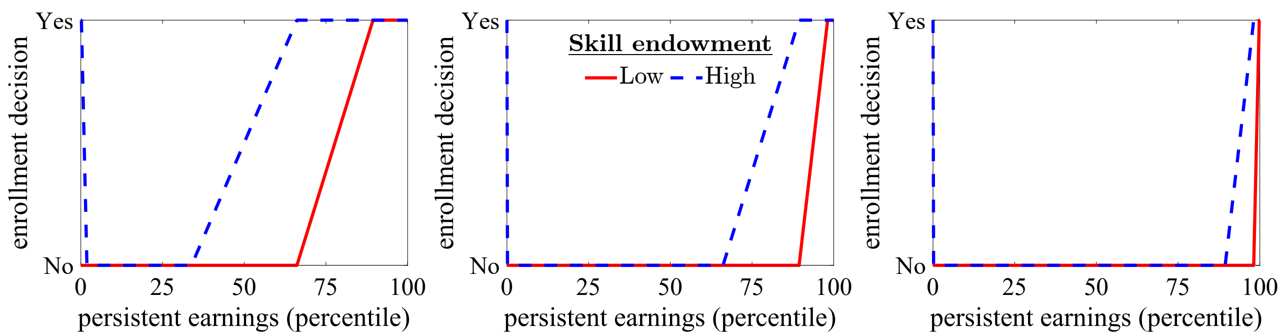
Figure C1: Initial distribution of assets among high school graduates

Notes: The figure depicts the initial distribution of assets among high school graduates in the baseline calibration. Net assets are reported in the units of the numeraire, where the GDP per capita for 18+ is calibrated so that it is equal to one in the baseline calibration.

C.2 Enrollment decision by persistent earnings

Figure C2 depicts the enrollment decision by years since high school completion across panels in the baseline calibration. Within each panel, the decision is reported by the percentile of persistent earnings for those with low skill and high skill. Additional details on the consumers' state space are provided in the figure notes.

The figure illustrates that waiting for higher persistent earnings is not a first order reason to delay enrollment in our calibrated model. With each year since high school completion, the highest threshold at which the consumer enrolls shifts to the right. At the same time, earnings realizations from the AR(1) process are highly persistent in our estimation (Table 7). As a result, the likelihood of enrolling later in the life cycle due to an increase in persistent earnings is small.



(a) Baseline: years = 0 (b) Baseline: years = 1 (c) Baseline: years = 2

Figure C2: Enrollment by years since high school completion and persistent earnings and skill

Notes: The figure depicts the enrollment decision by years since high school completion across panels in the baseline calibration. Within each panel, the decision is reported by the percentile of persistent earnings for those with low skill and high skill. We restrict our analysis to a consumer who has zero net assets and whose EFC is zero (that is, they are eligible for the most need-based federal aid).

C.3 Loan limit expansion welfare changes

Table A18 reports the welfare changes resulting from the federal student loan limit expansion experiment for high school graduates based on their parental income and skill.

Table A18: Welfare changes in consumption-leisure units

	Skill tercile		
Parental income tercile	**Low**	**Medium**	**High**
1	0.99	1.88	2.82
2	0.74	1.18	1.34
3	0.38	0.11	-1.02

Notes: The table presents welfare changes for high school graduates by parental income and skill after a federal loan limit expansion of 100 percent. Welfare changes are reported as percentage point changes in lifetime consumption-leisure equivalent units.