

Financing Human Capital with Student Aid*

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Abstract

Student aid can expand college access or direct students toward higher-earning fields. I quantify this tradeoff in a life-cycle model in which individuals choose schooling, borrowing, repayment, and a major, trading earnings against field of study preferences. I evaluate reforms to credit access, tuition, grants, and repayment, financing each through taxes. Universal free tuition raises Bachelor attainment and welfare more than STEM-contingent free tuition, with consumption-equivalent gains of 4.1 and 3.4 percent. The field condition generates more STEM graduates, and the two policies produce similar earnings values of human capital. Access to loans remains valuable when tuition is free, and modest loan expansions improve completion with little additional public financing. Benefits also depend on the form of assistance: last-dollar tuition subsidies favor high-resource entrants in percentage welfare terms, whereas flat grants favor those with fewer family resources.

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1 Introduction

Financing higher education requires students to bear costs today in exchange for returns that arrive later. Unlike physical capital, however, human capital generally cannot serve as collateral. Students must finance tuition and living expenses before receiving the earnings that schooling may generate, often at a time when their own resources are limited. Governments address this problem through student loans, grants, and tuition subsidies. Loans allow students to draw on future income but leave them responsible for repayment; grants and subsidies shift more of the cost to taxpayers. The conditions attached to assistance can also influence what students study. Education finance therefore affects both the amount of human capital individuals acquire and its composition across fields.

Recent federal reforms make these questions especially relevant. The 2025 legislation changes borrowing limits across graduate and professional programs and establishes an earnings-accountability framework that can withdraw federal loan eligibility from programs with persistently low graduate earnings.¹ These policies give program choice a direct role in access to public credit. Field-contingent assistance has an appealing fiscal rationale: higher earnings can generate more tax revenue and help borrowers repay their loans. Students also value the subjects they study, however, and some may forgo a degree rather than accept a field restriction. Whether directing assistance toward higher-return fields improves on broader support depends on both responses.

I study these questions in a life-cycle model in which heterogeneous individuals jointly choose schooling, work, financing, and repayment. Students choose full-time or half-time attendance, whether to continue toward an undergraduate or graduate degree, and their field of study. They finance tuition and consumption through earnings, parental support, assets, unsecured credit, grants, and student loans. After leaving school, borrowers choose between Standard and income-based repayment and decide whether to make required payments. A

¹See [Federal Student Aid \(2026\)](#); [U.S. Department of Education \(2026\)](#). The baseline uses 2019 financing and repayment rules. These experiments compare alternative aid designs rather than simulate the 2025 legislation.

continuous field of study index links higher earnings to a potentially greater departure from an individual's preferred field. Assistance can consequently change the decision to complete a degree and the return associated with that degree.

Major choice matters for the evaluation of aid because private and fiscal returns differ. Students receive the nonpecuniary benefits of their fields, while the government receives taxes and loan payments. Public assistance and repayment insurance leave students bearing only part of the fiscal consequences of their choices, creating a potential moral-hazard concern. A field of study condition on student aid can direct publicly supported education toward higher earnings, but it can also discourage completion or require students to give up fields they prefer. A preference for a lower-earning field is itself a source of utility. The welfare comparison must therefore account for that value alongside earnings and public costs.

I discipline the model with U.S. evidence on educational attainment, attendance intensity, earnings, household resources, student borrowing, and repayment. The initial distribution allows academic preparation, family resources, college prices, and parental support to be related. The calibration also uses the relationship between financing circumstances and field choice to discipline the strength of field preferences. The resulting framework permits aid to affect entry, persistence, graduate study, and major choice within the same household problem.

I evaluate changes to credit access, tuition subsidies, undergraduate grants and loan limits, and repayment rules. Field-contingent policies require a binding commitment to the higher-return portion of the field of study continuum, classified as 'STEM' using a cutoff calibrated to the observed STEM share in the data. Separate experiments restrict undergraduate eligibility by family resources or academic productivity. These comparisons distinguish the effects of the financing instrument, the recipients eligible for assistance, and the fields they must choose.

Each reform preserves the government's expected discounted net receipts from an entering cohort. I solve for a proportional adjustment to labor taxes that finances the reform over

that cohort's life cycle, including induced changes in earnings, repayment, and benefits. Institutional prices, parental support, and the parameters of the earnings schedule remain fixed, while education, earnings, and labor supply respond to policy.

The results first establish the continuing role of student credit. Eliminating new student loans reduces bachelor's attainment from 36.0 to 29.1 percent and lowers welfare by 0.6 percent in consumption-equivalent terms. STEM completion falls as well. Other resources do not fully replace the lost financing, and loans remain valuable even when tuition is free because students must finance living expenses while enrolled. Restricting credit to STEM raises STEM completion but reduces total attainment, illustrating how a field of study condition can redirect education while limiting access.

Free tuition expands completion under both universal and STEM-contingent eligibility, with different effects on field choice. Universal tuition raises bachelor's attainment to 55.1 percent, compared with 48.5 percent under the STEM condition. Targeting has a much larger effect on STEM completion: its share of the cohort with STEM degrees rises from 12.7 to 45.8 percent, compared with 19.2 percent under universal tuition. The targeted policy encourages both additional completion and movement toward higher-return fields among students who would already graduate. Universal tuition also enables some students to complete degrees in preferred, lower-earning fields.

These responses produce similar earnings values of human capital despite the differences in completion and field composition. Universal tuition generates more education, while STEM tuition raises the average field return among graduates. Universal tuition delivers the larger welfare gain—4.1 percent, compared with 3.4 percent—after accounting for its greater financing requirement. Thus, a policymaker seeking more STEM graduates would favor a different policy from one seeking greater completion or household welfare in these experiments.²

More moderate expansions show how the form of assistance affects this tradeoff. A \$2,000

²The reforms have different public costs. Their comparison evaluates financed policy packages rather than an allocation of a common budget.

annual undergraduate grant raises bachelor’s attainment by 3.4 percentage points, while an equally sized increase in annual borrowing capacity, accompanied by greater aggregate capacity, raises it by 2.8 points. Grants deliver larger welfare gains, but loans require much less public financing. A STEM condition changes the completion response. At the \$2,000 increment, STEM-contingent grants increase STEM degrees while reducing total bachelor’s attainment after financing, whereas STEM-contingent loan expansions increase both. The distinction persists under means and ability requirements. Additional borrowing capacity remains valuable only insofar as students wish to use credit that they must subsequently repay.

The distribution of benefits also depends on the instrument. Universal free tuition yields average individual welfare gains of 7.8 percent among high-resource entrants and 1.4 percent among low-resource entrants. Its last-dollar design pays tuition remaining after existing grants, so students whose grants already cover tuition receive no additional payment. A flat grant can instead provide resources for living expenses and delivers larger percentage welfare gains to low-resource entrants. Attendance, college prices, and graduate study also contribute to these differences.

Repayment reforms influence the obligations students anticipate when making schooling decisions. Requiring income-based repayment lowers attainment and welfare when borrowers retain participation costs, including those who would otherwise choose Standard. Removing the cost reverses the result and generates a small fiscal saving. The interpretation depends on what participation entails. Automatic enrollment might remove information and administrative costs, while a preference for a fixed repayment schedule or a shorter repayment horizon could remain. Understanding these sources is therefore important for assessing whether simplifying repayment can improve welfare while retaining the fiscal advantages of income-based payments.

The paper contributes to the quantitative literature on education finance and borrowing constraints ([Keane and Wolpin, 2001](#); [Lochner and Monge-Naranjo, 2011](#); [Johnson, 2013](#)).

[Garriga and Keightley \(2013\)](#) emphasize how student work and selection into college shape responses to aid. [Abbott et al. \(2019\)](#) incorporate endogenous family transfers and equilibrium prices in comparing education policies. I examine how financing also changes the earnings and nonpecuniary returns associated with the fields students choose. This margin helps explain why policies with similar effects on completion can differ in earnings, repayment, and welfare. The positive completion responses to broad credit and grant expansions also accord qualitatively with the evidence in [Black et al. \(2023\)](#) and [Denning et al. \(2019\)](#).

The analysis builds on research documenting the roles of preferences, information, and heterogeneous returns in major choice ([Arcidiacono, 2004](#); [Wiswall and Zafar, 2015](#); [Kirkebøen et al., 2016](#)). Evidence on tuition differences and field-contingent aid shows that financial incentives can change these choices ([Stange, 2015](#); [Denning and Turley, 2017](#); [Castleman et al., 2018](#)). Related quantitative studies connect financing and human-capital investment, including major choice ([Huang, 2023](#); [Hampole, 2024](#); [De Falco and Reichlin, 2026](#); [Murto, 2024](#)). I compare binding field conditions on tuition assistance and credit within a framework that follows students through completion, graduate study, and repayment. Following these outcomes together distinguishes additional high-return degrees generated through greater completion from those generated through changes in field choice.

Finally, the repayment experiments extend the insurance-and-incentives questions studied by [Matsuda and Mazur \(2022\)](#) and [de Silva \(2025\)](#) to schooling and field decisions made before repayment. [Catherine et al. \(2026\)](#) distinguish the transfer, consumption-smoothing, and insurance components of income-contingent lending. Here, anticipated repayment obligations also change the amount and composition of education, which in turn affect future taxes and loan payments. The comparison between optional and mandatory income-based repayment further shows how the value of insurance depends on the burdens associated with participation.

Section 2 presents the model. Section 3 describes the calibration and assesses model fit. Section 4 presents the policy experiments, and Section 5 concludes.

2 Model

I develop a life-cycle model in which individuals choose how much human capital to acquire, what type to acquire, and how to finance it. Individuals enter the model at age 18 with different academic productivity, labor-market productivity, family resources, college costs, and parental support. While they retain access to school, they choose whether to attend full-time, attend half-time, or leave school permanently. Students divide their available time between school and work, and they finance tuition and consumption using current resources, family transfers, grants, and student loans. Time in school produces human capital. Accumulating sufficient human capital produces a bachelor's degree and, with further study, a graduate degree.

When an individual leaves school with a degree, she chooses a field on a continuum from non-STEM to STEM. Fields closer to STEM provide larger earnings returns but may be farther from the individual's preferred field. Schooling therefore determines both the amount of human capital an individual produces and, through field choice, its composition. After leaving school, individuals work, save or borrow, and repay any student debt.

2.1 Environment and Timing

Time is discrete and annual. Individuals enter at age 18, retire at age T^R , and live to at most age T . They face age-specific survival probabilities. The model contains four stages: potential student, school exit and field choice, working life, and retirement. I suppress individual subscripts throughout the model description; variables and choices refer to a given individual unless otherwise stated.

An individual enters with liquid assets a_0 , persistent academic productivity z^H , persistent labor-market productivity ε_0^P , a family-resource type W^P , and a college-cost type q . The joint distribution of (z^H, W^P, q) allows academic preparation, family resources, and college costs to be correlated when the individual enters the model. Conditional on family resources

and college costs, the individual also draws a persistent exogenous parental-support state s . This state determines whether she receives help while enrolled and the amount of that help.

Dependency status changes with age. I treat students as dependent through age 23 and independent from age 24 onward. This transition changes the financing available during undergraduate study: independent students face higher annual and aggregate student-loan limits, a different federal-grant schedule, and reduced parental transfers. Dependency status is determined by age rather than chosen by the student. Independent students may continue to receive parental support.

A potential student chooses schooling intensity from

$$S_t \in \{0, S^{HT}, S^{FT}\}, \quad (1)$$

where S^{HT} and S^{FT} denote half-time and full-time attendance. Choosing $S_t = 0$ ends access to school permanently. Students may alter attendance intensity while enrolled, but an individual who leaves school cannot subsequently reenter. All individuals must leave school by age T^S .

Let h_t denote accumulated human capital and B_t the outstanding student-debt balance. The thresholds h_1 and h_2 determine bachelor's and graduate degree completion, respectively. Crossing h_1 records a bachelor's degree but does not require the student to leave school. She may continue accumulating human capital toward h_2 . A student who leaves with $h_t < h_1$ enters the labor market without a degree. A student who leaves with $h_t \geq h_1$ first chooses a field of study and then enters the working stage. Reaching h_2 ends further enrollment.

2.2 Preferences, Earnings, and Financial Assets

Individuals value consumption and dislike work. When not enrolled in school, flow utility depends on consumption net of the disutility of work,

$$u(c_t, n_t) = \frac{1}{1-\gamma} \left(c_t - \frac{\nu}{1+\phi} n_t^{1+\phi} \right)^{1-\gamma}, \quad (2)$$

where c_t is consumption, n_t is labor supply, ν scales the disutility of work, $1/\phi$ is the Frisch elasticity of labor supply, and γ governs risk aversion.³ Individuals discount future utility by β .

Gross labor earnings depend on age, labor supply, persistent productivity, transitory earnings risk, nonemployment, and the human capital acquired in school. Before incorporating educational returns, earnings are

$$y_t = (1 - \nu_t) \exp(\alpha + g(t) + \varepsilon_t^P + \varepsilon_t^T) n_t, \quad (3)$$

where α sets the level of earnings, $g(t)$ is a deterministic age profile, ε_t^P is persistent productivity, ε_t^T is a transitory shock, and $\nu_t \in \{0, 1\}$ indicates nonemployment.

Persistent productivity follows an AR(1) process,

$$\varepsilon_t^P = \rho_P \varepsilon_{t-1}^P + \eta_t, \quad \varepsilon_0^P \sim \mathcal{N}(0, \sigma_{P,0}^2). \quad (4)$$

Both the persistent innovation and the transitory shock are drawn from mixtures of two

³When $\gamma = 1$, utility is $\log\left(c_t - \frac{\nu}{1+\phi} n_t^{1+\phi}\right)$.

normal distributions:

$$\eta_t \sim \begin{cases} \mathcal{N}(\mu_{\eta,1}, \sigma_{\eta,1}^2) & \text{with probability } p_\eta, \\ \mathcal{N}(\mu_{\eta,2}, \sigma_{\eta,2}^2) & \text{with probability } 1 - p_\eta, \end{cases} \quad (5)$$

$$\varepsilon_t^T \sim \begin{cases} \mathcal{N}(\mu_{T,1}, \sigma_{T,1}^2) & \text{with probability } p_T, \\ \mathcal{N}(\mu_{T,2}, \sigma_{T,2}^2) & \text{with probability } 1 - p_T, \end{cases} \quad (6)$$

with means restricted so that each shock has mean zero, $p_\eta \mu_{\eta,1} + (1 - p_\eta) \mu_{\eta,2} = 0$ and $p_T \mu_{T,1} + (1 - p_T) \mu_{T,2} = 0$. The mixtures generate the negative skewness and excess kurtosis of earnings changes documented by [Guisen et al. \(2021\)](#): most years bring small changes, while a minority bring large, predominantly negative shocks.

The probability of nonemployment varies with age and persistent productivity,

$$\Pr(\nu_t = 1 \mid t, \varepsilon_t^P) = \frac{\exp(\xi_t)}{1 + \exp(\xi_t)}, \quad \xi_t = a + b\tilde{t} + c\varepsilon_t^P + d\varepsilon_t^P\tilde{t}, \quad (7)$$

where $\tilde{t}$ is normalized age. Nonemployment risk is therefore concentrated among young workers and workers with low persistent productivity. [Guisen et al. \(2021\)](#) model nonemployment as a draw of the fraction of the year spent out of work; I simplify it to a binary state in which a nonemployed worker has no labor earnings for the year and receives unemployment insurance, while retaining the dependence of nonemployment risk on age and persistent productivity.

Individuals may save or borrow through a liquid asset a_t . Positive assets earn the risk-free rate r , while negative positions carry the unsecured-credit rate $r^C > r$. Let

$$R(a_t) = \begin{cases} 1 + r, & a_t \geq 0, \\ 1 + r^C, & a_t < 0. \end{cases} \quad (8)$$

Liquid borrowing is subject to the age-dependent lower bound $a_{t+1} \geq -\bar{L}(t)$. Student debt

is separate from this asset because borrowing requires enrollment and follows its own interest rate and repayment rules.

2.3 Schooling and the Production of Human Capital

2.3.1 Schooling and Work

School and work compete for time. A student who chooses S_t may supply labor subject to

$$0 \leq n_t \leq 1 - S_t. \quad (9)$$

To reflect the smaller amount of nonschool time available to a student, I scale work effort by $1 - S_t$. While enrolled, flow utility is

$$u^S(c_t, n_t; S_t) = \frac{1}{1 - \gamma} \left(c_t - \frac{\nu}{1 + \phi} \left(\frac{n_t}{1 - S_t} \right)^{1 + \phi} \right)^{1 - \gamma}, \quad (10)$$

with the logarithmic limit when $\gamma = 1$. This coincides with Equation (2) when $S_t = 0$. Holding hours fixed, attending school raises the disutility of work, so enrollment competes with labor supply for the student's time. While in school, students do not face transitory or unemployment risk:

$$y_t = \exp(\alpha + g(t) + \varepsilon_t^P) n_t. \quad (11)$$

Attending school also carries a direct utility cost. Conditional on $S_t > 0$, this cost is

$$\kappa_S S_t + \kappa_{HT} \mathbf{1}\{S_t = S^{HT}\}. \quad (12)$$

The first term governs the general cost of schooling, while the second allows half-time attendance to have an additional alternative-specific cost. Each period, the potential student also receives independent type-I extreme-value taste shocks $\varepsilon_t^S(S_t)$ to the exit, half-time, and

full-time alternatives. These shocks allow otherwise similar individuals to make different attendance choices.

2.3.2 The Cost and Financing of School

Tuition depends on attendance intensity, degree stage, and the individual's college-cost type. Before the bachelor's threshold, q indexes the student's persistent undergraduate cost. On reaching that threshold, she draws a graduate cost type q^G , independently of her undergraduate circumstances, and retains it during graduate study. Let q_t denote the applicable cost type at age t .

Write tuition as $P_t(S_t, q_t, h_t)$, federal grants as $A_t^F(S_t, q_t, h_t, W^P)$, and other grants as $A_t^O(S_t, q_t, h_t, W^P)$. The student's net tuition bill is

$$K_t(S_t, q_t, h_t, W^P) = P_t(S_t, q_t, h_t) - A_t^F(S_t, q_t, h_t, W^P) - A_t^O(S_t, q_t, h_t, W^P). \quad (13)$$

When grants exceed tuition, the remaining aid can finance consumption while enrolled. Tuition and grant schedules vary with attendance, and the federal-grant schedule changes when a student becomes independent.

Parental transfers are $H_t(S_t, W^P, q, s, h_t)$. They depend on attendance, family resources, the undergraduate cost type, the persistent support state, and degree stage. Support declines when the student becomes independent. School-specific grants and parental help cease when she leaves school.

Let $b_t \geq 0$ denote new gross student borrowing and $\mathcal{L}_t(b_t, h_t)$ the amount received after origination fees⁴. Student loans can finance tuition and living expenses⁵. Undergraduate

⁴Origination fees reduce the amount disbursed to students without reducing the principal owed. I apply a fee of 1.062 percent to undergraduate borrowing and to the first \$20,500 of annual graduate borrowing, and a PLUS fee of 4.248 percent to graduate borrowing above that amount. These rates follow the federal schedule for loans first disbursed between October 1, 2018, and September 30, 2019 (Federal Student Aid, 2018).

⁵Federal student loans may cover non-tuition expenses included in a student's cost of attendance,

borrowing is subject to an annual limit $\bar{b}_t^{UG}$ and an interest-inclusive aggregate balance ceiling $\bar{B}_t^{UG}$:

$$b_t \leq \min \left\{ \bar{b}_t^{UG}, \max \left[0, \bar{B}_t^{UG} - (1 + r_B)B_t \right] \right\}. \quad (14)$$

The annual and aggregate undergraduate borrowing limits are higher for independent students. Outstanding student debt counts toward the aggregate limit, so the amount available for new borrowing depends on the student's existing balance.

For graduate students, the first \$20,500 of borrowing each year takes the form of Direct Unsubsidized Loans. Additional borrowing takes the form of Grad PLUS loans. The two loan types carry origination fees of 1.062 and 4.248 percent, respectively. I distinguish these loan types only when calculating origination fees. After disbursement, both enter a single student-debt balance with a common interest rate and repayment rules, abstracting from differences in their contractual terms.

No student-loan payment is due while the individual remains enrolled. Debt accrues at rate r_B :

$$B_{t+1} = (1 + r_B)B_t + b_t. \quad (15)$$

A student with no outstanding student debt incurs a fixed utility cost κ_B when taking out a positive student loan. This cost captures nonpecuniary barriers to borrowing, such as reluctance to hold student debt or the effort involved in arranging a loan. It is independent of the amount borrowed and does not reduce the funds available to the student. Suppressing the arguments of the tuition and transfer schedules, the student's budget constraint is

$$c_t + a_{t+1} + K_t = R(a_t)a_t + y_t - T_t(\tilde{y}_t) + Z_t + H_t + \mathcal{L}_t(b_t, h_t), \quad (16)$$

where $T_t(\tilde{y}_t)$ denotes income and payroll taxes and Z_t other public income support. A student

such as room and board, books, supplies, and transportation, subject to applicable borrowing limits (20 U.S.C. § 1087ll). Appendix A, Table 10, reports the non-tuition cost-of-attendance allowances used to set graduate borrowing limits in the model. While undergraduates face annual and cumulative limits, Grad Plus loans have traditionally allowed graduate students to borrow up to the cost of attendance, including more than tuition fees.

can respond to a financing shortfall by working more, reducing consumption or saving, using liquid credit, changing attendance intensity, borrowing through the student-loan program, or leaving school.

2.3.3 Human-Capital Production and Degree Completion

Persistent academic productivity z^H determines how effectively the individual converts time in school into human capital. For $S_t > 0$, define latent academic progress as

$$x_t = \max \left\{ z^H + \log S_t, 0 \right\}. \quad (17)$$

The production technology limits realized annual progress relative to an attendance-specific frontier. Let

$$\bar{x}(S_t) = \bar{q}_F \frac{S_t}{S^{FT}}, \quad (18)$$

and define

$$g_t = x_t \left[1 + \left(\frac{x_t}{\bar{x}(S_t)} \right)^\zeta \right]^{-1/\zeta}. \quad (19)$$

Human capital then evolves according to

$$\log h_{t+1} = \log h_t + g_t. \quad (20)$$

This technology separates academic productivity from attendance intensity. More productive students acquire human capital more quickly, while the smooth upper bound prevents arbitrarily rapid completion. The frontier also captures limits on the amount of coursework a student can complete in a year. Half-time attendance supplies less time to human-capital production and has a proportionally lower progress frontier. The degree thresholds h_1 and h_2 convert accumulated human capital into bachelor's and graduate credentials.

2.4 Field-of-Study Choice and the Returns to Education

An individual who leaves school with at least a bachelor's degree chooses a field of study $\theta \in [0, 1]$. The field index lies on a continuum, with higher values associated with higher earnings returns. When she leaves school, she draws from a uniform distribution a preferred field θ^* and incurs the utility cost

$$\kappa_\theta(\theta - \theta^*)^2 \quad (21)$$

when choosing a field away from that preference. The earnings return to field of study increases in θ :

$$g(\theta; \psi) = \begin{cases} \frac{\theta^{1-\psi}}{1-\psi}, & \psi \neq 1, \\ \log \theta, & \psi = 1. \end{cases} \quad (22)$$

I label fields with $\theta \geq \bar{\theta}^{STEM}$ as STEM. The cutoff is chosen in calibration to match the empirical STEM share among male bachelor's completers and is held fixed in the policy experiments. This classification identifies the high-return portion of the field continuum.

The preferred field and the earnings return create a tradeoff between taste and labor-market rewards. For $\psi > 0$, the field-return function is concave: successive increases in θ yield smaller increments in log earnings.

Let h^E denote human capital at final school exit. Accumulated human capital, degree completion, and field of study produce the log-productivity increment

$$\Delta(h^E, \theta) = \chi_h \log h^E + \left(m \mathbf{1}\{h^E \geq h_1\} + n \mathbf{1}\{h^E \geq h_2\} \right) g(\theta; \psi). \quad (23)$$

The term $\chi_h \log h^E$ is a continuous return to accumulated human capital, while m and n scale the sheepskin effects of completing bachelor's and graduate degrees. The graduate coefficient is incremental to the bachelor's coefficient. Individuals who leave before completing a bachelor's degree retain the continuous return but receive no degree or field return.

At exit, the increment enters persistent labor-market productivity once:

$$\varepsilon_t^{P,+} = \varepsilon_t^P + \Delta(h^E, \theta). \quad (24)$$

Productivity subsequently follows Equation (4). Thus the educational increment shares the persistence of the earnings state.

2.5 Working Life and Student-Loan Repayment

Once an individual leaves school, she supplies labor, chooses consumption and liquid saving, and, when indebted, resolves her student loan. Let J_t denote the number of qualifying repayment periods accumulated by the borrower. The baseline repayment plans mimic those offered by the Department of Education, containing Standard repayment and income-based repayment (IBR), which determine the minimum payment due in each period⁶.

2.5.1 Standard Repayment

Under Standard repayment, the required payment amortizes the current balance over the remaining repayment horizon. For $J_t < n_S$,

$$X_t^S(B_t, J_t) = \frac{r_B(1 + r_B)^{n_S - J_t}}{(1 + r_B)^{n_S - J_t} - 1} B_t, \quad (25)$$

where n_S is the Standard repayment horizon. A borrower who repays must pay at least X_t^S and may pay more. There is no penalty for early repayment.

⁶The model represents the two broad forms of repayment traditionally offered by the U.S. Department of Education: fixed-payment plans, including Standard, Graduated, and Extended repayment, and income-driven plans (such as ICR, IBR, PAYE, REPAYE, SAVE), which link payments to income. I summarize these alternatives with Standard repayment and IBR. The baseline reflects the pre-2026 system. Under the 2025 One Big Beautiful Bill Act, students receiving new Direct Loans on or after July 1, 2026 generally choose between the new Tiered Standard plan and the income-driven Repayment Assistance Plan (RAP).

2.5.2 Income-Based Repayment

Under IBR, the required payment is the smaller of a fraction ω_I of discretionary income and an n_S -period Standard amortization payment on the current balance⁷:

$$X_t^I(B_t, y_t) = \min \left\{ \bar{X}^S(B_t), \omega_I y_t^D \right\}, \quad \bar{X}^S(B_t) = \frac{r_B(1 + r_B)^{n_S}}{(1 + r_B)^{n_S} - 1} B_t. \quad (26)$$

Discretionary income is income above a multiple ω_f of the federal poverty guideline f ,

$$y_t^D = \max \{0, y_t - \omega_f f\}. \quad (27)$$

A borrower may pay more than the required amount. After $J_t \geq n_I$ qualifying payments, any remaining balance is forgiven.

2.5.3 Plan Choice, Repayment, and Nonpayment

When an indebted borrower leaves school, she chooses between Standard repayment and IBR. Enrolling in IBR carries a one-time utility cost κ_I , which captures the informational, administrative, and perceived costs of enrollment. A borrower who begins on the Standard plan retains the option to enroll in IBR at the start of any later period, before that period's payment decision. Enrollment in IBR is absorbing.

Conditional on repayment, the borrower chooses a payment D_t no smaller than the plan-specific requirement. The balance evolves according to

$$B_{t+1} = \max \{0, (1 + r_B)B_t - D_t\}. \quad (28)$$

A qualifying repayment period advances the repayment clock:

$$J_{t+1} = J_t + 1. \quad (29)$$

⁷This is a simplification of the Standard plan cap, to avoid keeping the debt at graduation as an additional state variable.

Borrowers may instead choose nonpayment. Nonpayment provides current liquidity but carries a utility cost ξ_D . Interest continues to accumulate and the repayment clock does not advance:

$$D_t = 0, \quad B_{t+1} = (1 + r_B)B_t, \quad J_{t+1} = J_t. \quad (30)$$

I use the term *nonpayment* because this choice captures failure to make a required economic payment rather than every administrative feature of federal default⁸.

Outstanding student debt is discharged upon death. The working individual's budget constraint is

$$c_t + a_{t+1} + D_t = R(a_t)a_t + y_t - T_t(\tilde{y}_t) + Z_t + \text{UI}_t. \quad (31)$$

Here UI_t denotes unemployment benefits. Student-debt repayment interacts with labor supply, consumption, liquid saving, and unsecured borrowing.

2.6 Retirement

At age T^R , individuals leave the labor market and receive a constant annual pension for the rest of their lives. The pension is based on the worker's earnings capacity in the final working year. Let

$$y^R = \exp(\varepsilon_{T^R-1}^P) n_{T^R-1}^E \quad (32)$$

denote the pension state, where $\varepsilon_{T^R-1}^P$ is persistent productivity and $n_{T^R-1}^E$ is the hours the individual would choose if employed in the last working year⁹. Gross pension income is

$$Y^R = \varrho \exp\{\alpha + g(T^R - 1)\} y^R, \quad (33)$$

⁸I abstract from wage garnishment and the administrative procedures associated with federal default. Although default technically makes the outstanding principal and accrued interest immediately due, in practice this is not the case. Borrowers can resolve default through loan rehabilitation or consolidation and resume scheduled repayment without paying the entire balance upfront. The model allows borrowers to resume repayment after nonpayment without explicitly modeling these procedures.

⁹This protects from a catastrophically low pension if the agent is unluckily unemployed in the last period prior to retirement.

where $\exp\{\alpha + g(T^R - 1)\}$ is the deterministic wage level at the last working age and ϱ is the replacement rate. Pension income therefore reflects persistent differences in earnings capacity but not the transitory shock or nonemployment status in the final working year, and it remains fixed throughout retirement. I write $Y_t^R = Y^R$ for this payment in the period budget. Pension income is taxed following the Social Security rules, under which zero, 50, or 85 percent of benefits are taxable depending on provisional income. Retirees choose consumption and saving subject to

$$c_t + a_{t+1} + D_t = R(a_t)a_t + Y_t^R - T_t(\tilde{y}_t) + Z_t. \quad (34)$$

Student debt is not mechanically discharged at retirement. A retiree with an outstanding balance continues to face the applicable repayment or nonpayment problem. This feature permits student debt to remain relevant late in life while separating retirement income from current labor supply.

Individuals anticipate future schooling, earnings, and repayment opportunities when making their current choices. I solve their problems by backward induction, from retirement through working life to schooling. Appendix B.1 presents the complete recursive formulation, including attendance, field choice, and repayment decisions.

2.7 Government

The government collects income and payroll taxes, provides income support and retirement benefits, and finances federal grants and student lending.

Taxes and transfers. Let $\tilde{y}_t$ denote taxable income: labor earnings plus unemployment benefits before retirement, and taxable pension income during retirement. The combined schedule $T_t(\tilde{y}_t)$ collects ordinary income taxes and employee payroll contributions, with the latter applying only to labor earnings. I suppress its dependence on income source and retirement status in the notation. Ordinary income taxes follow the 2019 progressive federal

schedule for a single filer. Workers also pay employee payroll contributions on labor earnings, including Social Security and Medicare provisions. In retirement, ordinary taxation follows the Social Security benefit-inclusion rules.

The government also provides means-tested assistance Z_t , modeled as a cash-equivalent benefit based on a simplified SNAP schedule. Eligibility and benefit amounts depend on income and liquid assets. This assistance is separate from unemployment insurance, retirement benefits, and student grants.

Public expenditures include federal student grants, unemployment insurance, means-tested support, and retirement benefits. Appendix A records the tax and benefit schedules used in the quantitative model.

Student lending and the government budget. Student loans create a current cash outflow and a claim on future repayments. Net disbursements are $\mathcal{L}_t(b_t, h_t)$ and actual repayments are D_t , as in the household budgets. Forgiveness reduces future receipts rather than adding an expenditure at discharge. Parental support and other grants are private resources in these accounts.

The government receives income and payroll taxes and student-loan repayments, and pays student-loan disbursements, federal grants, means-tested assistance, unemployment benefits, and pensions. Its net receipts associated with an individual at age t are

$$R_t = T_t(\tilde{y}_t) + D_t - \mathcal{L}_t(b_t, h_t) - A_t^F - Z_t - \text{UI}_t - Y_t^R. \quad (35)$$

Loan disbursements enter net of origination fees, while repayments include the amounts actually collected.

The expected lifetime net fiscal contribution per entrant in the baseline is

$$\bar{R} = \mathbb{E} \left[\sum_{t=18}^T (1+r)^{-(t-18)} R_t \right], \quad (36)$$

where the expectation accounts for initial heterogeneity and subsequent individual uncertainty, including survival. Receipts and expenditures are zero after death. A positive $\bar{R}$ represents resources available to finance government spending outside the programs modeled here.

3 Data and Calibration

The calibration focuses on the years in which individuals acquire postsecondary human capital and begin to repay student debt. I construct a simulated 2019 cross section of men aged 18–45 by following cohorts from age 18 and aggregating the survivors in 2019. The dynamic programs retain the full life cycle, including retirement.

The main data sources are the 2019 Survey of Consumer Finances (SCF), the 2020 Current Population Survey Annual Social and Economic Supplement (CPS ASEC), the High School Longitudinal Study (HSLs), the National Postsecondary Student Aid Study (NPSAS), Baccalaureate and Beyond (B&B), and the Beginning Postsecondary Students Longitudinal Study (BPS) ([Radwin et al., 2018](#); [Board of Governors of the Federal Reserve System, 2019](#); [U.S. Census Bureau, 2020](#)). I first describe the parameters assigned from institutions or external evidence and then the ten parameters selected jointly to match model moments. Dollar-valued budget flows are expressed in 2019 dollars. Appendix [A](#) provides the source definitions, construction steps, and data reproduction.

3.1 Parameters Assigned Outside the Joint Calibration

Preferences. I set $\gamma = 1$, so utility is logarithmic in consumption net of work disutility. This choice is motivated by the experimental evidence in [Noussair et al. \(2014\)](#), who find median relative risk aversion equal to one. I set the Frisch elasticity of labor supply to $1/\varphi = 0.15$, following [de Silva \(2025\)](#). His estimate uses borrowers’ labor supply responses to changes in Australia’s income-contingent student loan repayment schedule. This setting

is particularly relevant here because repayment obligations affect the return to working, and labor supply responses influence both the insurance benefits and fiscal costs of income-based repayment.

Earnings, financial markets, and demographics. I adopt the earnings-process specification and shock parameters from [Guvenen et al. \(2021\)](#), including the persistent coefficient $\rho_P = 0.991$. Persistent innovations and transitory shocks follow their two-normal-mixture specification.

I set unemployment benefits to 40 percent of reference employed earnings, guided by evidence on realized U.S. benefit replacement rates before the pandemic.¹⁰ Means-tested assistance Z_t represents a simplified version of the Supplemental Nutrition Assistance Program (SNAP). I treat assistance as a cash-equivalent resource, with a maximum annual benefit of \$2,500, an asset test, and a benefit phaseout as income rises. Appendix A reports the schedule and its relationship to the underlying SNAP rules.

I set the annual risk-free saving rate to four percent and use a common annual student-loan interest rate of 6.05 percent, abstracting from differences across federal loan types and origination years¹¹. The unsecured borrowing rate is 16 percent, guided by credit-card interest rates in the 2019 Survey of Consumer Finances (SCF). Age-dependent unsecured borrowing limits use rounded anchors motivated by the SCF credit-limit evidence.¹² Federal income taxes, employee payroll contributions, and student-loan origination fees follow the 2019 institutional baseline. Appendix A provides the corresponding schedules.

Retirement begins at age $T^R = 65$. Following [Cocco et al. \(2005\)](#), I set the pension

¹⁰[Ganong et al. \(2020\)](#) report a mean replacement rate of 36 percent in Department of Labor data for the second quarter of 2019. I use 40 percent as a rounded approximation, as many rules aim to replace 50 percent of earnings. Reference earnings are expected annual earnings when employed, conditional on age and persistent productivity, as described in Appendix A.

¹¹The federal interest-rate formula for undergraduate Direct Subsidized and Unsubsidized Loans adds 2.05 percentage points to the yield on the 10-year Treasury note at the final auction before June 1 preceding the applicable academic year. I apply this spread to the model’s four-percent benchmark rate and use the resulting 6.05 percent for all student debt, abstracting from differences across loan types and origination years.

¹²These anchors approximate available unsecured credit rather than directly observed borrowing constraints. Appendix A reports the anchor values and the interpolation used between ages.

replacement rate to $\varrho = 0.682$, applied to the earnings base defined in the retirement budget. The terminal age is $T = 90$. Schooling remains available through age 44, with mandatory exit at $T^S = 45$.

Tuition, family resources, and initial sorting. Individuals enter with academic productivity z^H , family resources W^P , and a college-cost type q . Initial liquid assets are zero. I construct the joint distribution of these characteristics using the High School Longitudinal Study and NPSAS:16. The former supplies the relationship between academic preparation and family resources; the latter supplies college prices conditional on these characteristics. I distinguish three family-resource groups, defined by fixed income bands, and three undergraduate price groups. This construction allows better-prepared students and students from wealthier families to face different distributions of college costs.

NPSAS:16 also supplies annual tuition, grants, and parental support. Parental support varies with family resources and college price and includes a persistent state with no support. I retain negative net tuition when grants exceed tuition. Half-time tuition, grants, and parental support equal one-half of their full-time amounts. At age 24, students become independent, and parental support falls to 0.2503 of its earlier level.¹³

Graduate financing varies by attendance intensity and price type. Students retain their parental-support rank when entering graduate school, while graduate prices are drawn independently of undergraduate prices and family characteristics. Graduate borrowing can also cover non-tuition expenses, with annual allowances of approximately \$18,963 for full-time students and \$17,767 for half-time students.

The construction assigns college-price distributions observed among enrolled students to potential entrants. This is a maintained assumption about the opportunities available to individuals who do not enroll. Appendix A details the samples, category boundaries, joint distribution, and financing amounts. All monetary amounts are expressed in 2019 dollars.

¹³The multiplier uses the ratio of mean parental support among full-time students ages 24–44 to that among full-time students ages 18–23 in NPSAS:16. I use this cross-sectional comparison to approximate the age-related decline in support; it also reflects differences in dependency status and student composition.

School time and the returns to education. I set full-time schooling to 27 hours per week, following [Babcock and Marks \(2011\)](#). I assume a 30-week academic year and normalize the weekly discretionary time endowment to 100 hours, so full-time attendance uses approximately 0.156 of annual available time. Half-time attendance uses half this amount. I normalize initial human capital to $h_0 = 1$ and set the degree thresholds so that a student with median academic productivity completes a bachelor’s degree in four years of full-time study and a master’s degree in two additional years. These normalizations give $h_1 = 256$ and $h_2 = 4096$. A cap on annual progress limits how quickly highly productive students can complete a degree; I use the fast tail of undergraduate completion times in Baccalaureate and Beyond to discipline this cap.

I use [Jaeger and Page \(1996\)](#) to distinguish the earnings return to additional schooling from the return to completing a degree. Their estimated schooling coefficients, controlling for degree completion, imply a continuous human-capital return of $\chi_h = 0.02535$ after conversion into the model’s units. I set the bachelor’s and additional graduate degree scales to $m = 0.238$ and $n = 0.073$, respectively, using their estimated degree premiums.

The earnings return to a degree also varies with field choice. I set the curvature parameter $\psi = 0.173$ to match the relative log-earnings gaps across three ACS-based field earnings observations, assigned to low-, middle-, and high-return positions on the field continuum. This value implies diminishing marginal gains in log earnings as students move toward higher-return fields. Preferred fields are uniformly distributed on $[0, 1]$ and independent of other initial characteristics. [Appendix A](#) details the completion evidence and the construction of the continuous and field-specific earnings returns.

Borrowing and repayment institutions. Federal undergraduate borrowing limits vary by dependency status and year of study. Dependent students can borrow \$5,500 in the first year, \$6,500 in the second, and \$7,500 annually thereafter; the corresponding limits for independent students are \$9,500, \$10,500, and \$12,500. In the model I use the second-year limits

of \$6,500 and \$10,500 as representative annual limits throughout undergraduate study. The aggregate principal limits are \$31,000 for dependent students and \$57,500 for independent students. Because the model tracks debt inclusive of accrued interest, I convert these principal limits into balance ceilings using annual borrowing and interest accrual. Appendix A describes this conversion and documents the federal borrowing rules.

The repayment parameters approximate the federal Standard and income-based repayment plans available to new borrowers under the institutional baseline. Standard repayment amortizes the outstanding balance over $n_S = 10$ annual payment periods. IBR requires payments of $\omega_i = 0.10$ of income above $\omega_f = 1.5$ times the federal poverty guideline, capped at the Standard payment, and forgives the remaining balance after $n_I = 20$ qualifying repayment periods. These parameters capture the principal payment and forgiveness provisions of the plans within the model’s annual time structure.

3.2 Jointly chosen parameters and targeted moments

I choose ten parameters jointly to minimize the sum of squared relative deviations between empirical and simulated moments:

$$\mathcal{Q}(\vartheta) = \sum_{j=1}^{10} \left[\frac{M_j(\vartheta) - M_j^{data}}{M_j^{data}} \right]^2. \quad (37)$$

Table 1 reports the parameters, their principal targets, and the model fit. The associations below describe the main source of discipline for each parameter within the joint calibration.

Wealth. The median financial-wealth-to-earnings ratio disciplines β through the incentive to save: more patient households accumulate more liquid assets. I calculate it in the 2019 SCF for single men and male-earner households, ages 18–45, with positive earnings. Financial wealth excludes retirement accounts and nets out credit-card balances; it excludes student debt. The model counterpart is liquid assets divided by earnings under the same age and positive-income restrictions.

Table 1: Joint calibration: parameters and targeted moments

Parameter	Value	Principal target	Data	Model
β	0.946	Median wealth/income, ages 18–45	0.0961	0.0949
κ_S	10.8	BA-or-higher share, ages 18–44	0.303	0.293
κ_{HT}	2.61	Full-time share among enrolled	0.856	0.894
σ_H	0.218	Full-time progress, p_{80}/p_{20}	1.24	1.24
κ_θ	5.50	STEM regression R^2	0.00878	0.00928
ν	3.11×10^7	Average work time, ages 18–45	0.317	0.316
Y_{18}	33,700	Mean earnings, ages 25–44 (\$)	58,700	57,800
κ_B	0.130	BA never-borrowing share	0.377	0.371
ξ_D	0.266	Nonpayment share	0.126	0.122
κ_I	3.72	Income-driven repayment share	0.395	0.373

Shares and work time are fractions; monetary quantities are in 2019 dollars. Y_{18} scales initial earnings, and ν uses the model’s dollar normalization. Values are rounded for display; all computations retain full precision. The graduate schooling cost equals κ_S . Sample definitions appear below. The progress target uses selected full-time students in the data and an unconditional model proxy.

School participation and progress. The bachelor’s-or-higher share among men ages 18–44 in the CPS disciplines the general schooling cost κ_S , which is shared by undergraduate and graduate study. Higher costs reduce the value of remaining enrolled. The full-time share among male NPSAS:16 undergraduates in the exclusively full-time and exclusively half-time categories disciplines κ_{HT} . A higher additional half-time cost favors full-time attendance. The two empirical categories match the enrollment intensities available in the model. Academic-productivity dispersion σ_H is disciplined by the p_{80}/p_{20} ratio of earned credits in the selected full-time BPS sample, $31/25 = 1.24$. The model counterpart is the unconditional analytical progress ratio. Appendix A discusses its relationship to the selected full-time sample used to construct the empirical target. The attendance and sample restrictions distinguish this dispersion target from variation caused by different course loads.

Field choice. The field-preference cost κ_θ governs how strongly financial circumstances affect students’ willingness to choose a higher-return field. I use male bachelor’s completers in NPSAS:16 and regress a STEM indicator on model-comparable variables for age, liquid resources, undergraduate borrowing history, debt, academic preparation, parental support,

and price. The target is the partial R^2 of this block after removing variation explained by institutional and demographic controls without model counterparts. I compare it with the R^2 from the corresponding model regression among bachelor’s-only permanent school exits.

I classify fields with $\theta \geq \bar{\theta}^{STEM}$ as STEM, mapping STEM degrees to the high-return portion of the model’s field continuum. I choose $\bar{\theta}^{STEM}$ so that the baseline model reproduces the 30.37 percent STEM share among male bachelor’s completers in the NPSAS:16 calibration sample. This gives $\bar{\theta}^{STEM} \simeq 0.8752$. The cutoff remains fixed across policy experiments, allowing changes in field choice to change the STEM share.

Work and earnings. Average annual hours among men ages 18–45, including nonworkers, discipline the labor-disutility scale ν . Mean earnings among men ages 25–44, also including zeros, discipline Y_{18} . Both labor-market targets use the 2020 CPS ASEC with 2019 as the income reference year; hours are divided by the annual 5,200-hour endowment.

Borrowing and repayment. The share of male bachelor’s completers who never borrowed for undergraduate study in NPSAS:16 disciplines the initial borrowing cost κ_B . It captures the extensive borrowing margin even among students who complete a degree. The nonpayment cost ξ_D and IBR entry cost κ_I are disciplined by SCF repayment moments for men ages 18–45 who are out of school and hold federal debt for their own education. The nonpayment target measures borrowers reporting a required payment that was not made; the IDR target measures participation in an income-driven federal plan. The model counterparts are current nonpayment and IBR participation among comparable borrowers. The model’s single IBR plan represents the income-driven plans grouped together in the survey.

Table 1 reports the fit to all ten moments. The model comes close to the wealth ratio, progress dispersion, earnings, and never-borrowing share, while it overstates full-time enrollment and understates IDR participation. The next subsection examines distributions and age profiles beyond these calibration targets.

3.3 Additional model fit

I assess distributions and age profiles beyond the ten targeted moments, focusing on the educational and financial margins that drive the policy comparisons. These exercises follow the emphasis on life-cycle resources, educational sorting, and completion in [Abbott et al. \(2019\)](#), [Huang \(2023\)](#), and [Garriga and Keightley \(2013\)](#).

3.3.1 Attainment and completion timing

The model closely tracks bachelor’s attainment across adult age groups. At ages 25–29, the BA-or-higher share is 36.0 percent in the model and 35.7 percent in the CPS data. It is about two percentage points lower than the data at ages 30–39 and close again at ages 40–44. Figure 1 shows both attainment and enrollment, using the published empirical age groups.

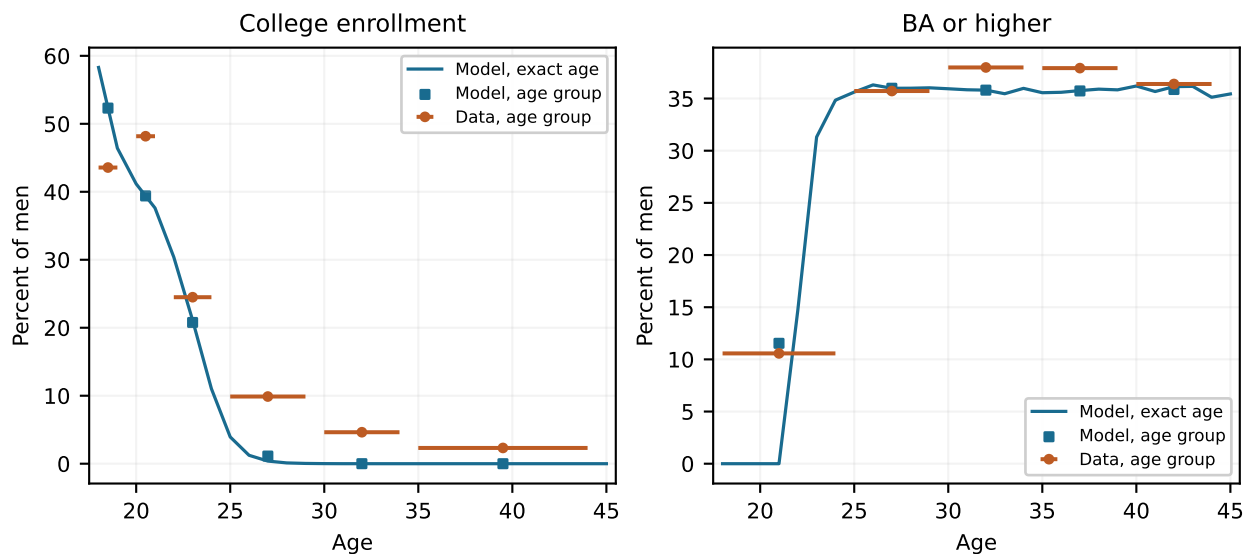


Figure 1: College enrollment and bachelor’s attainment by age

Lines show exact-age model shares. Circles show empirical shares in published age groups; horizontal bars mark those age ranges, not confidence intervals. Squares aggregate the model to the same groups. Enrollment compares CPS October 2019 college attendance with positive annual model school time. BA attainment uses beginning-of-period degree status.

The model describes the initial schooling spell more closely than later enrollment. Among men ages 25–29, enrollment is 1.1 percent in the model and 9.9 percent in the data. Entry at

18 and permanent exit exclude delayed first entry and return to school. Graduate completion also occurs earlier: at ages 25–29, model graduate attainment is 13.8 percent, compared with 7.7 percent for any graduate degree in the data. The empirical master’s-only share is 6.2 percent.

Completion timing provides a complementary check. Approximately 41 percent of model bachelor’s recipients finish within four years, compared with 40–41 percent in the B&B percentile grid. Median elapsed duration is 60 months under the annual model measure and 56 months in the data. The model has a shorter upper tail: about 98 percent finish within six years, compared with 72–73 percent in the data.

3.3.2 Financial resources and borrowing

Table 2 reports selected percentiles of financial wealth relative to earnings and of annual earnings. Both samples condition on positive earnings. Financial wealth comprises nonretirement financial assets net of credit-card balances, excluding student debt. The model matches the central resource ratios closely: the 30th percentile is 0.017 versus 0.018 in the data, and the 70th is 0.338 versus 0.301. The model has thinner wealth-ratio tails and more earnings dispersion above the median. Differences in age composition and household definitions also affect these comparisons.

Table 2: Selected financial-resource and earnings percentiles

Percentile	Ratio: data	Ratio: model	Earnings: data	Earnings: model
10	−0.046	−0.004	14,000	11,832
30	0.018	0.017	29,000	22,580
50	0.096	0.095	42,000	36,779
70	0.301	0.338	66,000	60,853
90	1.486	1.151	110,000	132,210

Ages 18–45, positive earners; annual earnings in 2019 dollars. Ratio denotes financial wealth divided by earnings within each observation. The SCF sample includes single men and male-earner households with a female homemaker or partner out of the labor force; the model has no marital state.

The model captures the substantial share of bachelor’s recipients who complete with no

federal debt. The 10th and 30th percentiles are zero in both the model and the data. The never-borrowing share is targeted, while the balance distribution tests the amounts borrowed among the remaining recipients. At the 70th percentile, model debt is \$29,800, compared with \$28,967 in the data. Balances are more concentrated in the model: the median is higher and the 90th percentile lower. Table 3 measures balances after the final period’s borrowing and includes recipients with zero balances.

Table 3: Federal student debt at bachelor’s completion

Percentile	Data	Model
10	0*	0
30	0*	0
50	10,321	23,203
70	28,967	29,800
90	47,452	35,178

2019 dollars, including zero balances. Data describe male NPSAS:16 bachelor’s completers. Model balances are measured at the end of the degree-crossing period. 0* denotes an empirical estimate that rounds to zero.

The undergraduate comparisons support the model’s central attainment and liquid-resource patterns, including the mass of graduates with no debt. The model compresses variation in completion time.

4 Policy Results

I use the model to examine how access to credit, tuition subsidies, grants, and repayment rules affect college completion, major choice, and welfare. The experiments compare assistance available across fields with assistance conditional on choosing a higher-return field. This comparison weighs the earnings and fiscal benefits of field targeting against its effects on college access and students’ ability to pursue their preferred majors.

The analysis proceeds in three steps. First, I examine eliminating new student loans and making tuition free, then consider how conditioning credit or tuition assistance on STEM

changes the results. Second, I compare annual undergraduate grant and loan-limit expansions of \$2,000, with different requirements for family resources, academic ability, and field choice. Third, I examine how anticipated repayment obligations affect borrowing, schooling, and major choice. The final subsections compare welfare across family-resource groups and the fiscal consequences of the reforms.

4.1 Policy Design and Financing

I evaluate each reform together with the taxes required to finance it. Across experiments, the government retains the same expected present value of net receipts from an entering cohort as under the status quo. This holds the resources available for other government uses fixed while allowing education spending, loan repayments, taxes, and benefit payments to respond to household choices. Each reform is financed within the entering cohort that faces the new policy. I apply the tax adjustment to that cohort over its life cycle, leaving earlier cohorts under the status-quo aid and tax rules. Thus, the reform cannot finance assistance for new students by imposing additional taxes on older cohorts that were ineligible for that assistance.

For each policy, I solve for a constant proportional adjustment τ to positive tax liabilities under the combined income and employee payroll tax schedule. Let $R_t^p(\tau)$ denote the government's net receipts under policy p before this adjustment, extending Equation (35) to include the reform's aid and repayment rules. The financing rate solves

$$\mathbb{E} \sum_{t=18}^{90} d_t [R_t^p(\tau) + \tau \max\{T_t(\tilde{y}_t^p(\tau)), 0\}] = \bar{R}, \quad (38)$$

where $\bar{R}$ is the status-quo balance defined in Equation (36). A positive τ finances a shortfall, while a negative τ returns a fiscal saving through lower taxes. Households anticipate this tax adjustment when choosing schooling, work, borrowing, and repayment. The required financing therefore accounts for changes in earnings and tax receipts, as well as changes in

public expenditures.

The tuition experiments provide last-dollar assistance: the government covers tuition charges remaining after existing grants. Let $K_t = P_t - A_t^F - A_t^O$ denote the student's pre-reform tuition bill. For an eligible enrolled student,

$$Q_t^p = \max\{K_t, 0\}, \quad K_t^p = K_t - Q_t^p = \min\{K_t, 0\}. \quad (39)$$

The subsidy eliminates a positive tuition bill and preserves any existing grant surplus available for consumption. Parental transfers remain separate from this calculation. Both universal and STEM-contingent free tuition cover undergraduate and graduate study, and payments cease when the student leaves school.¹⁴

For STEM-contingent policies, eligibility requires a binding commitment to choose a field $\theta \geq \bar{\theta}^{STEM}$, using the cutoff established in Section 3. Students may commit in any enrollment year. From that point forward, they can receive the contingent assistance and must choose a qualifying field at final school exit. Commitment generates no retroactive payments, and the government does not recover earlier assistance after dropout. Under STEM-only lending, students must commit to obtain new student loans. Under the targeted grant and loan-limit expansions, students retain access to ordinary aid without committing.

I measure aggregate welfare using consumption-equivalent variation (CEV). This is the permanent percentage change in goods consumption under the status quo that equates expected utility at entry with expected utility under the financed reform, before initial characteristics are known. To calculate it, I multiply goods consumption in utility by $1 + \lambda$ at every age and state, retain the status-quo budget constraints and non-consumption utility costs, and resolve household choices. I choose λ to equate expected age-18 utility across the two environments and report 100λ . Positive values indicate welfare gains. Appendix B provides the formal definition, and Section C.5 compares this measure with the alternative welfare

¹⁴Tennessee Promise and New York's Excelsior Scholarship also provide last-dollar assistance ([Tennessee Board of Regents, 2026](#); [New York State Higher Education Services Corporation, 2026](#)), although their institutional coverage and eligibility restrictions differ from these experiments.

measures.

Attainment and field outcomes describe the 2020 entrant cohort at age 45. Welfare and fiscal outcomes account for the cohort’s full life cycle, including individuals who die before age 45.¹⁵

To measure how changes in attainment and field choice affect earning capacity, I value the human capital acquired under each policy relative to a counterfactual in which schooling is unavailable. I evaluate both earnings paths at the hours chosen in that no-school counterfactual. The value at age 45 is

$$\mathcal{V}_{45}^p = \mathbb{E} \left[\sum_{t=45}^{64} \frac{(w_t^p - w_t^{NS})n_t^{NS}}{(1+r)^{t-45}} \middle| \text{alive at 45} \right], \quad (40)$$

where NS denotes the no-school counterfactual and w_t is the effective hourly earnings rate, set to zero during nonemployment or after death. Holding hours fixed isolates the contribution of education to earnings from changes in labor supply.¹⁶ This measure captures the discounted earnings value remaining at age 45 through age 64. It excludes pension income and does not deduct tuition or forgone earnings.

Finally, I use the model’s earnings equation to separate the school-exit wage premium from accumulated human capital and the degree premium associated with field choice. These components help explain how policies change earning capacity through both schooling and the fields students choose.

4.2 Credit, Free Tuition, and Field Conditions

Universal free tuition produces more graduates and larger welfare gains than STEM-contingent tuition, while generating a similar earnings value of human capital. To understand this comparison, I first consider two broad changes to education finance: eliminating

¹⁵The age-45 comparisons use the same surviving individuals across policies.

¹⁶Table 14 in Appendix C reports alternative valuations using policy-specific fixed hours and endogenous hours in both paths.

access to student loans and eliminating tuition payments. Removing loans tests how far students can finance education through work, family support, and other borrowing. Free tuition removes the remaining tuition bill, but students may still need credit to support consumption while enrolled. I then examine how restricting loans or tuition assistance to STEM changes completion, field choice, and welfare (Table 4).

Table 4: Student loans, free tuition, and field conditions

Policy	CEV (%)	BA (%)	STEM (%)	$\bar{\theta}$	HC value (\$)
Status quo	0.00	35.98	12.65	0.719	89,166
No student loans	-0.64	29.07	9.86	0.710	71,618
Universal free tuition	4.12	55.06	19.18	0.717	134,155
Free tuition, no loans	3.79	48.35	16.12	0.707	117,573
STEM-only loans	-0.21	32.14	16.21	0.759	81,753
STEM free tuition	3.35	48.53	45.76	0.893	131,754

All policies are financed. CEV is the aggregate goods-consumption equivalent. BA includes graduate degree holders. STEM is the percentage of the age-45 cohort with a STEM degree, and $\bar{\theta}$ is the mean among BA-or-higher graduates. HC value is the age-45 present value of additional pre-retirement earnings relative to a no-school counterpart, using common no-school hours. It is not a net return after tuition costs.

Eliminating access to new student loans reduces bachelor’s attainment from 36.0 to 29.1 percent and lowers welfare by 0.6 percent.¹⁷ Students can still work, receive family support, and use unsecured credit, but these sources do not fully replace student loans. STEM completion falls from 12.7 to 9.9 percent of the entering cohort, while the average field index among graduates changes little. Removing student credit therefore reduces completion in both STEM and other fields, with little change in the average field choice of those who graduate.

Removing tuition expands completion with little change in the field chosen by the average graduate. Bachelor’s attainment rises from 36.0 to 55.1 percent under universal tuition, while the mean field index remains close to 0.72. Students spend longer in school, and some

¹⁷The reform eliminates new borrowing in the student’s own name. Parental transfers remain available and may include funds that parents obtain through Parent PLUS loans. Because the model does not distinguish the sources of parental support, the experiment leaves this channel unchanged.

continue into graduate study. The graduate response combines direct tuition assistance with the larger pool of bachelor’s recipients; the experiment does not isolate these channels. The larger STEM share—19.2 percent of the cohort, compared with 12.7 percent in the baseline—comes mainly from students who would otherwise leave without a degree.

Students still benefit from credit when tuition is free. Removing access to new student loans from the universal tuition policy reduces bachelor’s attainment from 55.1 to 48.4 percent and the welfare gain from 4.1 to 3.8 percent. STEM completion falls from 19.2 to 16.1 percent of the cohort. Tuition relief leaves consumption and other needs during school to be financed; access to credit allows students to spread those costs over their working lives.

Field conditions address the moral-hazard concern that students do not bear the full fiscal consequences of their choices. This incentive concern is distinct from treating a preference for a lower-earning field as wasteful: those preferences enter household welfare. The next two experiments attach the condition to different forms of support, withdrawing ordinary credit or offering a tuition subsidy.

Conditioning credit on STEM changes both access and the composition of degrees. Compared with the status quo, STEM-only loans raise STEM completion to 16.2 percent but reduce total bachelor’s attainment to 32.1 percent and welfare by 0.2 percent. Students can retain access to borrowing by accepting the field commitment, while those who forgo it must finance school without student loans. The policy directs more graduates toward high-return fields at the cost of fewer degrees overall.

STEM-contingent free tuition instead offers a subsidy while preserving ordinary borrowing for students who decline the commitment. Students who would already complete a degree can obtain the subsidy by accepting a higher-return field. That option attracts many switchers: STEM completion reaches 45.8 percent of the cohort, even though total bachelor’s attainment rises less than under universal tuition. Figure 2 follows the same individuals across policies to distinguish these two sources of additional STEM degrees.

Universal tuition also allows some students to complete a degree in a lower-earning field:

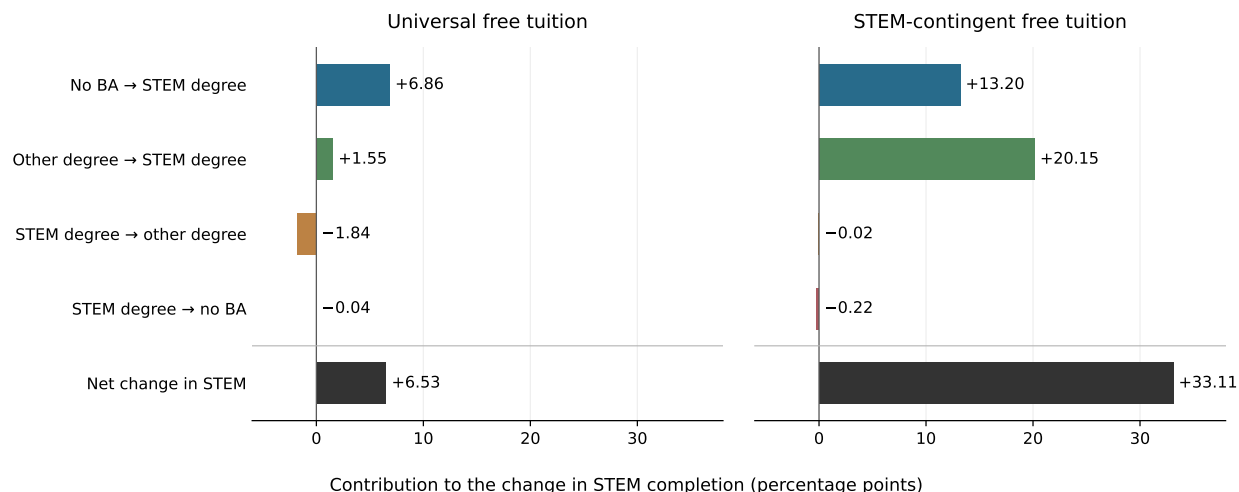


Figure 2: Additional completion and field switching under tuition subsidies

Rows compare each individual’s status in the baseline (left of the arrow) with that individual’s status under the policy (right), both at age 45. “Other degree” means a non-STEM BA-or-higher degree; “no BA” includes never-attenders and noncompleters. Positive bars add STEM graduates; negative bars subtract them. Every bar begins at zero, and the first four rows sum to the net change. These are comparisons across scenarios, not transitions after a degree has already been earned.

1.84 percent of the cohort would finish in STEM under the baseline but choose another field under the reform, while only 0.04 percent move from a baseline STEM degree to no BA. This response is consistent with the field-preference mechanism: tuition relief makes a preferred, lower-earning field more affordable. It also illustrates the tradeoff behind field conditions. Such choices can reduce future earnings and tax receipts while improving students’ welfare through the value they place on their field. STEM-contingent tuition ties the subsidy to a higher-return field; the corresponding flows out of baseline STEM are only 0.02 percent into another field and 0.22 percent into no BA.

Most of the increase in STEM graduates under targeted tuition comes from students who would have completed another degree. Field switching contributes about 20 of the 33 percentage points of additional STEM completion, while entry from no degree contributes about 13 points. Universal tuition generates little switching but more new degrees overall: bachelor’s attainment rises by 19 points, compared with 13 under the STEM condition. Most of its additional graduates choose non-STEM fields.

STEM-contingent tuition raises the earnings return to the bachelor’s credential by directing graduates toward higher-return fields. Among graduates, the average field-dependent degree premium rises from 24.5 percent in the status quo to 30.0 percent under STEM tuition. Under universal tuition, it remains nearly unchanged at 24.4 percent.¹⁸

Universal tuition instead raises earnings primarily by enabling more students to complete degrees and continue their education. Despite their different effects on attainment and field choice, the two policies generate similar earnings values of human capital: approximately \$134,000 under universal tuition and \$132,000 under STEM tuition, compared with \$89,000 in the status quo. These values measure discounted earnings gains from ages 45 to 64 at fixed labor input. The comparison shows how broader educational attainment can produce earnings gains comparable to those from a stronger concentration in higher-return fields.

Universal tuition raises welfare by 4.1 percent, compared with 3.4 percent for STEM tuition, even with the larger financing adjustment: 5.85 versus 4.95 percent of baseline income and payroll tax liabilities. The fiscal advantage of requiring a higher-return field is therefore insufficient to offset the combined loss of completion and preferred-field value in these experiments.

4.3 Grant and Loan Expansions

I compare an annual undergraduate grant expansion of \$2,000 in 2019 dollars with an equally sized increase in annual borrowing capacity. The common increment allows me to compare additional assistance delivered through grants and loans. It equals approximately 31 percent of the model’s dependent annual borrowing limit and 19 percent of its independent limit.

Both the scale of assistance and its targeting feature in recent policy proposals. The Pell Grant Preservation and Expansion Act of 2026 proposed increasing the maximum annual award from \$7,395 to \$10,000 and providing an additional means-tested supplement of up

¹⁸I calculate this premium as the mean of $\exp\{mg(\theta)\} - 1$ among graduates. It isolates the bachelor’s credential component of the model’s earnings equation at school exit, holding other earnings determinants fixed. It excludes the continuous return to accumulated human capital, the additional graduate credential, and subsequent earnings dynamics.

to \$1,500.¹⁹ The loan expansion also has a historical precedent: the 2008 reform studied by [Black et al. \(2023\)](#) raised annual undergraduate borrowing limits by \$2,000.

I study twelve experiments that vary three features: grants versus loan capacity, unrestricted versus STEM-contingent aid, and broad versus means- or ability-based eligibility. Means eligibility uses the lowest initial parental-resource group; ability eligibility uses the top academic-productivity quartile. Graduate aid remains unchanged. Holding the annual offer fixed permits an instrument comparison, although realized assistance and public costs differ with eligibility, attendance, and borrowing. These common-amount comparisons do not identify the optimal subsidy or borrowing limit.

The grant is \$2,000 for full-time students and \$1,000 for half-time students. The loan expansion adds \$2,000 to annual capacity and \$8,000 to the aggregate principal benchmark, adjusted for interest. Existing balances count against the expanded ceiling. Loans retain the full annual expansion under half-time attendance, following the historical annual-limit approximation²⁰. STEM commitment unlocks future assistance without retroactive disbursements. Grants are paid only while enrolled and may exceed tuition, leaving resources for consumption. Eligibility is fixed by initial parental resources or ability, so students cannot qualify by reducing current earnings.

A grant and a loan expansion can relax the same financing constraint while leaving students with different repayment obligations. Under broad eligibility, both raise bachelor's attainment by roughly three percentage points and generate almost identical earnings values of human capital, about \$96,400. The loan expansion produces more graduate completion, suggesting that undergraduate credit also changes the resources students carry into the next schooling decision. Graduate aid rules themselves remain fixed ([Table 5](#)).

Broad aid changes completion more than field choice. The mean field index is 0.717

¹⁹The supplement would apply to students whose families participate in specified federal benefits programs, including SNAP and Medicaid.

²⁰Historically, annual loan limits did not reduce for half-time students. Beginning in 2026, new legislation now allows for a prorated reduction. However, the baseline model and policy analysis uses the historical rules.

Table 5: Effects of undergraduate grant and loan expansions

Eligibility	Unrestricted fields			STEM commitment		
	CEV	Δ BA	Δ STEM	CEV	Δ BA	Δ STEM
<i>A. Grants</i>						
Broad	0.92	+3.4	+1.2	0.37	−1.4	+13.4
Means-tested	0.32	+1.0	+0.3	0.14	−1.0	+5.7
Ability-tested	0.23	+0.9	+0.3	0.06	−0.4	+2.3
<i>B. Loan capacity</i>						
Broad	0.19	+2.8	+1.2	0.06	+0.4	+1.9
Means-tested	0.07	+1.1	+0.5	0.02	+0.2	+0.7
Ability-tested	0.06	+0.7	+0.3	0.02	+0.1	+0.4

CEV is the aggregate goods-consumption equivalent, in percent. Δ BA and Δ STEM are percentage-point changes in shares of the age-45 cohort relative to the status quo (35.98 and 12.65 percent). Broad eligibility adds no means or ability restriction. Means eligibility selects the lowest initial parental-resource group; ability eligibility selects the top productivity quartile. Graduate aid is unchanged.

under grants and 0.722 under expanded credit. Among individuals who complete a BA in both environments, the mean field changes are approximately -0.0030 and 0.0008 , respectively. Grants and repayable credit therefore generate slightly different field incentives even without an explicit field condition; changes in degree level and exit timing also enter these comparisons.

The grant delivers a much larger welfare gain, 0.92 percent versus 0.20 percent, and requires about \$1,627 in additional present-value financing per entrant compared with \$38 for loans. Borrowers repay part of the loan disbursements, and their additional education can expand the future tax base. Grants provide the larger transfer; loans achieve similar educational gains with much less additional public financing.

A STEM condition more than doubles targeted graduates under the broad grant but reduces total completion. STEM graduates rise to 26.0 percent of the cohort, while bachelor's attainment falls to 34.6 percent. About 13.1 percent of the cohort switch from a non-STEM degree to STEM and 1.2 percent enter STEM from no BA; some baseline graduates cease to complete. These outcomes reflect both the field commitment and the financing adjustment,

which also changes incentives for individuals who receive no new grant.

The STEM loan expansion induces much less field switching. A student gains from the offer only if additional credit is valuable enough to justify both repayment and the field commitment. The grant pays students for accepting the condition even when they could already finance their studies. This difference helps explain why the STEM loan expansion produces a modest increase in completion, whereas the STEM grant generates a large field response alongside lower total attainment.

Means and ability requirements preserve the main distinction between the grant and loan experiments. Within each eligibility group, grants available across fields increase bachelor's completion, while STEM-contingent grants reduce it. Additional borrowing capacity increases completion with or without a field condition. Thus, the different completion responses to STEM-contingent grants and loans persist when assistance is restricted by family resources or academic ability.

Narrower eligibility reduces aggregate welfare gains under both instruments. These comparisons hold the annual offer fixed, so restricting eligibility also changes the number of recipients and the public resources committed to the reform. They therefore do not establish which eligibility rule would deliver the greatest welfare gain at a common budget. STEM-contingent loan expansions generate net fiscal savings under all three eligibility rules, although adding a field condition does not improve the fiscal balance in every case. The appendix reports financing rates and fiscal requirements for the full set of experiments.

The field response is particularly pronounced among students eligible for the means-tested STEM grant. Within the lowest-resource group, the share completing a STEM degree rises from 13.4 to 31.3 percent. This response is qualitatively consistent with [Denning and Turley \(2017\)](#), who find that SMART Grants encouraged students to choose eligible majors. The experiments here examine how such field incentives interact with degree completion and the taxes required to finance assistance.

The positive completion response to additional credit also accords with [Black et al. \(2023\)](#),

who find that higher federal loan limits improve degree completion among credit-constrained students. The targeting comparisons complement [Abbott et al. \(2019\)](#), whose analysis emphasizes the benefits of ability-tested grants when family transfers and equilibrium prices respond to policy. Here, family support and prices remain fixed, while students can adjust both their schooling and their field. This field-choice margin adds to the student-work and selection mechanisms studied by [Garriga and Keightley \(2013\)](#): assistance can redirect education toward higher-return fields even when it produces fewer completed degrees overall.

Increasing the annual offer to \$5,000 preserves the welfare advantage of unrestricted aid over STEM-contingent aid, but changes the completion response to targeted grants. STEM-contingent grants now raise bachelor’s attainment under all three eligibility rules; with broad eligibility, the increase is 2.8 percentage points, compared with 9.1 points under unrestricted grants. Loans still require less public financing than grants, although the cost of unrestricted credit rises substantially. Appendix [C.7](#) reports the larger expansions and their financing requirements. The completion loss under STEM grants depends on the size of the expansion.

4.4 Repayment Policies

Repayment rules determine how students share the risks of education with the government. Fixed payments leave borrowers more exposed to low earnings, while income-based payments provide insurance but reduce the additional income borrowers retain when they earn more. These arrangements can affect both the willingness to borrow for college and the choice between higher-earning and preferred fields.

I compare the baseline menu of Standard and income-based repayment with systems offering only one plan. I then vary three features of mandatory IBR: its participation cost, the cap that limits payments to the Standard amount, and forgiveness of the remaining balance. Table [6](#) reports the results.

In the main mandatory-IBR experiment, borrowers with positive debt incur the calibrated participation cost when repayment begins. Under the baseline, they can avoid this cost by

choosing Standard. A separate experiment removes the cost to consider the possibility that it arises entirely from learning about and enrolling in IBR, and could therefore be eliminated by making participation automatic.

Table 6: Repayment design and education

Policy	CEV (%)	BA (%)	$\bar{\theta}$	HC value (\$)	100τ
Status quo	0.000	35.98	0.719	89,166	0.000
Standard only	-0.013	35.19	0.719	87,119	-0.325
IBR only	-0.639	29.81	0.710	73,842	1.142
IBR: zero entry cost	3.788	49.66	0.711	125,630	-0.213
IBR: no payment cap	-0.637	29.79	0.710	73,797	1.117
IBR: no forgiveness	-0.617	29.67	0.709	73,508	0.921

All policies include their financing adjustment. The no-entry-cost policy changes only the IBR entry-cost assumption within mandatory IBR. “No forgiveness” retains the repayment formula but does not discharge debt after the usual payment count.

Standard-only repayment leaves aggregate welfare almost unchanged after financing, although bachelor’s attainment falls to 35.2 percent and graduate attainment to 13.8 percent. Part of the fiscal saving returns to households through lower income and payroll tax liabilities, offsetting losses from the narrower repayment menu.

With the entry cost retained, mandatory IBR lowers welfare by 0.6 percent and bachelor’s attainment to 29.8 percent. Borrowers who would have stayed on Standard must now bear the cost, changing the appeal of borrowing and education before graduation. STEM graduates fall to 10.0 percent of the cohort, alongside the decline in total completion.

Removing the entry cost reverses the welfare and attainment results: welfare rises by 3.8 percent, bachelor’s attainment reaches 49.7 percent, and graduate attainment reaches 27.8 percent. The reform is also self-financing: induced fiscal responses permit a tax reduction with a present value of \$516 per entrant (Appendix Table 13). The earnings value of human capital increases to approximately \$126,000. STEM degrees rise to 16.8 percent of the cohort through broader completion, despite a small decline in the average field return among

graduates.

This reversal depends on what the calibrated cost represents. If researching plans and completing the switching process account for all of it, a default arrangement could remove it. Any burden associated with participation itself would remain. The calibration cannot distinguish these components, and the model charges the cost once at repayment entry even when it summarizes anticipated participation burdens. I therefore retain it in the main experiment and interpret the zero-cost variant conditionally.

Removing the payment cap or eliminating forgiveness changes welfare little relative to mandatory IBR with its entry cost: all three policies imply losses of roughly 0.6 percent after financing (Table 6).

4.5 Welfare by Family Resources

I highlight eight policies to compare how the instrument and field condition affect welfare across family-resource groups. The tuition, grant, and loan pairs each compare assistance available across fields with assistance requiring a STEM commitment. For grants and loans, I use broad eligibility so that this comparison does not also change means or ability requirements. Standard-only and mandatory IBR show the incidence of narrowing the baseline repayment menu.

The form of assistance matters for who benefits. Universal free tuition delivers larger percentage welfare gains to entrants from high-resource families, while a flat grant benefits low-resource entrants more. Table 7 reports these gains by initial parental resources, averaging individual consumption equivalents within each group.²¹

Under universal free tuition, mean welfare gains are 7.8 percent for high-resource entrants and 1.4 percent for low-resource entrants. The last-dollar design helps explain this difference. Assistance covers tuition remaining after existing grants, so students with larger

²¹These averages differ from the aggregate welfare measure, which applies a single consumption adjustment to equate expected utility across all entrants. Resource groups are determined before the reform and remain fixed across policies.

Table 7: Welfare incidence by initial family resources

Policy	Low resources	Middle	High	Gainers (%)
Universal free tuition	1.44	3.06	7.80	87.96
STEM free tuition	0.95	2.33	6.69	81.92
Grant: all fields, broad	1.07	0.96	0.74	94.27
Grant: STEM, broad	0.50	0.39	0.24	78.53
Loan: all fields, broad	0.23	0.22	0.14	99.99
Loan: STEM, broad	0.06	0.07	0.06	100.00
Standard only	−0.04	−0.02	0.01	53.86
IBR only	−0.65	−0.68	−0.59	0.00

The first three columns report mean individual goods-consumption equivalents, in percent. Gainers reports the percentage of all matched entrants whose expected utility increases. Parental-resource groups are fixed income bands and need not contain equal numbers of entrants.

uncovered bills receive larger subsidies. Given the initial joint distribution of student types, this makes sense as students from high resource families are more likely to face a high tuition environment. Students whose grants already cover tuition receive no additional assistance, even if they have few resources for living expenses. Differences in college prices, enrollment, and graduate attendance also influence the benefits each group receives, while the financing taxes affect their net welfare gains.

A flat grant reaches students whose tuition is already covered and can help finance consumption while enrolled. Mean welfare gains are 1.1 percent among low-resource entrants and 0.7 percent among high-resource entrants. Additional borrowing capacity produces smaller gains, with the same ordering across resource groups. These results suggest that assistance with living expenses is particularly valuable to students, even for whom existing grants already cover much of tuition.

Field conditions change the value of this assistance. Adding a STEM requirement reduces the gains from the grant expansion in every resource group. Students who accept the condition obtain additional resources but may move farther from their preferred field; those

who decline it forgo the additional aid while still facing the taxes that finance the policy. The resulting welfare effects depend on both financial circumstances and field preferences. A reform can therefore raise earnings through higher-return majors without delivering larger welfare gains to the students it targets.

4.5.1 Alternative Welfare Measures

The main welfare measure allows households to adjust their choices when consumption is scaled in the status-quo environment. I also calculate the consumption increase required to match the reform’s utility while holding baseline choices, including hours worked, fixed. Under universal free tuition, this measure gives a gain of 4.15 percent, close to the main estimate of 4.1 percent. Allowing choices to adjust within the welfare benchmark therefore makes little difference for this policy.

Three further measures express the utility change in different terms. The first scales consumption net of work disutility, the composite that enters the GHH utility function. The second scales wages, initial assets, and parental transfers together, allowing households to reoptimize under the status quo. The third gives households a one-time transfer of liquid wealth at age 18, again allowing their choices to adjust. Each asks how much of the specified adjustment would make households as well off as under the reform.

The principal policy rankings remain similar across these measures, although their magnitudes differ because they change different resources and opportunities. In particular, an upfront wealth transfer can relax borrowing constraints immediately, while higher wages provide resources over the working life. Appendix [C.5](#) provides the definitions and full results.

4.6 Fiscal Costs

The welfare gains from student aid depend partly on how much of its initial cost the government recovers through subsequent loan repayments, higher tax receipts, and changes in benefit payments. Table [8](#) reports the additional financing required after accounting for these

responses. I consider the same eight policies as in the welfare-incidence comparison, covering tuition subsidies, broad grant and loan expansions with and without a STEM condition, and the two main repayment reforms.

Universal free tuition requires approximately \$14,294 in additional present-value financing per entrant, compared with \$12,086 for STEM-contingent tuition. These amounts equal 1.33 and 1.13 percent of the respective policy cohorts' discounted labor earnings. Universal tuition therefore delivers its larger attainment and welfare gains at a higher net public cost. The comparison incorporates both the broader coverage of universal assistance and the different earnings paths induced by completion and field choice.

Table 8: Net Fiscal Financing Requirements

Policy	100τ	Additional tax revenue (\$)	Share of earnings (%)
Universal free tuition	5.847	14,294	1.329
STEM free tuition	4.954	12,086	1.126
Grant: all fields, broad	0.703	1,627	0.158
Grant: STEM, broad	0.324	745	0.073
Loan: all fields, broad	0.017	38	0.004
Loan: STEM, broad	-0.153	-351	-0.034
Standard only	-0.325	-741	-0.073
IBR only	1.142	2,548	0.256

Financing requirements are expected present values per entrant, discounted at the market interest rate over the cohort's life cycle. They equal the revenue collected through the tax adjustment that preserves the status-quo government balance. Negative values indicate fiscal savings returned through lower taxes. The final column expresses financing as a percentage of the policy cohort's discounted labor earnings. The adjustment 100τ applies proportionally to positive liabilities under the combined income and employee payroll tax schedule.

Grants and loans also differ in how their initial costs are recovered. Grants provide resources without requiring repayment, whereas additional lending generates future payments from borrowers. Both can increase tax receipts by enabling students to complete degrees or choose higher-earning fields. STEM-contingent loan expansions generate sufficient net receipts to permit a tax reduction, while tuition subsidies require additional financing even after accounting for their effects on earnings and repayment. The appendix reports fiscal

requirements for the complete set of policies, including means- and ability-targeted aid.

5 Conclusion

Student aid affects both how much education individuals acquire and which fields they choose. I study these decisions in a life-cycle model that combines schooling, major choice, borrowing, and repayment. Each reform preserves the government's expected discounted net receipts from an entering cohort, so its welfare effects incorporate the taxes needed to finance it.

Access to student credit supports degree completion in both STEM and other fields. Eliminating new student loans reduces attainment and welfare, and credit remains valuable even when tuition is free because students must still finance living expenses while enrolled. Conditioning on field of study changes this role. Restricting loans to STEM increases STEM completion but reduces the total number of graduates. Offering free tuition conditional on STEM instead expands completion and encourages many students who would already graduate to choose a higher-return field.

Universal free tuition produces more graduates than STEM-contingent tuition, while the field condition raises the average degree premium among those who complete. Despite these different responses, the two policies generate similar earnings values of human capital. Universal tuition delivers the larger welfare gain even after financing its higher public cost. In these experiments, the additional completion and freedom to pursue preferred fields outweigh the fiscal advantage of restricting assistance. Moving toward a higher-return field raises earnings, but may also require students to give up something they value.

The grant and loan expansions show that the form of assistance also matters. At a common annual increment of \$2,000, grants produce larger welfare gains, while additional borrowing capacity requires much less public financing. Attaching a STEM condition increases targeted degree completion under both instruments, but their effects on total completion differ: STEM-contingent grants reduce bachelor's attainment, whereas STEM-contingent loan

expansions increase it. These patterns persist under means and ability requirements at the \$2,000 increment. At \$5,000, STEM-contingent grants also increase attainment, although unrestricted grants continue to yield larger completion and welfare gains. The distribution of benefits differs across instruments as well. Last-dollar free tuition delivers larger percentage welfare gains to entrants from high-resource families, while flat grants favor those with fewer family resources.

Repayment reform offers another route to expanding education, but its benefits depend on why borrowers avoid IBR. Mandatory IBR lowers attainment and welfare when the calibrated participation cost remains. If that cost can be eliminated, the reform instead raises completion and welfare while generating sufficient net fiscal receipts to permit a small tax reduction. Understanding the source of the cost is therefore consequential for policy design. Information, application, and administrative burdens may be reduced through simpler enrollment or automatic participation. A preference for predictable payments or for a schedule that commits the borrower to repay debt more quickly would call for preserving repayment choice. The calibration does not distinguish these explanations; evidence separating them would help determine how much of the potential gain from repayment reform policymakers can achieve.

The appropriate aid policy ultimately depends on its objective. If the priority is to increase STEM completion, field-contingent tuition directs substantially more students toward those degrees. If the priority is broader degree attainment and household welfare, universal tuition performs better in these experiments, even after financing its higher cost. When fiscal resources are limited, expanded lending offers gains in completion and welfare with little additional financing, while flat grants deliver larger percentage welfare gains to students from low-resource families. These comparisons do not establish an optimal policy at a common budget, but they clarify the choices policymakers face. Increasing the number of high-return degrees, expanding access to education, and improving student welfare are related objectives that can favor different forms of assistance.

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A Data Construction and Parameter Sources

A.1 Sources and measurement

The High School Longitudinal Study of 2009 (HSL:09) supplies the initial distribution of preparation and family resources. The National Postsecondary Student Aid Study (NPSAS:16) supplies college prices, grants, parental support, attendance intensity, and the field-choice moment. Beginning Postsecondary Students (BPS:12/17) supplies first-year credit progress and longitudinal parental-support evidence. Baccalaureate and Beyond (B&B:16/20) supplies bachelor’s completion duration and cumulative borrowing. The Survey of Consumer Finances (SCF 2019) supplies household wealth, unsecured-credit statistics, and repayment targets. The Current Population Survey (CPS) supplies population attainment, earnings, and work hours. These sources are combined statistically; individuals are not linked across surveys.

NCES statistics use PowerStats with the survey, weight, variables, and restrictions specified below. Valid zero amounts enter means and percentiles; missing and inapplicable codes are excluded. NPSAS:16 monetary flows and balances are converted to 2019 dollars by annual CPI. Income and tuition thresholds used to classify source observations remain in the corresponding source-year dollars. SCF and CPS timing conventions are stated with their respective targets.

A.2 Initial preparation and resources: HSL:09

I use male respondents ($X1SEX=1$) with positive $W3W1W2STU$, positive mathematics scores ($X2TXMTSCOR$), and valid family-income categories ($X2FAMINCOME>0$). The weight is $W3W1W2STU$. Cumulative transcript GPA ($X3TGPAOT$) defines three preparation groups: below 2.5, 2.5 to below 3.5, and at least 3.5. Values from 0 through 4 are valid. The 2011 family-income categories $X2FAMINCOME=1-2$, $3-4$, and 5 or higher define resources of at most \$35,000, above \$35,000 through \$75,000, and above \$75,000.

For missing GPA, I fractionally allocate each observation across the three preparation groups using the weighted GPA distribution among respondents in the same mathematics-score tercile, resource group, and 2013 high-school completion category (X3HSCOMPSTAT). Mathematics terciles use X2TXMTSCOR in the eligible sample. With fewer than 20 observed-GPA donors, I pool completion categories; if fewer than 20 remain, I pool mathematics groups within the resource category. This assumes GPA is missing at random conditional on the donor characteristics. The resulting weighted preparation–resource probabilities are denoted $\pi^H(g, r)$.

A.3 Undergraduate prices and support: NPSAS:16

Price probabilities. I use the undergraduate survey (PowerStats dataset 121), weighted by WTA000. The entrant sample includes men (GENDER=1), in bachelor’s programs (UGDEG=3), dependent (DEPEND=1), ages 18–23 (AGE), at one institution (STUDMULT=1). First postsecondary enrollment occurs in July 2015–June 2016 (PSECTYM=201507–201606). The price-probability construction further requires exclusively full-time attendance (ATTNPT=1) and 9–12 enrolled months (ENLEN).

Tuition and fees paid (TUITION2) have 33rd and 67th percentiles of \$10,056 and \$24,854 in 2016 dollars in this sample. The three common price intervals are $[0, 10056]$, $[10057, 24854]$, and $[24855, 1000000]$. High-school GPA categories (HSGPA) 1–4, 5–6, and 7 approximate the HSLS preparation groups. Dependent family income (DEPINCL) is grouped into $[0, 36835]$, $[36836, 78933]$, and $[78934, 2500000]$. These thresholds translate the HSLS 2011 bands into the 2014 income reference year using CPI-U 236.736/224.939, with integer cutoffs.

Within each preparation–resource group, weighted price shares define $\pi^N(q \mid g, r)$. If any price share is suppressed, I replace the entire conditional row with the price distribution for that resource group pooled over preparation, then normalize the row to sum to one. Thus preparation affects price probabilities, while the dollar menus below depend on resources and price.

Annual tuition and grants. The annual financing sample uses the same sex, degree, dependency, age, institution-count, and full-time/full-year restrictions, but does not restrict first-enrollment date. It therefore includes continuing students. I require TUITION2, total grants (TOTGRT), and federal grants (TFEDGRT) to lie between zero and \$1,000,000. Within each resource-price cell, I calculate weighted means of these three variables on this common sample. Other grants equal TOTGRT-TFEDGRT; net tuition equals TUITION2-TOTGRT. Net tuition may be negative. Parental support is separate from grants.

Table 9: Undergraduate full-time annual financing menu

Resources	Price	Tuition	Other grants	Federal grants	Net bill
Low	Low	7,646	5,468	5,485	-3,307
Low	Middle	16,576	8,929	5,502	2,146
Low	High	40,263	23,516	5,672	11,074
Middle	Low	8,053	4,384	1,900	1,769
Middle	Middle	15,543	7,369	1,936	6,238
Middle	High	40,011	24,397	1,989	13,625
High	Low	8,174	2,779	82	5,314
High	Middle	16,068	5,708	137	10,223
High	High	41,821	16,728	12	25,082

Annual 2019 dollars, rounded to the nearest dollar. Net bill equals tuition less federal and other grants and excludes parental support. Negative bills are retained.

Half-time undergraduate tuition and grants equal one-half of the full-time menu. At age 24, the model replaces federal grants with a pooled annual full-time amount of \$3,300.29. These are model schedules rather than grants recalculated from endogenous student earnings.

Parental support. I measure parental support using NPSAS:16 variable PARHPAMT2, which reports annual parental contributions toward education and living expenses in twelve dollar categories. I assign each category a representative amount, using approximate midpoints for the bounded positive categories and \$75,000 for the open-ended category of

\$50,000 or more. The resulting amounts are

0, 250, 750, 1250, 1750, 3500, 7500, 12500, 17500, 22500, 37500, 75000.

These amounts are in 2016 dollars and are converted to 2019 dollars before entering the model. I use the survey weights to construct the support distribution within each family-resource and undergraduate-price group. The comparison for older students includes independent students, who may also receive parental assistance.

Each cell is compressed into four support states: zero help and three equal-probability intervals of the positive-support distribution. A positive state's amount is its conditional mean under the category-node distribution; probability mass may be split across intervals. This preserves zero receipt and the discretized mean. Half-time support is one-half of full-time support. From age 24, undergraduate support is multiplied by 0.250315. This factor is the ratio of the older (ages 24–44, with no dependency restriction) to younger full-time support means; other sex, degree, institution-count, and enrollment-duration restrictions remain. It is a cross-sectional scaling rule, not an estimated causal effect of turning 24.

Joint entrant distribution. Let s index the support states. The initial probabilities are

$$\pi(g, r, q, s) = \pi^H(g, r) \pi^N(q \mid g, r) \pi^N(s \mid r, q). \quad (41)$$

Three preparation groups, three resource groups, three prices, and four support states produce 108 cells. Assigning distributions observed among students to potential entrants is a maintained assumption. Support states persist throughout schooling; the model does not estimate annual transfer transitions from NPSAS.

A.4 Graduate financing: NPSAS:16

The graduate survey (PowerStats dataset 122) uses WTA000. I select men (GENDER=1) in master’s programs (GRADDEG=1), ages 18–44, with 0–12 months between the BA and graduate enrollment (GRADGAPM), one institution (STUDMULT=1), and 9–12 enrolled months (ENLEN). Attendance is exclusively full-time or half-time (ATTNPT=1 or 2). The common sample requires TUITION2, TOTGRT, and net tuition (NETCST9) between zero and \$1,000,000. Unlike the undergraduate financing sample, this graduate restriction excludes negative reported net tuition.

Full-time tuition categories use the 2016-dollar cutoffs \$13,671 and \$25,620: $[0, 13671]$, $[13672, 25620]$, and $[25621, 1000000]$. Within these bins I calculate means of TUITION2, TOTGRT, and TFEDGRT. Weighted bin counts of 28,610, 29,647, and 28,066 imply price probabilities (0.33143, 0.34344, 0.32513). Half-time tuition and grants are pooled across prices. The non-tuition cost-of-attendance allowance is the attendance-specific pooled mean of BUDNONAJ.

Table 10: Graduate annual financing menu

Attendance/price	Tuition	Other grants	Federal grants	Non-tuition COA
Full-time, low	10,029	3,039	19	18,963
Full-time, middle	20,165	4,350	96	18,963
Full-time, high	39,853	8,663	0	18,963
Half-time, pooled	11,933	2,376	9	17,767

Annual 2019 dollars. COA denotes the institutional non-tuition budget allowance, not actual household expenditure. The high-price federal-grant cell follows the source display-rounding convention and is set to zero. The common full-time COA allowance uses the pooled full-time estimate.

Graduate prices are drawn independently of undergraduate price and family resources and persist after the draw. This independence is an assumption. Graduate parental support uses the full-time PARHPAMT2 distribution in the matched graduate sample and the same category nodes as undergraduate support. I map undergraduate support states into graduate support by preserving their relative position in the support distribution. Let $[a, b]$ denote the percentile interval represented by an undergraduate support state within its family-resource

and price group. I assign that state the average support over the same interval of the graduate distribution:

$$S^{GR}(a, b) = \frac{1}{b - a} \int_a^b Q^{GR}(u) du,$$

where Q^{GR} is the quantile function of the discretized full-time graduate support distribution.

This mapping assumes persistence in relative parental support across undergraduate and graduate study. Weighted by the initial state probabilities, the assigned amounts reproduce the graduate support mean within each resource–price group. Average support among students who enter graduate school can differ because enrollment selects students from these states. Half-time graduate support is one-half of the mapped full-time amount; half-time tuition and grants are estimated separately.

Graduate borrowing covers remaining school-financing needs and the non-tuition allowance in Table 10. Origination fees are 1.062 percent on Direct Loans and 4.248 percent on PLUS loans. The first \$20,500 of annual gross borrowing receives the Direct fee; additional borrowing receives the PLUS fee. Both tranches enter one debt balance.

A.5 Schooling targets: NPSAS, BPS, and B&B

Attendance intensity: NPSAS:16. The calibration sample uses undergraduate dataset 121 and WTA000, restricted to men (`GENDER=1`) in bachelor’s programs (`UGDEG=3`). From `ATTNPT`, I divide the weighted exclusively full-time share (code 1) by the sum of exclusively full-time and exclusively half-time shares (codes 1 and 2). The target is 0.856260. Mixed and less-than-half-time attendance are outside this denominator.

Academic progress: BPS:12/17. The progress target uses dataset 71 with transcript weight `WTD000`. I select men (`GENDER=1`), initially in bachelor’s programs (`UGDEG=3`), full-time in the first year (`ENINPT1=1`), and with 27–33 known attempted credits (`QTYR1ATT`). Including valid zeros, the 20th and 80th percentiles of known earned credits (`QTYR1ERN`) are 25 and 31, giving $31/25 = 1.24$. The calibration compares this ratio with unconditional

model productivity under full-time input. The model has no attempted-credit variable.

Support persistence: BPS:12/17. A separate BPS calculation uses WTB000, not the transcript weight. The sample comprises initially dependent men in bachelor’s programs, ages 18–23, at one institution. I compare 2013–14 support (PARAMT14) conditional on zero versus positive 2011–12 support (PARHPAMT, code 0 versus codes 1–11). Later support is observed among the later enrollment/interview population. This comparison informs persistence in receipt; it does not supply the model’s transfer amounts or a lifetime transition matrix.

Borrowing and completion duration: B&B:16/20. Dataset 134, weighted by WTA000, follows 2015–16 bachelor’s recipients. Among men (GENDER=1), the share with zero cumulative undergraduate federal borrowing (FEDCUM1) is 0.376979. I calculate it as one minus the weighted share with FEDCUM1>0, retaining valid zeros. This is a cumulative-origination measure, distinct from outstanding balances. Completion duration uses B1PSE_BA, months between initial postsecondary enrollment and the 2015–16 bachelor’s award, on the male-recipient sample without a full-time or uninterrupted-enrollment restriction.

Field-choice moment: NPSAS:16. I estimate a weighted linear probability model in undergraduate dataset 121 using WTA000, men (GENDER=1), and graduating bachelor’s seniors (COLLGRAD=1). The outcome is STEMMAJ=1 against codes 2 and 4. The model-comparable regressors are AGE, FIN2000, FEDCUM1, FEDDUE1, HSGPA, PARHPAMT2, PCTALL, and NETCST9. These represent age, access to \$2,000, borrowing history, outstanding debt, preparation, parental help, income rank, and net tuition.

Age groups are below 24, 24–29, 30–39, and 40 or older. FIN2000 codes 1–2 indicate an ability to raise \$2,000; positive FEDCUM1 indicates prior borrowing. Debt enters continuously and GPA uses its released categories. Parental help is grouped into zero, positive amounts below \$10,000, \$10,000–19,999, and \$20,000 or more. PCTALL groups use boundaries 33 and

67; net-tuition groups use boundaries \$1,289 and \$7,710 in 2016 dollars. These regression groups differ from the initial-resource and gross-tuition groups above.

The additional controls are institutional control (CONTROL), race (RACE), selectivity (SELECTV3), SAT-equivalent score (TESATDER), high-school mathematics and physics (HCMATHHI, HCTKPHYS), high-school type (HSTYPE), and Census division (CENSUSDIV). On the same complete-case sample, let R_C^2 be the fit using these controls and $R_{C,X}^2$ the fit after adding the model-comparable block. The target is $(R_{C,X}^2 - R_C^2)/(1 - R_C^2) = 0.0087806$. It is compared with the model regression's full R^2 as a proxy for sorting associated with observed financing circumstances.

A.6 Field-return construction and degree premiums

The earnings observations come from NCES Digest Table 505.10 (2023 edition), based on the 2022 ACS. They are median annual earnings of full-time, full-year workers ages 25–29, classified by first bachelor's field; the sample can include advanced-degree holders. I use liberal arts and humanities, business (general), and general engineering as the low, middle, and high anchors, respectively.²² For the earnings triplet $(y_L, y_M, y_H) = (47210, 62420, 79160)$ and field anchors $(0.1, 0.5, 0.9)$, solve

$$\frac{g(0.9; \psi) - g(0.5; \psi)}{g(0.5; \psi) - g(0.1; \psi)} = \frac{\log y_H - \log y_M}{\log y_M - \log y_L}. \quad (42)$$

This yields $\psi \simeq 0.173$. The assumed field anchors determine curvature; m and n separately determine degree-return levels. A common price deflator cancels from the log-earnings gaps.

For the continuous schooling effect, let b_k be the postsecondary year coefficients $(0.020, 0.073, 0.052, 0.178, 0.164, 0.224)$ for years 13 through 18 in the selected Jaeger and

²²https://nces.ed.gov/programs/digest/d23/tables/dt23_505.10.asp.

Page (1996) specification. With $x_k = k - 12$,

$$\hat{b} = \frac{\sum_{k=13}^{18} x_k b_k}{\sum_{k=13}^{18} x_k^2}, \quad \chi_h = \frac{\hat{b}}{\log 4} = 0.0253502. \quad (43)$$

The origin restriction uses 12 years of schooling as the reference. At $\theta = 0.5$, the degree effects are $mg(0.5) \simeq 0.162$ and $ng(0.5) \simeq 0.050$ log points, corresponding to percentage premiums of $100[\exp(\cdot) - 1]$.

Average bachelor's premiums equal $\mathbb{E}[\exp\{mg(\theta_i)\} - 1 \mid BA_i = 1]$. The full school-exit increment also includes $\chi_h \log h_i$ and the graduate increment $ng(\theta_i)$ where applicable. Subsequent earnings contributions depend on years since exit and persistence ρ_P .

A.7 Household finances and repayment: SCF 2019

I use the full public SCF questionnaire file, pooling its five implicates with weight **X42001**/5. Reference-person age is **X14**. Sex is **X8021** for the reference person and **X103** for the spouse; code 1 denotes male. Marriage or partnership is **X8023**=1 or 2. The SCF unit is a household, whereas the model describes an individual.

Financial wealth and earnings. The wealth target restricts reference-person age to 18–45 and household wage income (**X5702**) to positive values. It includes single male reference persons and partnered households with a male current worker and a female homemaker or partner out of the labor force. Current work uses **X4100** or **X4700** codes 11–17 or 96. The female partner must have employment-status code 80 or raw status 5 or 16, with no current work, temporary layoff, or job search (raw statuses 1–3), and no reported search in the prior year. Raw statuses are **X6670**–**X6677** for the reference person and **X6678**–**X6685** for the spouse; past-year search is **X6780** or **X6784**, retaining codes 0 or 5.

Financial wealth includes transaction accounts, certificates of deposit, non-money-market mutual funds, stocks, bonds, savings bonds, cash-value life insurance, managed assets, and other qualifying financial assets. Quasi-liquid retirement assets are excluded. I subtract

nonnegative revolving balances X413, X421, X427, and X7575; student loans remain separate. The target is the pooled weighted median of this wealth divided by X5702, equal to 0.0960714.

Repayment. The repayment sample requires reference-person age 18–45 and at least one positive federal loan owed by a male reference person or male spouse. Table 11 lists the six corresponding loan slots.

Table 11: SCF student-loan variables by loan slot

Variable	1	2	3	4	5	6
Balance	X7824	X7847	X7870	X7924	X7947	X7970
Federal indicator	X7879	X7884	X7889	X7894	X7899	X7994
Loan owner	X7978	X7883	X7888	X7893	X7898	X7993
Payment status	X7806	X7829	X7852	X7906	X7929	X7952
Reason for no payment	X9300	X9301	X9302	X9303	X9304	X9305
IDR, no-payment branch	X7422	X7424	X7426	X7428	X7430	X7432
IDR, payment branch	X9306	X9307	X9308	X9309	X9310	X9311

A qualifying loan has positive balance, federal indicator 1, and owner 1 for a male reference person or owner 2 for a male spouse. I exclude households with any qualifying loan coded as no payment (payment status 5) because of school or grace (reason 4). IDR is present if any qualifying loan reports IDR in the payment branch (status 1 and IDR code 1) or no-payment branch (status 5 and IDR code 1). Nonpayment requires a qualifying loan with status 5 and reason 1 or 3, excluding households classified as IDR. Weighted household shares on this common denominator are 0.394594 for IDR and 0.125736 for nonpayment.

Unsecured credit. For age-specific limits, I extend the wealth-sample age range to 18–65 and retain positive general-purpose-card balances ($X413 > 0$) and finite positive limits ($X414 > 0$). Interpolated weighted median limits for ages 18–24, 25–29, 30–34, 35–44, and 45–54 are approximately \$2,000, \$7,432, \$12,000, \$12,000, and \$15,000. I round these to age-limit anchors (21, 2000), (27, 7500), (32, 12000), (40, 12000), and (50, 15000), interpolate linearly, and hold the endpoints fixed outside that range. These approximate credit available

to observed borrowers. The 16 percent borrowing rate is motivated by the median positive reported card APR, $X7132/100$, among positive-balance borrowers; inapplicable and no-interest codes are excluded from that calculation.

A.8 Population targets: CPS and demographic series

The 2020 CPS ASEC person file measures 2019 income and annual work. Using `MARSUPWT`, I select men (`A_SEX=1`). For ages 18–45 (`A_AGE`), mean annual hours equal the weighted mean of $\max\{HRSWK, 0\}$ $\max\{WKSWORK, 0\}$, divided by 5,200 for model time units. The target is 0.316790. For ages 25–44, mean earnings equal the weighted mean of $\max\{PEARNVAL, 0\}$, retaining nonworkers and zeros, giving \$58,698.65.

The bachelor’s attainment target uses the Census Bureau’s 2019 CPS educational-attainment table for men ages 18–44. I sum bachelor’s, master’s, professional, and doctoral categories over the published age groups 18–24, 25–29, 30–34, 35–39, and 40–44, then divide by the total male population in those groups. This gives 0.302888. The denominator includes men without a high-school diploma.

Cohort weights use national age-18 populations. For 1969–2009, I aggregate SEER county records by age and sex. For 2010–2019, I use the Census Bureau’s 2019-vintage national resident-population estimates for age 18 in July. For 1947–1968, I multiply births eighteen years earlier by 0.9813476, the median ratio of age-18 population to lagged births over 1969–1979. I round the total, multiply by the overlap’s median male share, 0.5044592, and round again. This earlier-period approximation accounts for average survival and migration.

A.9 Institutional parameters and earnings risk

Positive liquid wealth earns four percent and student debt accrues at 6.05 percent. These rates and statutory student-loan limits are separate from the SCF-based unsecured-credit schedule.

Representative annual undergraduate limits are \$6,500 for dependent and \$10,500 for

independent students. Independence begins at age 24 in the model. The aggregate principal benchmarks are \$31,000 and \$57,500. To translate principal benchmark P and annual limit L into a balance ceiling, initialize $B = 0$ and repeatedly apply $B \leftarrow (1 + r_B)B + \min\{P_{\text{remaining}}, L\}$ until the benchmark is exhausted. For an annual expansion Δ , I repeat this construction with $P + 4\Delta$ and $L + \Delta$. The main experiments use $\Delta = \$2,000$, while Appendix C.7 uses $\Delta = \$5,000$. The household then faces the resulting absolute ceiling, with existing interest-inclusive debt counting against it. This allows additional annual draws without repeatedly increasing the total ceiling upon commitment.

The institutional baseline follows the 2019–20 Federal Student Aid framework ([Federal Student Aid, 2019](#)). Statutory undergraduate annual limits vary by grade and dependency; the model uses representative amounts. Borrowing may continue beyond four years subject to the aggregate ceiling. The four-year increase in the principal benchmark specifies the expansion’s size, not a maximum study duration. Annual loan capacity is not prorated for ordinary half-time attendance.

The federal income-tax schedule uses the 2019 single-filer standard deduction of \$12,200 and marginal rates of 10, 12, 22, 24, 32, 35, and 37 percent. Employee Social Security contributions have a 6.2 percent rate and a \$132,900 wage base; Medicare uses 1.45 percent plus the applicable additional 0.9 percent above \$200,000. These payroll components are separate from the progressive ordinary schedule but belong to the combined financing base. Income support includes a simple cash-assistance schedule with a \$2,500 maximum, an earnings disregard, income phaseout, and an asset test, which approximates SNAP. Retirement benefits and unemployment insurance are separately recorded in the ledger.

The earnings process follows [Guvenen et al. \(2021\)](#). The persistent innovation mixture has probability 0.176, first-component mean -0.524 , and standard deviations 0.113 and 0.046. Persistence is 0.991 and initial log-productivity dispersion is 0.10. The transitory mixture has probability 0.044, first-component mean 0.134, and standard deviations 0.762 and 0.055. Each second-component mean makes its mixture mean zero.

B Numerical Implementation and Welfare Definitions

B.1 Recursive formulation

This subsection collects the household problems for schooling, field choice, working life, and retirement. Individual subscripts are suppressed. Let v_t denote the conditional probability of surviving from age t to $t+1$. Continuation utility is zero after death and after the terminal age.

B.1.1 Schooling

Let $\mathbf{z} = (z^H, W^P, q, s)$ collect the permanent student characteristics, and let q^G denote the graduate cost type if already drawn. The student state is

$$x_t^S = (a_t, B_t, h_t, \varepsilon_t^P, \mathbf{z}, q^G). \quad (44)$$

Before the graduate cost type is drawn, q^G takes a placeholder value.

After observing the current attendance taste shocks, the student chooses among permanent exit, half-time enrollment, and full-time enrollment. Her value before observing these shocks is

$$V_t^S(x) = \mathbb{E}_{\varepsilon_t} \left[\max_{j \in \mathcal{J}_t(x)} \{W_t^j(x) + \varepsilon_t^j\} \right], \quad \mathcal{J}_t(x) \subseteq \{0, HT, FT\}. \quad (45)$$

The feasible set incorporates the schooling-age limit and degree thresholds. The 0 alternative means permanent exit. The expectation is over current attendance shocks.

For an enrollment alternative $j \in \{HT, FT\}$, let $\mathcal{A}_t^j(x)$ denote the set of consumption, work, saving, and borrowing choices satisfying the time constraint, student budget, and

applicable loan limits. The choice-specific value is

$$W_t^j(x) = \max_{(c,n,a',b) \in \mathcal{A}_t^j(x)} \left\{ u^S(c, n; S^j) - \kappa_S S^j - \kappa_{HT} \mathbf{1}\{j = HT\} \right. \\ \left. - C_B(x, b) + \beta v_t \mathbb{E}[V_{t+1}^S(x') \mid x, j, a', b] \right\}. \quad (46)$$

The borrowing-entry cost is

$$C_B(x, b) = \kappa_B \mathbf{1}\{B = 0, b > 0\}. \quad (47)$$

Human capital and student debt follow Equations (20) and (15). The continuation expectation includes persistent earnings innovations and any graduate-cost draw triggered by reaching the bachelor's threshold. Permanent student characteristics remain unchanged.

B.1.2 School exit and field choice

Let $V_t^{entry}(a, B, \varepsilon^P, h)$ denote the post-school value before the initial repayment-plan decision, with the relevant first-worker shocks integrated out. Its productivity argument includes the education return when this value is evaluated at school exit.

For an individual leaving school with a degree, let V_t^G denote value before observing the preferred field θ^* . After observing this preference, the graduate chooses her field:

$$V_t^G(a, B, \varepsilon^P, h) = \mathbb{E}_{\theta^*} \left[\max_{\theta \in (0,1]} \left\{ V_t^{entry}(a, B, \varepsilon^P + \Delta(h, \theta), h) - \kappa_\theta (\theta - \theta^*)^2 \right\} \right]. \quad (48)$$

The education increment enters persistent productivity once, and the individual keeps the chosen field thereafter.

The value of permanent school exit is

$$W_t^0(x) = \begin{cases} V_t^{entry}(a, B, \varepsilon^P + \chi_h \log h, h), & h < h_1, \\ V_t^G(a, B, \varepsilon^P, h), & h \geq h_1. \end{cases} \quad (49)$$

Individuals leaving without a bachelor's degree receive the continuous return to accumulated human capital. Those leaving with a degree also choose a field and receive the corresponding degree premium. Field choice and initial repayment-plan choice occur within the school-exit period.

B.1.3 Working life and repayment

For a working-age borrower, write the state as

$$x_t^W = (a_t, B_t, J_t, \varepsilon_t^P, \varepsilon_t^T, \nu_t, k_t^R), \quad (50)$$

where J_t is the number of accumulated qualifying repayment periods and k_t^R denotes the repayment plan.

Let $\mathcal{A}_t^{\ell, d}(x)$ denote the feasible worker choices under plan $\ell \in \{S, I\}$ and payment status $d \in \{\text{repayment}, \text{nonpayment}\}$. This set incorporates the worker budget, labor-supply constraints, the liquid borrowing bound, and the applicable debt and repayment-clock transitions. Under repayment, the payment must meet the plan-specific minimum; under nonpayment, $D = 0$. The plan-specific branch value is

$$\begin{aligned} \hat{V}_t^\ell(x) = & \max_{d, (c, n, a', D) \in \mathcal{A}_t^{\ell, d}(x)} \left\{ u(c, n) - \xi_D \mathbf{1}\{d = \text{nonpayment}\} \right. \\ & \left. + \beta v_t \mathbb{E}[V_{t+1}(x') \mid x, \ell, d, c, n, a', D] \right\}. \end{aligned} \quad (51)$$

The continuation value incorporates future repayment-plan decisions. At the final working age, it is a retirement value.

A borrower on Standard repayment may remain on that plan or enter IBR. Entering IBR incurs κ_I once. An IBR borrower cannot return to Standard. The plan comparison evaluates each branch at the appropriate plan and repayment-clock state. At initial repayment entry, an indebted individual faces the same comparison, with no qualifying repayment periods yet accumulated. A debt-free worker has neither a repayment-plan choice nor a student-loan payment.

A legitimate zero-dollar IBR payment counts as repayment and advances the qualifying-payment clock. Nonpayment instead incurs ξ_D , leaves the clock unchanged, and allows interest to accumulate, as in Equation (30). Any remaining IBR balance is forgiven upon reaching the required number of qualifying periods.

B.1.4 Retirement

The retirement state contains liquid assets, student debt, the repayment clock, the repayment plan, and the fixed annual pension Y^R . Retirees choose consumption and saving and, when indebted, payment status and the amount repaid. Conditional on plan ℓ , their branch value is

$$\begin{aligned} \widehat{V}_t^{R,\ell}(x) = & \max_{d, (c, a', D) \in \mathcal{A}_t^{R,\ell,d}(x)} \left\{ u(c, 0) - \xi_D \mathbf{1}\{d = \text{nonpayment}\} \right. \\ & \left. + \beta v_t \mathbb{E}[V_{t+1}^R(x') \mid x, \ell, d, c, a', D] \right\}. \end{aligned} \quad (52)$$

The feasible set incorporates the retirement budget in Equation (34), the liquid borrowing bound, and the applicable repayment requirements and debt transitions. The available repayment-plan transitions and IBR entry cost apply as during working life. Debt-free retirees choose only consumption and saving.

The pension remains fixed throughout retirement. Student debt is discharged at death, and the terminal continuation value is zero.

B.1.5 Policy changes to the household problem

Policy experiments change the relevant feasible sets, budgets, and repayment rules. A binding field commitment restricts the field-choice set in Equation (48); the commitment status is included in the student state when relevant.

Mandatory IBR removes the initial repayment-plan comparison. A borrower entering repayment with positive debt receives the IBR value net of κ_I in the cost-bearing experiment. The separate zero-entry-cost experiment removes this cost. Subsequent periods do not charge the entry cost again.

I solve the household problems backward from retirement. Retirement values supply the last working-period continuation values; worker values determine the returns to field choice at school exit; and school-exit values determine the returns to continued enrollment.

B.2 Solution order and state representation

Solution method. I solve the household problem by backward induction, beginning at the terminal age. I first solve the retirement and working-life problems without student debt, followed by the corresponding problems for borrowers under each repayment plan. These continuation values determine the value of leaving school, including the choice of field and any cost of entering repayment. I then solve the student problem backward through the schooling ages. At each state, students compare leaving school with full-time and half-time enrollment, choosing work, saving, and borrowing conditional on attendance.

Discretization and optimization. The baseline grid specification is as follows. The liquid-asset grid contains 40 nodes spanning $-\$15,000$ to $\$5$ million. Zero is included explicitly. The student-debt grid contains 27 nodes between zero and $\$400,000$. Human capital retains 15 nodes and ranges from $h_0 = 1$ to the graduate-degree threshold $h_2 = 4096$. Nodes are geometrically spaced between degree thresholds, with explicit nodes at $h_1 = 256$ and h_2 , with additional nodes immediately below each threshold. These additional closely spaced

threshold nodes distinguish continuation values before and after degree completion. Persistent earnings use 13 age-specific nodes. Their probability locations are equally spaced between the first and ninety-ninth percentiles of the earnings distribution generated by the shock process. I construct these distributions from 100,000 simulated earnings paths. Academic productivity uses seven nodes at the 0.1, 7, 24, 50, 76, 93, and 99.9 percentiles of its calibrated distribution. Expectations over transitory earnings use six quadrature nodes, and employment has two states. Preferred fields use 101 equally weighted midpoint nodes on $[0, 1]$. Graduate prices and repayment status enter as additional discrete states.

Interpolation and optimization. I use piecewise-linear interpolation in each continuous state dimension. In the student problem, continuation values are interpolated jointly over liquid assets, student debt, and human capital.

Conditional on borrowing or repayment, the solver searches feasible asset intervals, checking interior first-order-condition candidates and relevant boundaries. It compares candidates across intervals rather than assuming that the objective is globally concave.

For the student borrowing choice and the ordinary working-life repayment problem, the outer search evaluates feasible endpoints and choices that place next-period debt on a grid node. It also includes applicable policy breakpoints, such as the graduate loan-fee threshold. The solver then applies six golden-section refinement steps within each interval adjacent to the best candidate. Repayment and nonpayment are evaluated separately. At school exit, I optimize field choice using Brent’s method over the admissible field interval.

Simulation. I simulate household histories forward using the solved decision rules. Persistent earnings evolve continuously, with innovations drawn from the two-normal-mixture process used to construct expectations. Interpolation evaluates decisions between the solved state nodes.

For indebted workers, I compare interpolated values of repayment and nonpayment before interpolating policies within the selected alternative. This avoids averaging repayment and

nonpayment decisions together. Across policy experiments, individuals retain the same initial characteristics and random draws.

B.3 Policy solution and financing

For each reform, I choose a constant tax adjustment τ that preserves the government’s expected discounted net receipts per cohort under the status quo, as defined in Equation (38). The calculation includes taxes, student-loan disbursements and repayments, education subsidies, and other government benefits over the entrant’s full life cycle, including retirement.

I first solve and simulate the reform with $\tau = 0$ to calculate its fiscal effect before financing. I then search over candidate tax adjustments, solving household decisions and simulating the resulting fiscal flows at each rate. This procedure accounts for how the financing adjustment itself changes schooling, field choice, work, saving, and repayment. Reported policy outcomes use the resulting financed solution.

The fiscal closure applies to entering cohorts: the reform and its financing adjustment do not apply to individuals who entered before its introduction. Thus, the reform does not draw additional revenue from older cohorts to finance assistance for new entrants. I also follow the first ten reform cohorts, entering from 2020 through 2029, under the same financing rate. Budget balance holds in expected present value over the cohort’s life cycle, allowing expenditures during schooling to precede the tax receipts and loan repayments that help finance them.

B.4 Welfare measures

I express each reform’s welfare effect as a change in consumption or resources under the status quo that delivers the same expected utility as the financed reform. The measures differ in what changes in this benchmark problem and whether households can adjust their choices.

Let s denote an entrant’s initial characteristics, with distribution $F(s)$. Let $V^0(s)$ and

$V^p(s)$ denote expected age-18 utility under the status quo and financed policy p . Average expected utility is

$$\bar{V}^j = \int V^j(s) dF(s), \quad j \in \{0, p\}.$$

The aggregate comparisons evaluate welfare before an entrant knows her initial characteristics. All measures retain the model's attendance tastes and utility costs associated with schooling, field choice, borrowing, nonpayment, and IBR participation.

Consumption equivalent. The main measure asks how much goods consumption must increase at every age and in every state under the status quo to make an entrant indifferent to the reform. For a candidate increase λ , I replace the consumption component of period utility with

$$\log((1 + \lambda)c - G(n, S)),$$

where $G(n, S)$ is the work-disutility term defined in the model. Budget constraints and financial institutions remain those of the status quo. Households choose schooling, work, saving, borrowing, and repayment again under this modified utility function.

Let $V^g(s; \lambda)$ denote the resulting value. The consumption-equivalent variation solves

$$\int V^g(s; \lambda^g) dF(s) = \bar{V}^p. \tag{53}$$

I report $100\lambda^g$. A value of two percent means that a permanent two-percent increase in goods consumption under the status quo provides the same expected utility as the financed reform.

Consumption equivalent with fixed choices. A second measure holds status-quo decisions fixed and asks how much consumption must increase along those histories to match the reform's utility gain. Hours, attendance, field choice, saving, borrowing, and repayment remain at their baseline choices.

Write baseline consumption net of work disutility as $x_t^0 = c_t^0 - G(n_t^0, S_t^0)$. The fixed-choice equivalent solves

$$\bar{V}^p - \bar{V}^0 = \mathbb{E} \sum_{t=18}^{90} \beta^{t-18} \mathbf{1}\{\text{alive at } t\} \log \left(\frac{(1 + \lambda^{fix})c_t^0 - G(n_t^0, S_t^0)}{c_t^0 - G(n_t^0, S_t^0)} \right). \quad (54)$$

The expectation averages over initial characteristics and subsequent histories. I calculate the utility change along simulated baseline histories and compare it with the difference in solved policy values. This measure requires no additional optimization. Its comparison with the main consumption equivalent shows how allowing choices to adjust affects the welfare benchmark.

Net-consumption equivalent. This measure scales consumption net of work disutility, $x = c - G(n, S)$, rather than goods consumption alone. With logarithmic utility,

$$\log((1 + \lambda)x) = \log x + \log(1 + \lambda).$$

Scaling the composite therefore adds the same utility increment in every surviving period. Define the expected discounted number of periods alive as

$$A = \sum_{t=18}^{90} \beta^{t-18} \Pr(\text{alive at } t).$$

Because survival is exogenous, the aggregate net-consumption equivalent is

$$\lambda^x = \exp \left(\frac{\bar{V}^p - \bar{V}^0}{A} \right) - 1. \quad (55)$$

This expression leaves the other utility costs unchanged and requires no additional household solution. It differs from the main measure because it scales the entire consumption–work composite.

Resource equivalent. The resource equivalent asks how much household endowments must increase under the status quo to provide the same expected utility as the reform. I multiply wage capacity, initial liquid assets, and parental transfers by $1 + \lambda$, then solve the household problem again. Let $V^R(s; \lambda)$ denote the resulting value. The resource equivalent satisfies

$$\int V^R(s; \lambda^R) dF(s) = \bar{V}^p. \quad (56)$$

Tuition, grants, borrowing limits, tax thresholds, and utility-cost parameters retain their baseline values. Taxes and benefits respond according to their existing rules. Since initial assets are zero in the baseline, their proportional scaling adds no wealth at entry; the resource increase operates through wage capacity and parental support.

Unlike consumption scaling inside utility, this experiment changes what households can afford. Its welfare value depends on when resources arrive, how much households work, and whether borrowing constraints limit their ability to move resources across ages.

Initial-wealth equivalent. Dollar equivalent variation measures the one-time change in liquid wealth at age 18 that delivers the reform's expected utility under the status quo. Let $s(e)$ denote initial characteristics s with liquid assets increased by e . The uniform aggregate equivalent solves

$$\int V^0(s(EV)) dF(s) = \bar{V}^p. \quad (57)$$

Households can adjust all subsequent choices. A positive EV is the initial transfer required to make the status quo as attractive as the reform; a negative value is the amount that could be removed while leaving the entrant indifferent.

An initial transfer can relax schooling-age borrowing constraints immediately. It can therefore have a different welfare value from additional earnings received later in life, even when the two have the same present value.

Aggregate and individual equivalents. The aggregate measures use a common percentage change or dollar transfer for all entrants and equate average expected utility. For distributional comparisons, I additionally calculate an equivalent separately for each initial individual. For example, individual goods equivalents satisfy

$$V^g(s; \lambda^g(s)) = V^p(s).$$

The welfare-incidence tables average these individual equivalents within family-resource groups. These averages generally differ from the uniform aggregate equivalent because the value of a given consumption or resource change varies across individuals.

C Additional Policy Results

C.1 Main policy comparison

Table [12](#) reports the main policies and twelve \$2,000 aid expansions. Graduate attainment is a subset of BA-or-higher attainment. Human-capital value is the age-45 present value of remaining pre-retirement earnings gains evaluated at no-school hours; it excludes schooling costs.

C.2 Fiscal requirements for the main policy menu

Table [13](#) reports net financing requirements for the main policy menu. Amounts include induced taxes, benefits, and loan cash flows. Negative requirements permit tax reductions. The final column scales financing by discounted cohort labor earnings. Appendix [C.7](#) reports the larger expansions.

Table 12: Financed results for the main policy menu

Policy	CEV (%)	BA (%)	Grad. (%)	STEM (%)	HC (\$)
Status quo	0.000	35.98	14.66	12.65	89,166
No student loans	−0.639	29.07	9.04	9.86	71,618
Standard only	−0.013	35.19	13.82	12.44	87,119
IBR only	−0.639	29.81	10.89	10.03	73,842
IBR: no payment cap	−0.637	29.79	10.88	10.03	73,797
IBR: no forgiveness	−0.617	29.67	10.60	9.97	73,508
Universal free tuition	4.120	55.06	23.51	19.18	134,155
Free tuition, no loans	3.795	48.35	18.75	16.12	117,573
STEM-only loans	−0.210	32.14	11.93	16.21	81,753
STEM free tuition	3.353	48.53	22.61	45.76	131,754
IBR: zero entry cost	3.788	49.66	27.81	16.84	125,630
Grant: all fields, broad	0.916	39.38	14.90	13.84	96,440
Grant: all fields, means	0.323	36.99	14.47	12.94	91,223
Grant: all fields, ability	0.229	36.86	14.81	12.95	91,013
Grant: STEM, broad	0.372	34.62	14.12	26.04	92,266
Grant: STEM, means	0.139	35.01	14.19	18.31	89,629
Grant: STEM, ability	0.062	35.61	14.56	14.97	89,474
Loan: all fields, broad	0.195	38.78	16.80	13.90	96,428
Loan: all fields, means	0.069	37.09	15.51	13.12	92,095
Loan: all fields, ability	0.059	36.67	15.17	12.95	90,902
Loan: STEM, broad	0.065	36.42	15.02	14.52	91,259
Loan: STEM, means	0.018	36.16	14.81	13.32	89,960
Loan: STEM, ability	0.018	36.07	14.75	13.05	89,638

BA, graduate attainment, and STEM counts use the common cohort at age 45. Welfare uses the full matched entrant population. HC is the common-hours earnings value described in the text. Aid expansions in this table are \$2,000 annually.

Table 13: Fiscal requirements for the main policy menu

Policy	100τ	Additional tax revenue (\$)	Share of earnings (%)
Status quo	0.000	0	0.000
No student loans	0.669	1,488	0.150
Standard only	-0.325	-741	-0.073
IBR only	1.142	2,548	0.256
IBR: no payment cap	1.117	2,492	0.250
IBR: no forgiveness	0.921	2,054	0.206
Universal free tuition	5.847	14,294	1.329
Free tuition, no loans	6.207	14,808	1.405
STEM-only loans	0.026	58	0.006
STEM free tuition	4.954	12,086	1.126
IBR: zero entry cost	-0.213	-516	-0.048
Grant: all fields, broad	0.703	1,627	0.158
Grant: all fields, means	0.327	750	0.074
Grant: all fields, ability	0.129	296	0.029
Grant: STEM, broad	0.324	745	0.073
Grant: STEM, means	0.233	533	0.052
Grant: STEM, ability	0.067	153	0.015
Loan: all fields, broad	0.017	38	0.004
Loan: all fields, means	0.043	99	0.010
Loan: all fields, ability	-0.052	-119	-0.012
Loan: STEM, broad	-0.153	-351	-0.034
Loan: STEM, means	-0.033	-76	-0.008
Loan: STEM, ability	-0.042	-96	-0.009

Dollar amounts are present values in 2019 dollars per entrant, discounted at the market interest rate. The financing adjustment 100τ is a proportional percentage change in positive income-tax and employee payroll liabilities. Negative values denote tax reductions. The earnings denominator is discounted labor earnings of the same policy cohort. All values include behavioral responses.

C.3 Earnings valuation and implied wage premiums

Equation (40) evaluates education's earnings contribution at no-school hours. Table 14 also evaluates both earnings paths at policy hours and allows hours to differ between paths. The latter includes labor-supply responses.

At school exit, accumulated human capital and degree completion contribute $\chi_h \log h$ and $[m\mathbf{1}\{h \geq h_1\} + n\mathbf{1}\{h \geq h_2\}]g(\theta)$ to log earnings, respectively. Their combined percentage premium is

$$100 (\exp\{\chi_h \log h + [m\mathbf{1}\{h \geq h_1\} + n\mathbf{1}\{h \geq h_2\}]g(\theta)\} - 1). \quad (58)$$

I calculate these components for each individual before averaging; evaluating them at mean human capital and mean θ would give a different answer. These are premiums holding other earnings determinants fixed at school exit, before the education increment evolves through the persistent earnings process. Continuous and credential percentage premiums combine multiplicatively.

C.4 Field switches and implied return components

Universal tuition offsets its lower average field return by generating more education. Across all age-45 survivors, the average continuous log-return component rises from 0.080 to 0.119 under universal tuition and to 0.111 under STEM tuition; the degree-and-field component rises from 0.088 to 0.135 and 0.145, respectively. Combining these effects with life-cycle earnings and survival yields similar earnings values of human capital: \$134,155 for universal tuition and \$131,754 for STEM tuition, compared with \$89,166 in the status quo. These values hold labor input fixed and exclude schooling costs and field preferences.

Table 15 reports selected paired flows for age-45 survivors. "Other" denotes a completed non-STEM BA-or-higher degree. These transitions distinguish a larger STEM count generated by new graduates from one generated by a change in fields among graduates. Rows report selected flows rather than an exhaustive transition matrix.

Table 14: Earnings value of acquired human capital under alternative hours assumptions

Policy	No-school hours	Policy hours	Endogenous hours
Status quo	89,166	96,228	110,685
No student loans	71,618	76,895	88,587
Standard only	87,119	93,979	108,145
IBR only	73,842	79,421	91,434
IBR: no payment cap	73,797	79,371	91,382
IBR: no forgiveness	73,508	79,039	91,009
Universal free tuition	134,155	144,937	166,454
Free tuition, no loans	117,573	126,625	145,626
STEM-only loans	81,753	88,211	101,513
STEM free tuition	131,754	143,118	164,055
IBR: zero entry cost	125,630	136,117	156,294
Grant: all fields, broad	96,440	103,976	119,607
Grant: all fields, means	91,223	98,374	113,174
Grant: all fields, ability	91,013	98,221	112,982
Grant: STEM, broad	92,266	99,843	114,754
Grant: STEM, means	89,629	96,816	111,323
Grant: STEM, ability	89,474	96,608	111,119
Loan: all fields, broad	96,428	104,224	119,755
Loan: all fields, means	92,095	99,455	114,349
Loan: all fields, ability	90,902	98,141	112,842
Loan: STEM, broad	91,259	98,578	113,329
Loan: STEM, means	89,960	97,111	111,675
Loan: STEM, ability	89,638	96,760	111,285

2019 dollars per survivor at age 45, discounted at the market interest rate over ages 45–64. Each column subtracts earnings in a no-school counterfactual. The first evaluates both earnings paths at no-school hours; the second evaluates both at the policy’s hours; the third allows hours to differ endogenously between paths. All columns exclude pension income, tuition costs, and forgone earnings before age 45. The first column is the HC value reported in the main tables.

Table 15: Paired changes in completion and fields, as percentages of the age-45 cohort

Policy	No BA $\rightarrow$ STEM	Other $\rightarrow$ STEM	STEM $\rightarrow$ Other	STEM $\rightarrow$ no BA	Other $\rightarrow$ no BA
Universal free tuition	6.86	1.55	1.84	0.04	0.02
STEM free tuition	13.20	20.15	0.02	0.22	0.45
Grant: all fields, broad	1.52	0.51	0.65	0.19	0.26
Grant: STEM, broad	1.20	13.09	0.01	0.89	1.68
Loan: all fields, broad	1.17	0.63	0.55	0.00	0.00
Loan: STEM, broad	0.40	1.51	0.03	0.02	0.03

The same individuals are matched across policies. No BA includes never-attenders and noncompleters.

Table 16: Final fields and implied school-exit return components

Policy	$\bar{\theta}$	BA component (%)	$E[\chi_h \log h]$	$E[M(h)g(\theta)]$
Status quo	0.719	24.47	0.080	0.088
Universal free tuition	0.717	24.42	0.119	0.135
STEM free tuition	0.893	29.98	0.111	0.145
IBR: zero entry cost	0.711	24.25	0.110	0.126
Grant: all fields, broad	0.717	24.43	0.087	0.096
Loan: all fields, broad	0.722	24.57	0.085	0.096
Grant: STEM, broad	0.835	28.13	0.081	0.096
STEM-only loans	0.759	25.75	0.074	0.082
No student loans	0.710	24.20	0.067	0.069

$\bar{\theta}$ and the BA component condition on BA-or-higher attainment. The latter is $100\mathbb{E}[\exp\{mg(\theta)\} - 1 \mid BA]$. The last two columns average the continuous and degree-and-field log increments over all age-45 survivors, using completed education and final fields. $M(h) = m\mathbf{1}\{BA\} + n\mathbf{1}\{graduate\}$. These are school-exit increments associated with those outcomes, before subsequent AR(1) decay; they are not current wage gaps.

Conditional degree premiums and population-average education returns can move differently when completion changes.

C.5 Alternative welfare metrics

The fixed-choice goods equivalent scales every consumption realization on baseline histories while retaining hours, schooling, and other choices. The resource equivalent instead scales wage capacity, initial assets, and parental transfers in the baseline environment and allows choices to adjust until expected utility reaches the policy value. Initial assets are zero in the baseline, so scaling them has no effect for those entrants. The GHH-composite equivalent scales $x = c - G(n, S)$ rather than goods alone. Dollar equivalent variation asks how much additional liquid wealth at age 18 would deliver the policy value.

Table 17: Alternative welfare equivalents

Policy	Goods	Fixed	Composite	Resources	EV (\$)
Universal free tuition	4.12	4.15	4.56	5.16	11,357
STEM free tuition	3.35	3.38	3.71	4.20	9,095
IBR: zero entry cost	3.79	3.82	4.19	4.74	10,368
Grant: all fields, broad	0.92	0.92	1.01	1.15	2,263
Loan: all fields, broad	0.19	0.20	0.21	0.24	454

The first four columns are percentages. Goods allows adjustment in the consumption-scaling benchmark; Fixed holds baseline choices fixed; Composite scales the GHH composite; Resources scales wage capacity, initial assets, and parental support. EV is the uniform age-18 dollar transfer equating average expected utility, not the average of individually inverted EVs.

The main rankings are stable across these measures. Universal tuition yields 4.12 percent under the main goods measure, 4.15 percent with fixed choices, 4.56 percent in composite units, and 5.16 percent in resource units. Its uniform dollar EV is approximately \$11,357. The fixed-choice and reoptimized goods measures are close for these experiments, so choice adjustment in the measurement exercise contributes little to their difference.

C.6 Aid design and fiscal interpretation

A full-time eligible student receives an additional \$2,000 grant and a half-time student \$1,000. Grant surpluses may finance consumption but no education grant is paid after exit. The loan experiments increase annual capacity by \$2,000 and the aggregate principal benchmark by \$8,000, with the latter translated into the model's interest-inclusive ceiling. This is one expanded ceiling, not an increment repeatedly added each year. Existing balances count against it. STEM eligibility becomes available on commitment, without retroactive disbursements. Loans are not automatically prorated for ordinary half-time enrollment, consistent with the historical annual-limit approximation; this makes equal offered full-time amounts an imperfect equalization of assistance across attendance paths.

Half-time grants are prorated; annual loan expansions are not. The comparison therefore includes different attendance incentives. Appendix C.7 applies the same rules to the \$5,000 expansions.

C.7 Larger undergraduate aid expansions

I repeat the twelve undergraduate experiments with an annual increment of \$5,000 in 2019 dollars. Full-time grant recipients receive \$5,000 and half-time recipients \$2,500. Annual loan capacity increases by \$5,000 for either attendance intensity, and the aggregate principal benchmark increases by \$20,000 before conversion to an interest-inclusive ceiling. Eligibility, binding field commitments, and graduate aid follow the \$2,000 experiments. Each reform has its own cohort-balancing tax adjustment.

The larger STEM-contingent grants increase bachelor's attainment under all three eligibility rules, reversing the declines at \$2,000. With broad eligibility, the increase is 2.8 percentage points, compared with 9.1 points under the unrestricted grant. STEM completion rises by 26.1 points under the field condition. In this experiment, all degree recipients choose a field above the STEM cutoff. The larger subsidy therefore generates a particularly strong composition response, alongside a smaller expansion in total completion than

Table 18: \$5,000 annual undergraduate aid expansions

Eligibility	Unrestricted			STEM commitment		
	CEV	Δ BA	Δ STEM	CEV	Δ BA	Δ STEM
<i>A. Grants</i>						
Broad	2.39	+9.1	+2.8	1.67	+2.8	+26.1
Means-tested	0.84	+3.2	+1.0	0.62	+0.8	+8.6
Ability-tested	0.59	+2.4	+0.7	0.35	+0.6	+7.5
<i>B. Loan capacity</i>						
Broad	0.46	+6.8	+2.6	0.29	+3.0	+9.3
Means-tested	0.15	+2.5	+1.0	0.08	+1.0	+3.7
Ability-tested	0.15	+2.0	+0.8	0.09	+0.8	+2.1

CEV is the aggregate goods-consumption equivalent, in percent. Attainment changes are percentage points relative to baseline BA-or-higher and STEM shares of 35.98 and 12.65 percent. Means eligibility uses the lowest initial parental-resource group; ability eligibility uses the top productivity quartile. All results include policy financing.

unrestricted assistance.

Unrestricted grants continue to generate larger welfare gains than STEM-contingent grants: 2.39 versus 1.67 percent under broad eligibility. The corresponding loan expansions yield gains of 0.46 and 0.29 percent. The larger STEM-contingent loan expansion raises bachelor's attainment by 3.0 points, slightly more than the STEM grant, but produces a smaller increase in STEM completion and a smaller welfare gain.

Broad unrestricted grants require \$5,242 in additional present-value financing per entrant, compared with \$2,157 for unrestricted loans. The credit expansion is less costly, although its financing requirement is appreciably larger than at \$2,000. STEM-contingent grants require \$4,453 under broad eligibility; STEM-contingent loans permit a tax reduction of \$809. STEM credit also permits tax reductions under means and ability targeting. The welfare and relative financing comparisons thus survive the larger offer, while the sign of the STEM-grant completion response depends on its size.

Table 19: Financing requirements of the \$5,000 expansions

Instrument/eligibility	Field condition	100 τ	Financing (\$)	Earnings share (%)
Grant: broad	None	2.225	5,242	0.503
Grant: broad	STEM	1.895	4,453	0.428
Grant: means	None	1.011	2,336	0.228
Grant: means	STEM	0.851	1,964	0.192
Grant: ability	None	0.399	920	0.090
Grant: ability	STEM	0.370	852	0.083
Loan: broad	None	0.917	2,157	0.208
Loan: broad	STEM	-0.347	-809	-0.078
Loan: means	None	0.540	1,247	0.122
Loan: means	STEM	-0.021	-48	-0.005
Loan: ability	None	0.077	177	0.017
Loan: ability	STEM	-0.180	-415	-0.041

Financing is the expected present value of additional financing taxes per entrant, in 2019 dollars, discounted at the market rate. Negative values indicate tax reductions. The adjustment 100 τ applies proportionally to positive combined income-tax and employee payroll liabilities. The final column divides financing by discounted labor earnings of the same policy cohort.