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Development of a Counterfactual Model of Career-Long Financial Outcomes in Master's Engineering Education

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Development of a Counterfactual Model of Career-Long Financial Outcomes in Master's Engineering Education

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Abstract

This full empirical research paper will explore the financial costs of pursuing graduate education in engineering. Engineering graduate degrees are commonly perceived as financially advantageous investments, particularly since most are funded through assistantships that minimize immediate student debt. While recent research has explored various costs (both tangible and emotional) associated with graduate education, a comprehensive financial analysis of different graduate pathways compared to industry employment after a bachelor's degree remains lacking. Because graduate education reshapes both the timing and structure of early career earnings and debt, its long-term financial consequences require explicit and systematic analysis. This paper focuses on the development of a modeling method for conducting counterfactual financial analyses of engineering education pathways that explicitly accounts for time, uncertainty, and the dynamic interaction between earnings, debt, savings, and investment growth. We present a net-worth–based framework that tracks individuals' financial trajectories over the life course, incorporating delayed workforce entry, student loan amortization, emergency fund accumulation, and the compounding effects of early-career foregone earnings. Rather than producing definitive estimates of return on investment, this work offers a transparent and extensible tool for evaluating how alternative educational pathways generate divergent wealth outcomes under comparable economic assumptions. We demonstrate the functionality of the model using two illustrative cases that contrast immediate entry into industry after a bachelor's degree with delayed entry following a master's degree. These examples show how small differences in timing, debt burden, and salary progression can produce substantial differences in lifetime financial position.

Introduction

In recent years, the United States annually produces approximately 150,000 bachelor's-, 60,000 master's-level engineers [1–10]. These numbers have grown steadily for the past decade [1–10] with trends, primarily driven by business and industry sectors where the majority of MS holders are employed [11,12], expected to persist [11,12]. The National Science Board reported in their 2024 Science and Engineering Indicators report that labor-market projections indicate rapid growth of occupations requiring a STEM master's degree [10,13], continuing from significant growth in MS engineering degrees between 2012 and 2021 [10].

While industry needs drive overall trends in graduate-level engineering careers due to their majority share of the workforce, other factors influence master's students' decisions to pursue graduate degrees in engineering. The reasons that students give for enrolling in engineering master's programs include primarily supporting professional aspirations (e.g., gaining technical expertise and improving salary and promotion prospects) but also include a desire to learn about a new area of interest (some may use an MS degree to pivot fields within engineering) [12]. These reasons are primarily aligned with industry-focused career goals.

Even though obtaining an MS in engineering may seem well-aligned with the career goals of master's engineering students, who primarily seek industry-related career outcomes, there may be significant misalignment between the goals that motivate reasons for degree attainment and outcomes. One key example of this is the assumed projected financial value of the graduate engineering degree. Across all fields, it is generally true that graduate degrees pay-off: in 2015, Baum and Steele [14] found that mean earnings for those with a graduate degree was 23% higher for those with a master's degree compared to a bachelor's. This pay-off is a function of both the earnings with a graduate degree, compared to the counterfactual (an alternative scenario used for comparison) earnings from a career with only a bachelor's. Thus, it is the difference between career paths within a field that truly determines this pay-off. For careers like engineering, where bachelor's-level positions pay competitively, this difference is potentially mitigated. Thus, a field-specific analysis is required to appropriately determine the financial value of a graduate degree.

Background

In 2020, Cooper estimated the return on investment (ROI) of 14,000 graduate programs across the United States by leveraging publicly available data via the College Scorecard, and American Community Survey data to create counterfactual earnings profiles for similar students who enter industry and end their education journeys at different levels (e.g., BS, MS, PhD) [15]. His calculation compares total lifetime expected earnings minus the tuition and opportunity cost of time spent in graduate school. Then, graduate ROI is presented as the total lifetime earnings with a graduate degree minus those that would have been incurred with just a bachelor's in the same field. For tuition, Cooper estimates costs including tuition, fees, and estimated aid (not loans) and the opportunity cost is the expected earnings that person would have made had they been working in their respective industry for the duration of their time in graduate school [15]. From this work, Cooper debunks the myth that a graduate degree will necessarily pay off [16]. Even within a field such as engineering there can be huge variation in this number. The range in calculated ROI for an engineering master's degree is [$-534,064.00, $ 6,534,312.00] [17]. While these program-level ROI estimates provide a useful first approximation, they rely on highly stylized assumptions and do not account for real-world financing strategies, career trajectories, or the timing of income and investments.

This emerging body of work on program-level ROI provides an important first approximation of the financial consequences of pursuing graduate engineering degrees, but the underlying calculations remain highly stylized and incomplete. First, current ROI models typically assume a uniform financing structure that omits how graduate engineering students pay for school, including widespread use of assistantships, tuition waivers, and employer sponsorship, as well as heterogeneous reliance on federal and private loans with varying interest rates and repayment plans. Second, these estimates generally treat students as completing degrees on a standard timeline and progressing smoothly into stable, full-time employment, thereby obscuring the effects of extended time-to-degree, part-time enrollment, unpaid internships, and periods of underemployment that are common in engineering career trajectories. Third, most frameworks handle foregone earnings as a static cost and ignore the missed investment horizon: early-career income not only supports current consumption but can be deployed into retirement accounts and other assets where compounding returns over several decades generate large downstream differences in wealth, while student loan balances simultaneously accrue interest over the same period.

Existing ROI models also bracket a wide range of non-pecuniary outcomes—such as job satisfaction, research autonomy, intellectual community, and geographic flexibility—that many find valuable, yet whose value is extremely difficult to evaluate in the abstract or compare directly to large, uncertain financial tradeoffs. The complexity of these choices is not to be underestimated: not only do the intangible benefits of graduate study vary dramatically from person to person, but there is also a nontrivial statistical risk of program non-completion [18,19].

In practice, decisions about whether to enroll in, persist through, or leave a graduate program are almost impossible to interrogate without a clear, individualized sense of the financial stakes: a prospective masters student who understands that their degree may entail, for example, a $500,000 lifetime financial cost can more deliberately assess whether the anticipated non-pecuniary benefits are truly worth at least that amount. On the other hand, a student contemplating leaving their degree can move beyond a vague sense of "sunk cost" [18] to recognize how much additional financial downside may accumulate with each extra year in the program. These financial evaluations are likely more critical for those with lower socioeconomic status (which often co-occurs with marginalized groups in engineering) for whom financial risk may be less tolerable [19,20]. Without explicit attention to these uneven financial risks, equity-driven efforts to diversify engineering may inadvertently channel marginalized students into pathways that demand greater personal sacrifice, undermining the very aims of such initiatives. Thus, the research objective of this work is to develop a method that can better model projected financial outcomes over the course of a career and can incorporate the numerous pathways through graduate study in engineering. Guided by this objective, we ask: *How can a counterfactual, net-worth–based model be developed to represent and compare the long-term financial consequences of alternative pathways to the engineering master's degree?*

Theoretical Orientation

The theoretical and conceptual framing of this paper is grounded on Eccles' Expectancy Value Theory (EVT) [21–23]. EVT is a psychological motivation theory that explains motivation as a function of how likely people think they are to succeed at a task (expectancy) and how much they care about or value that task (value) [21–23]. The theory posits that when both expectancy and value are high in a certain context, people are motivated to choose, persist-in, and/or perform a given task. Within EVT, value can be further broken down into four core components: intrinsic value, utility value, attainment value, and cost. Intrinsic value is the enjoyment or interest in the task, attainment value is the importance of doing well for one's identity or goals, utility value is the perceived usefulness for future goals (e.g., career), and cost is the perceived negative aspects such as effort, anxiety, or lost opportunities, which can reduce motivation even when expectancy and value are high.

EVT has been shown to explain the decision to enroll and persist in (or quit) graduate education [18,24–26]. Within EVT, the construct of cost is more complex than a simple measure of effort or difficulty. Sallai et al. [18] shows that graduate students experience multiple, interacting forms of cost, including emotional, opportunity, financial, and identity-related costs, and that students often persist even as these costs grow substantially. Importantly, sunk cost is one of the few reasons students give for continuing in graduate programs, suggesting that prior investments of time, effort, and money can become psychologically binding even when continuation is no longer clearly beneficial.

Financial considerations sit at the core of this dynamic. In EVT, financial benefits are typically mapped onto utility value because they reflect how useful a degree is for achieving future economic and career goals (e.g., higher salary, job security, funding), while financial burdens such as tuition, fees, debt, and foregone earnings are conceptualized as part of cost. These financial components therefore play a central role in how students evaluate the overall value of graduate education. However, financial benefits and costs are uniquely difficult to forecast over the long-time horizons of engineering careers. This uncertainty can amplify sunk-cost reasoning, as students who cannot clearly estimate future outcomes may persist to justify past investments rather than because continuation is objectively advantageous. As Paul and Quiggin argue, "If a prospective student can't, through no fault of their own, properly evaluate the disvalue of not [obtaining a desired outcome], this changes the way we need to assign responsibility for the choice" [27]. While EVT is powerful for explaining motivation, it implicitly assumes that individuals can reasonably evaluate expectancy and value. This limitation motivates the need for better methods to estimate the long-term financial value and cost of graduate education, which is the central aim of this study.

Methods

Selection of Key Variables

The primary outcome of interest is net worth (W_t), defined as the difference between an individual's total financial assets (e.g., savings and investments) and outstanding liabilities (e.g., student loans) at a given age. Net worth was chosen because it integrates three central dimensions of the graduate education decision—education costs, projected earnings, and time—into a single, interpretable measure of financial position over the life course. Modeling W_t as a function of age allows the analysis to capture not only how much an engineer earns but also how early and consistently they convert earnings into wealth while servicing education-related debt.

To operationalize net worth trajectories, the model requires ten input variables:

- **Starting Age (A_0)**: the age at which an individual enters the full-time workforce.
- **Starting Salary (S_0)**: first-year earnings, averaged across engineering sub-disciplines.
- **Starting Net Worth (W_0)**: the individual's financial position at workforce entry, typically zero or negative if student loans are present.
- **Fixed Loan Interest Rate (APR)**: the annual nominal interest rate on education-related debt, used to calculate loan payments.
- **Repayment Duration Period (N)**: length of the loan amortization schedule.
- **Annual Salary Increase (g_s)**: the expected real salary growth rate applied each year until the maximum salary is reached.
- **Maximum Salary (S_{max})**: the upper bound on annual earnings in the model.
- **Annual Savings Rate (α)**: the fraction of annual income allocated to debt repayment, emergency fund contributions, and retirement or other long-term investments.
- **Months of Salary to be Saved in an Emergency Fund (m_E)**: the target size of the liquid reserve.
- **Retirement Age (A_R)**: the age at which the modeled career and net worth trajectory ends.

These variables were selected to capture all major financial flows impacting net worth: income, savings behavior, loan obligations, and investment accumulation. By defining these variables explicitly, the model can simulate net worth trajectories under differing educational pathways while remaining flexible to user-specified input values.

Net Worth Calculation

We begin by specifying a fixed annual savings rate, α (e.g., 10%), which represents the fraction of income allocated each year to debt repayment and long-term savings (emergency and retirement). The total amount of money available for these purposes in year t is given by:

$$\Sigma_t = \alpha S_t \qquad \text{Eq. 1}$$

Annual salary evolves over time according to a real growth rate, g_s, until it reaches a prescribed maximum salary S_{max}:

$$S_t = \min\left(S_{max}, S_{t-1}(1 + g_s)\right) \qquad \text{Eq. 2}$$

The salary growth rate is inflation-adjusted. That is, if the expected nominal annual raise is g_S^{nom} and the expected annual inflation rate is π, then the real salary growth rate used is:

$$g_S = g_S^{nom} - \pi \qquad Eq. 3$$

For example, a nominal raise of 5% with an inflation rate of 3% corresponds to a real salary growth rate of g_S = 2%. This same adjustment was applied consistently to all interest-bearing quantities in the model. All rates governing investment returns, loan interest, and salary growth were converted from nominal to real terms by subtracting the expected inflation rate, ensuring that all calculations are performed in inflation-adjusted (constant-dollar) values.

The model prioritizes allocating available savings to student loan repayment. The loan is assumed to follow a standard fixed-interest, fixed-term amortization schedule. The fixed monthly payment is computed using the equal monthly installment formula:

$$P_L = L_0\left(\frac{i_L(1 + i_L)^n}{(1 + i_L)^n - 1}\right) \qquad Eq. 4$$

where L_0 is the initial loan principal, i_L is the real monthly interest rate, and n is the total number of payments (e.g., $n = 12T_L$, where T_L is the loan duration in years). The corresponding annual loan payment is then,

$$Y_L = 12P_L \qquad Eq. 5$$

Consistent with the treatment of salary growth, the loan interest rate is expressed in real terms by adjusting the nominal APR for inflation. This maintains all monetary values in constant dollars and ensures comparability across income, savings, and debt repayment calculations. The remaining loan balance after year t is updated as:

$$L_t = \max(0, L_{t-1} - Y_L) \qquad Eq. 6$$

After allocating the annual savings allotment to loan repayment, the next priority is building an emergency fund. Following recommended best practices [cite], the target emergency fund is set to three months of salary:

$$E_t^* = m_E\left(\frac{S_t}{12}\right) \qquad Eq. 7$$

Each year, any remaining savings after loan repayment are contributed toward the emergency fund until the target is reached:

$$E_t = \min(E_t^*, E_{t-1} + \Sigma_t - Y_L) \qquad Eq. 8$$

Once the loan is fully paid off ($Y_L = 0$), all available savings are allocated to the emergency fund until the target E_t^* is met.

Finally, after annual loan payments have been made and the emergency fund target is reached, any remaining portion of the savings allotment is allocated to retirement savings. We denote this annual contribution as $C_{I,t}$[1]. The investment balance at the end of each year, I_t, is calculated as:

$$I_t = C_{I,t} + I_{t-1}(1 + r_{I,t}) \qquad Eq. 9$$

where $r_{I,t}$ is the real (inflation-adjusted) annual rate of return. Consistent with other inflation adjustments in the model, the real rate of return is calculated by subtracting the expected annual inflation from the nominal return. The nominal rate of return is estimated using a model portfolio based on the Vanguard target-date fund glide path, in which the percentage allocated to stocks

[1] This model assumes that all annual investment contributions are deposited at the end of each year, after savings have been accumulated. In practice, contributions may be made monthly or at the beginning of the year; however, end-of-year investing represents a conservative assumption, as it minimizes time in the market and therefore yields a lower-bound estimate of accumulated investment growth and net worth.

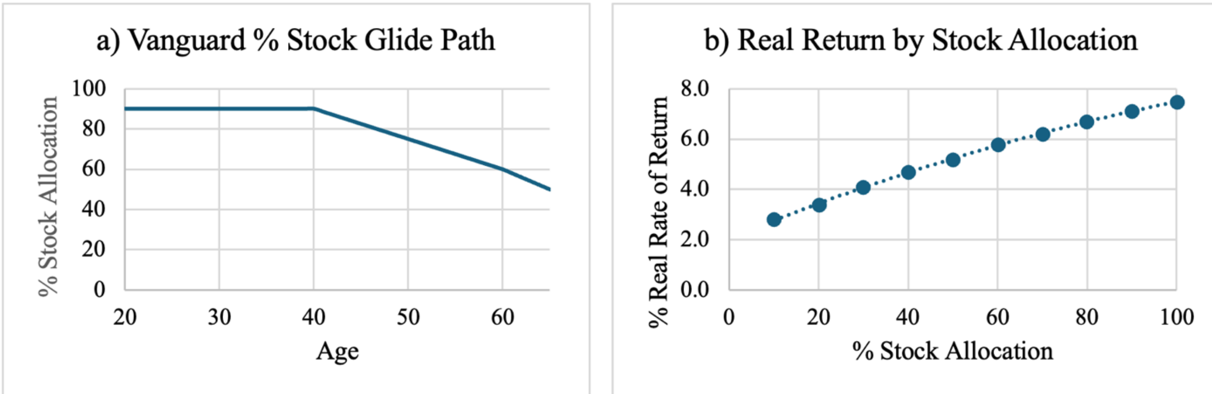

Figure 1. a) the Vanguard target-date fund glide path—demonstrating percent stock allocation of target-date fund investments. b) the Vanguard estimated real return rate on target-date funds based on % stock allocation.

decreases with age [28]. Historical stock and bond market performance data were used to translate the stock allocation into expected portfolio returns[2] [29]. This glide path reduces portfolio risk as retirement approaches, generally lowering expected returns while increasing stability. *Figure 1.a* illustrates the Vanguard stock allocation glide path as a function of age, and *Figure 1.b* shows the corresponding real rate of return for the portfolio at each age.

The starting net worth, W_0, of the student was assumed to be either zero or equal to any debt accumulated during their engineering studies. While the model allows for pre-existing wealth, we did not assume students had accumulated savings prior to graduation. Finally, total net worth at the end of each year is calculated as the sum of the investment balance and emergency fund, minus any remaining loan balance:

$$W_t = E_t + I_t - L_t \qquad Eq. 10$$

Estimating Input Values

To illustrate the functioning of the model and demonstrate counterfactual comparisons, we constructed two example cases representing common pathways through engineering education:

1. Case A: a bachelor's-level engineer entering the workforce with typical student debt.
2. Case B: an individual completing a three-year master's program with no additional debt (e.g., they are funded by an assistantship, industry sponsor, or alternative).
3. Case C: an individual completing a two-year master's program with additional debt (e.g., they are self-funded).

These cases were selected to explore the effects of differences in: age at workforce entry, debt burden, emergency fund accumulation, and early-career salary trajectory. This allows the model to demonstrate how educational decisions interact with savings, debt repayment, and investment accumulation to produce distinct net worth trajectories.

The starting age (A_0) was set to 22 for Case A, 25 for Case B, and 24 for Case C reflecting normative ages of entry into the full-time engineering workforce following completion of a

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[2] Stocks are represented by the Standard & Poor's 90 Index from 1926 through March 3, 1957; the S&P 500 Index from March 4, 1957, through 1974; the Wilshire 5000 Index from 1975 through April 22, 2005; the MSCI US Broad Market Index from April 23, 2005, through June 2, 2013; and the CRSP US Total Market Index thereafter. Bonds are represented by the S&P High Grade Corporate Index from 1926 through 1968, the Citigroup High Grade Index from 1969 through 1972, the Lehman Brothers US Long Credit AA Index from 1973 through 1975, the Bloomberg US Aggregate Bond Index from 1976 through 2009, and the Bloomberg US Aggregate Float Adjusted Bond Index thereafter. When determining which index to use and for what period, we selected the index that we deemed to fairly represent the characteristics of the referenced market, given the available choices.

bachelor's and a two-year master's degree, respectively. These values capture the opportunity cost associated with delayed workforce entry for graduate study and directly affect the length of the earning and investment horizon. The retirement age (A_R) was set to 65 for all cases—the typical age at which individuals transition out of full-time employment in the United States—consistent with conventional retirement planning assumptions and the guidelines around U.S. social security benefits [30]. This establishes a common endpoint for all modeled net worth trajectories and ensures comparability across educational pathways.

Table 1. Input values for counterfactual cases A, B, and C. Case A is an engineer who entered the workforce immediately following their bachelor's degree with the mean undergraduate engineering student loan debt. Case B is an engineer who went directly to a master's program, but took on no additional student debt before graduating and entering the workforce three years later. Case C is an engineer who went directly to a master's program and self-funded (took on aditional debt), but graduated in two years.

Model Input	Case A (BS)	Case B (MS1)	Case C (MS2)
Starting Age (A_0),	22	25	24
Starting Salary (S_0),	$78,731.00	$94,086.00	$94,086.00
Starting Net Worth (W_0),	-$26,529.00	-$26,529.00	-$54,858.00
Fixed Loan Interest Rate (APR),	5%*	5%*	5.7%*
Repayment Duration Period (in years) (N),	10	10	10
Annual Salary Increase (g_s),	3.7%*	3.7%*	3.7%*
Maximum Salary (S_{max}),	$157,462.00	$188,172.00	$188,172.00
Annual Savings Rate (as a percentage of annual income) (α)	10%	10%	10%
Months of Salary to be Saved in an Emergency Fund (m_E),	3	3	3
Retirement Age (A_R).	65	65	65

*interest rates and annual salary increase base values. Model adjusts for inflation by subtracting 3% from APR, and annual raise.

The starting salary (S_0) and maximum salary (S_{max}) were estimated based on data from the National Association of Colleges and Employers [31]. The starting salary for each case was selected to represent typical first-year earnings for engineers at the bachelor's and master's levels, averaged across engineering sub-disciplines for which data are available for the most recent graduating class of 2025 [31]. This parameter establishes the baseline income from which savings, loan repayment, and investment contributions are derived. The maximum salary (S_{max}) was included to impose a realistic upper bound on earnings growth and prevent unbounded salary escalation in the simulation. We estimate the maximum salary to be approximately double that of the starting salary (~.8X the maximum salary reported across engineering fields) [32,33]. The annual salary increase (g_s) was set to 0.7%, representing a real (inflation-adjusted) growth rate in earnings (based on an annual median increase of 3.7% [33]. Applying this rate until the maximum salary is reached allows the model to approximate typical career earnings trajectories without assuming indefinite exponential growth.

The starting net worth (W_0) for both case A and B was set to −$26,529 based on the median bachelor's level student loan debt for engineers [34]. Case C was given an additional −$27,858 in student loan debt to reflect the median amount of graduate debt accumulated by engineers [34]. These values reflect the assumption that students generally do not accumulate positive wealth while enrolled and instead graduate with education-related debt. This value is entered into the model as a negative asset in the year prior to workforce entry. Case B assumes that no additional debt is accumulated during the master's degree, representing a pathway in which graduate education is financed through assistantships, employer sponsorship, or other mechanisms.

The fixed loan interest rate (APR) was set to 5% for undergraduate related debt and 6.4% for graduate debt, as the interest rates on undergraduate and graduate loans differ [35,36]. These values were selected based on the historical range of federal subsidized and unsubsidized student loan interest rates as these loans make up 81.96% of all student loan debt [37]. For Case C, where the student has both undergraduate and graduate debt at different interest rates, we calculated a weighted average (5.7%) as the total interest rate on all accumulated debt. This value represents a reasonable effective average rate for education loans and is converted to a real interest rate in the model to maintain consistency with inflation-adjusted salary growth and investment returns. The repayment duration period (N) was set to 10 years, consistent with the standard federal student loan amortization schedule [38]. This choice reflects the most common repayment structure and provides a realistic time horizon over which education-related debt is serviced.

We selected an annual savings rate (α) of 10% for all cases. Data from financial institutions indicates that most people save between 6% and 14% of their annual salary with individual contributions (prior to employer matches) around 9.5% [39–41]. This parameter controls the total resources available for loan repayment, emergency fund accumulation, and retirement investment and allows the model to examine how competing financial priorities are balanced over time.

The emergency fund target, expressed as months of salary saved (m_E), was set to 3 months for both cases. This reflects standard financial guidance recommending liquid reserves equivalent to three to six months of income [42–44]. Selecting the lower bound of this range represents a conservative and achievable target for early-career engineers while still capturing the stabilizing role of emergency savings in the model.

Limitations

This model simplifies several aspects of real financial behavior. Savings rates are held constant, although in practice they vary with income, life stage, and personal circumstances. Salary growth is modeled using a fixed annual increase, which does not capture larger, discontinuous changes associated with promotions or job transitions. Further, the cases examined are not intended to represent the full range of pathways to an engineering master's degree, but rather to illustrate how a counterfactual, time-sensitive approach can clarify long-term financial consequences. Future work will relax these assumptions by incorporating variable savings behavior, more realistic salary dynamics, and a broader, empirically grounded set of MS and PhD pathways.

Results

Figure 2 shows the modeled net worth trajectories for Case A (BS with mean debt), Case B (three-year MS with no additional debt), and Case C (two-year MS with additional graduate debt) as a function of age. In all cases, the model captures the expected early-career period of negative or low net worth driven by student loan repayment, followed by steady growth as debt is eliminated and savings are increasingly allocated to long-term investments. The transition from loan repayment to emergency fund accumulation and finally to retirement investing is visible in the changing slope of each curve, demonstrating that the model accurately represents the intended financial prioritization structure. The two trajectories diverge primarily due to differences in workforce entry age, salary progression, and early-career compounding time. Case A benefits from an earlier start to earnings and investing, while Case B reflects delayed entry but a different income profile, and Case C reflects additional debt from graduate loans, illustrating the central trade-offs the model is designed to explore. By retirement age ($A_R = 65$), the modeled net worth of Case A is $W_{A,65} = \$1{,}340{,}003.81$, while the modeled net worth of Case B is $W_{B,65} = \$1{,}334{,}545.61$ and

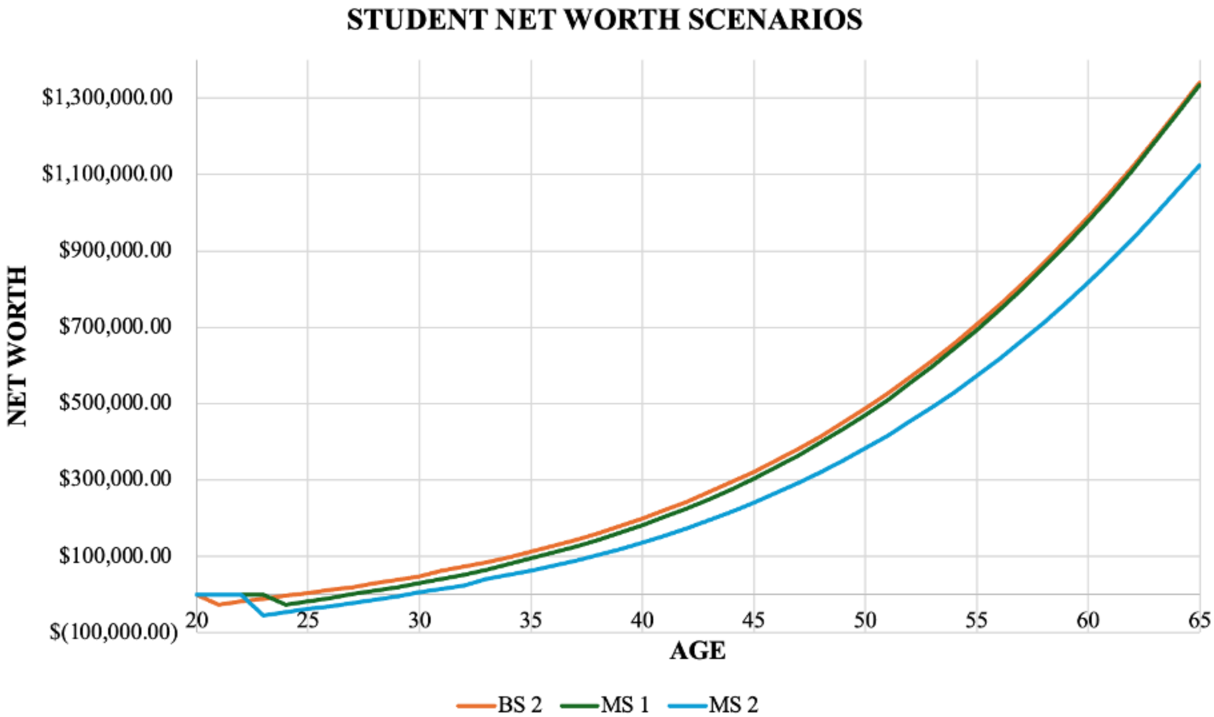

Figure 2. Predicted student net worth as a function of age for two master's degree pathways compared to the counterfactual case (entering industry after obtaining a bachelor's degree). MS1 (Case B) reflects a three-year degree period with no additional student debt, while MS2 (Case C) reflects a two-year degree period with additional student debt.

Case C is $W_{C,65} = \$1,123,759.06$. These values are inflation adjusted and represent the net present value of different career paths in engineering. Our calculations show that the financial ROI in a graduate engineering degree is not necessarily better than a career with a bachelor's alone and that servicing early-career debt and/or savings can have significant financial impacts long-term.

Discussion

From an Expectancy–Value Theory perspective, this model provides a concrete mechanism for making the "cost" and "utility value" components of graduate education decisions more observable, comparable, and interpretable. Rather than treating financial costs as abstract or static, the model operationalizes them as dynamic quantities that evolve through the interaction of delayed earnings, debt accumulation and repayment, and long-term investment growth. In doing so, it translates financial considerations into explicit net-worth trajectories that align directly with EVT's emphasis on how perceived value and cost shape educational choice and persistence.

Importantly, this quantification of financial cost does not reduce the role of non-financial values such as intrinsic or attainment value; instead, it clarifies their weight in decision-making. By providing a defensible estimate of the long-term financial cost (or benefit) of a given pathway, the model creates an implicit "accounting baseline" against which non-pecuniary values can be evaluated. If an individual knowingly persists in a pathway that entails a projected lifetime financial cost of, for example, several hundred thousand dollars, then the combined intrinsic, attainment, and identity-based value of that pathway must exceed that amount for that individual. In this way, the model does not replace subjective valuation but rather enables a more transparent and theoretically meaningful comparison between financial utility and non-financial sources of value component within EVT.

The results also illuminate why sunk-cost dynamics emerge so strongly in graduate education. EVT assumes that individuals can reasonably evaluate both the value and the cost of an action. However, the modeled trajectories show that financial consequences unfold over decades through interacting processes that are difficult to intuit, including compounding investment growth and the long-term effects of early-career income delays. When future outcomes are opaque, students may persist not because the expected value remains high, but because prior investments of time, effort, and money become psychologically binding. This aligns with Sallai et al.'s [18] findings that sunk cost is a central reason for persistence and suggests that sunk-cost effects may be less a cognitive error than a rational response to deep financial uncertainty.

These dynamics have direct implications for equity in graduate engineering education. Because students do not begin from the same financial position, the same educational pathway can represent fundamentally different levels of risk and cost. EVT highlights that motivation depends on perceived value and cost; when financial information is incomplete or opaque, those perceptions are shaped by background, resources, and risk tolerance. A model that clarifies long-term financial consequences therefore supports more equitable decision-making by reducing informational asymmetries and making the stakes of educational choices more transparent. It also demonstrates a quantifiable long-term net-worth impact that undergraduate scholarships can have, especially for low-income students who would otherwise graduate with substantial debt, bolstering current programming and funds like the NSF S-STEM program [20,45,46].

Taken together, this work demonstrates that counterfactual financial modeling can serve as a bridge between motivational theory and real-world educational decision-making. Methodologically, it provides a time-sensitive, net-worth–based framework for comparing alternative pathways. Theoretically, it strengthens the empirical grounding of EVT's cost and utility constructs and creates new opportunities to examine how financial and non-financial values are weighed in high-stakes educational choices. By making financial consequences explicit, the model supports more informed, ethically responsible, and theoretically grounded analyses of graduate engineering education pathways.

Conclusion

This paper introduces a modeling framework for evaluating the long-term financial implications of different pathways through graduate engineering education using net worth as an integrated, life-course metric. By explicitly incorporating salary growth, student debt, savings behavior, emergency reserves, and investment compounding, the model provides a more complete and realistic representation of financial outcomes than existing ROI-style approaches.

Future work will focus on grounding the model in more precise empirical estimates. This includes conducting deeper analyses of available datasets to determine realistic distributions for input values such as starting salaries, salary growth rates, maximum salaries, time-to-degree, loan amounts, financing mechanisms, and savings behavior for common pathways to the MS and, later, PhD. These refined inputs will enable systematic comparisons between a wide variety of graduate education pathways and their bachelor's-only counterfactuals, allowing for robust assessments of when graduate degrees are financially beneficial, neutral, or costly. Ultimately, this work aims to support evidence-based advising, more transparent graduate recruitment practices, and a clearer understanding of the financial equity implications embedded in graduate engineering education.

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Appendix

List of Variables:

W- net worth [$]
L – student loan balance [$]
I – investment balance [$]
E – emergency fund balance [$]
E^* - emergency fund goal [$]
S – annual salary [$]
S_{max} – salary cap [$]

S_0 – starting salary [$]
A – age [years]
N – loan repayment duration [years]
n – loan repayment duration [months]
P_L – monthly loan payment [$]
Y_L – annual loan payment [$]
Σ– total annual savings [$]
C_I – annual investment contribution [$]
C_E – annual emergency fund contribution [$]
r_L – real annual loan APR [-]
i_L – real monthly loan rate [-]
r_I – real investment return [-]
g_s – real salary growth [-]
α – savings rate [-]
π – inflation rate [-]