

ADVANCES IN FINANCIAL EDUCATION

Summer 2025

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Home Bias and Ambiguity Aversion: Insights from Classroom Experiments

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The paper examines the phenomenon of investor home bias, which refers to the tendency of investors to hold a larger proportion of domestic stocks in their portfolios than what is suggested by standard portfolio theories. While previous research has identified factors such as transaction costs and foreign exchange risks, recent studies have emphasized the role of ambiguity aversion in understanding this bias. This study proposes conducting a classroom experiment based on Ellsberg's (1961) findings to provide students with a hands-on experience that deepens their understanding of ambiguity aversion and its implications for investor behaviour. By bridging the gap between academic research and standard textbooks, this experiment aims to shed light on the psychological factors driving home bias and challenge traditional economic and finance paradigms.

Keywords: Home bias; International diversification; Ellsberg's paradox; Ambiguity aversion; Experimental approach.

Introduction

Investor home bias refers to the tendency of investors to hold a larger proportion of domestic stocks in their portfolios than what is suggested by standard portfolio theories (French & Poterba, 1991). Previous research has shown that traditional explanations such as international capital flows, equity investments, transaction costs, foreign exchange risks, and taxes are unlikely to fully account for the magnitude of this bias (Tesar & Werner, 1995; Lewis, 1999). However, recent studies have highlighted the role of ambiguity aversion in explaining investor home bias in their international portfolio choice, drawing inspiration from Ellsberg's (1961) experimental findings. Ambiguity aversion refers to the preference for known probabilities over unknown probabilities, and in the context of investor home bias, it suggests that investors perceive domestic investments as having known probabilities, while foreign investments are seen as more ambiguous (Guiso et al., 2008). Epstein and Miao (2003) and Uppal and Wang (2003) show that differences in the level of ambiguity concerning alternative returns distributions can generate substantial home bias in international portfolio allocation. Guidolin and Liu (2016) conduct a further examination of the effects that investors' aversion to both parameter and model ambiguity can have.

Dimmock, Kouwenberg, Mitchell, and Peijnenburg (2016) provide empirical evidence demonstrating that ambiguity aversion helps explain the observed home bias in investors' portfolio holdings. This finding aligns with the theoretical works of Epstein and Wang (1994), Maenhout (2004), Chen and Epstein (2002), and the textbook treatment by Hansen and Sargent (2008), which has explored the implications of ambiguity aversion in various economic and financial contexts.

Apart from that, numerous studies have sought to understand the reasons behind investors' home bias for domestic assets. The common theories involving transaction costs or capital controls struggle to align with the reality of extensive international capital movement and the higher activity in foreign stock trading compared to domestic markets, as noted by Tesar and Werner in 1995. An alternative theory suggests that investors may have better insights into local companies or the domestic economy, as argued by Pástor in 2000, and Portes, Rey, and Oh in 2001. Van Nieuwerburgh and Veldkamp in 2009 propose a model where the informational edge of domestic investors arises from their strategic choice to acquire knowledge where they have a comparative advantage, particularly regarding home assets. Nonetheless, empirical findings on this matter are inconsistent. Ivković and Weisbenner in 2005, and Massa and Simonov in 2006, present evidence that local investors indeed have an informational edge. They also report that households earn an extra annualized return from local investments over non-local ones, indicating that the advantage comes from local knowledge rather than mere familiarity. Massa and Simonov's research in Sweden supports the idea that local bias is driven by information. Conversely, Seasholes and Zhu (2010) conclude that local stock purchases actually perform worse than sales, implying that local investors may not possess superior information after all.

Despite this progress in academic research, there is a disconnect between this research and the coverage of home bias in standard textbooks of international finance¹, which often fail to provide a deeper foundation for understanding this bias. To bridge this gap, this paper proposes conducting a classroom experiment based on Ellsberg's (1961) experimental findings to provide students with a hands-on experience that highlights the importance of ambiguity aversion and its implications for investor behaviour.

Objectives of the Study

This study has several objectives. Firstly, it aims to investigate the role of ambiguity aversion in explaining investor home bias, shedding light on the underlying psychological factors driving this phenomenon. By exploring the relationship between ambiguity aversion and the tendency of investors to hold a disproportionate amount of domestic assets, this research aims to provide empirical evidence supporting the relevance of ambiguity aversion in understanding home bias.

Secondly, this study aims to bridge the gap between academic research and standard textbooks by providing students with a hands-on experience that deepens their understanding of ambiguity aversion. By conducting an abridged version of Ellsberg's experiment in the classroom, students can gain insights into their own preferences and attitudes towards ambiguity. This experiential learning approach allows for a better understanding of why investors exhibit a bias towards domestic investments.

Thirdly, the research aims to highlight the limitations of Expected Utility Theory, which forms the foundation of traditional economic and finance paradigms. By demonstrating the need to incorporate ambiguity aversion into decision-making models, the study challenges existing theories and encourages a more comprehensive understanding of investor behaviour.

Finally, this study strives to establish a decision-theoretic foundation for investors' preference for domestic investments and their aversion to foreign investments. By providing a conceptual framework rooted in decision theory, this research aims to elucidate the cognitive processes underlying investors' familiarity bias and its impact on portfolio choices.

¹ These textbooks include Shapiro (2014), Bekaert and Hodrick (2018), Eun and Resnick (2018), Madura (2018), Moffet, Stonehill, and Eiteman (2018), and Eiteman, Stonehill, and Moffett (2019).

The Experiment

The experiment presented in this study is an abridged version of Ellsberg's (1961) original experiment, adapted for classroom settings. A total of 116 postgraduate students in accounting and finance were invited to take part in the experiment during their multinational finance lecture. Participants were presented with an urn containing 30 red balls and 60 balls of other colors, including blue and green. They were informed of this composition of the colored balls in the urn (i.e., 30 balls that are red and 60 balls that are either blue or green) and then asked to make choices between various gamble options. In the first experiment, participants must choose between Gambles I and II. The Gamble I offers a reward of \$100 if a red ball is drawn, while Gamble II offers the same reward for drawing a blue ball. Subsequently, participants face another set of gambles based on the same urn of balls. In Gamble III, participants receive \$100 for drawing either a red or a green ball, whereas in Gamble IV, the reward is tied to drawing either a blue or a green ball.

Consistent with Ellsberg's original findings and subsequent studies, the majority of participants exhibit ambiguity aversion. They show a preference for gambles with known probabilities over those with unknown probabilities. Specifically, participants tend to prefer Gamble I over Gamble II and Gamble IV over Gamble III, even though these choices contradict the predictions of Expected Utility Theory. Importantly, participants discover through their own behaviours the limitations of Expected Utility Theory and the necessity of accounting for ambiguity aversion in decision making.

Implications and Conclusion

The experiment's findings have significant implications for understanding investor home bias. The observed preference for known probabilities over unknown probabilities mirrors investors' behaviour in the real world, where domestic investments are often perceived as having known probabilities, while foreign investments are seen as more ambiguous (Heath & Tversky, 1991; Kilka & Weber, 2000; Abreu et al., 2011). By establishing this decision-theoretic foundation, the experiment provides an explanation for investor home bias that goes beyond traditional economic and finance theories.

By conducting the experiment in the classroom, students are actively engaged in the decision-making process and gain first-hand experience of ambiguity aversion. This experiential learning approach fosters a deeper understanding of the psychological factors that contribute to home bias. Students can reflect on their own decision-making tendencies and connect them to real-world investment choices.

Moreover, incorporating the experiment into the curriculum addresses the concern about the intuitive connection between the experiment and home bias. Actively participating in the experiment enables students to intuitively grasp the concept of ambiguity aversion and its impact on investor behaviour. This hands-on experience enhances their understanding and facilitates more engaging discussions on the topic compared to passive lecturing alone.

This study's findings can expand the practical implications for financial education on investor perceptions of home bias and ambiguity. The results have relevance across business, economics, and investment, not just in accounting and finance. Applying the framework in other areas could uncover important parallels and differences. The framework could be expanded to fields like international finance, economics, and accounting. By adapting the experimental approach in

diverse contexts, the research could yield insights to enhance teaching and learning. The practical applications extend beyond finance, as exploring investor biases through an interdisciplinary lens can inform educational initiatives aimed at developing sophisticated financial acumen across disciplines. Leveraging the methodology in diverse settings could lead to more impactful teaching strategies.

Moreover, this project aligns with academia's mission of advancing knowledge and experimental frontiers to better meet evolving societal needs. By generating new empirical insights on investor perceptions, home-bias, and ambiguity, the study contributes to expanding the knowledge base. Conducting novel experiments with students also pushes the boundaries of research methodologies in these domains. This study has the potential to provide important insights not just for the participants, but to inform teaching and research across finance and business-related disciplines. Its broader applications and pedagogical implications are significant, encapsulating academia's core pursuits of expanding relevant research.

In conclusion, the proposed classroom experiment provides valuable insights into the role of ambiguity aversion in explaining investor home bias. By bridging the gap between academic research and standard textbooks, this study contributes to a deeper understanding of the psychological factors driving home bias and challenges traditional economic and finance paradigms. The experiment's findings have practical implications for investors and educators, offering a tangible and relatable experience that enhances students' understanding of ambiguity aversion and its influence on investment decisions.

However, this study focuses on examining the role of ambiguity aversion in shaping investors' source preferences, which can contribute to home bias. In fact, the literature indicates home bias may also be influenced by other factors like locality bias and information advantages. Future research could explore how these additional drivers of home bias interact and manifest in investors' decisions. Incorporating a more comprehensive set of explanations would provide a richer understanding of the investor home bias. Exploring the relative importance and interplay of ambiguity aversion, locality bias, and information advantages could yield valuable implications for investors, scholars, and policymakers seeking to better understand and mitigate home bias in financial markets.

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Integrating FINRA's Securities Industry Essentials (SIE) Content into a Finance Program

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Financial Industry Regulatory Authority (FINRA) developed the Securities Industry Essentials (SIE) content to unify the foundational knowledge required to engage in several securities business areas such as those requiring Series 6 (Investment Company Representative), 7 (General Securities Representative), 57 (Securities Trader), 79 (Investment Banking Representative), 86/87 (Research Analyst), and other registrations. While obtaining these registrations requires employment at a FINRA-member firm, completing the SIE, a prerequisite for each of these, does not. It can be completed by students. This paper analyzes the SIE's purpose, relevance, and benefits to students as well as alternatives for integrating the SIE's content into traditional finance curriculum.

Keywords: finance education, industry certifications, industry preparation, SIE, career readiness

Introduction

The high level of competition for entry-level financial services industry jobs and the similarly high level of competition for finance students among colleges and universities pushes forward innovation in financial education. Producing finance graduates who are more industry-ready is one way that academic institutions can innovate. Traditional curricula emphasize theoretical concepts in corporate finance, investments, and financial markets, but can fall short of equipping students with the industry-specific knowledge required in the professional world.

The Securities Industry Essentials (SIE) content, developed by the Financial Industry Regulatory Authority (FINRA) in 2018, offers an opportunity to bridge this gap by providing students with a broad understanding of the financial services industry. The SIE content, ultimately assessed by FINRA via an exam like the Chartered Financial Analyst (CFA) or Certified Financial Planner (CFP) exams, is a prerequisite for individuals seeking to work in regulated functions of the securities industry. It covers key topics not covered in standard finance classes including an expanded review of financial products with details on the trade settlement processes, regulatory frameworks and dealer/broker representative responsibilities for each product. It also reviews various types of investor accounts, know-your-customer rules, and the specific regulations associated with each account type. Completing the SIE requirement can thus be a valuable credential for students pursuing careers in finance.

Financial Industry Regulatory Authority

FINRA is a self-regulatory organization (SRO) established in 2007 through the consolidation of the National Association of Securities Dealers (NASD) and the regulation, enforcement, and

arbitration arms of the New York Stock Exchange (NYSE). Its creation is tied to the regulatory framework established by the Securities Exchange Act of 1934, which formed the Securities and Exchange Commission (SEC) to oversee and regulate U.S. securities markets. Under the Act, the SEC granted authority to SROs like FINRA to help enforce compliance with securities laws, maintain market integrity, and protect investors. FINRA operates under the SEC's oversight, which approves its rules and ensures its actions align with federal securities laws.

FINRA registers individuals working in the financial markets to ensure that they meet the necessary qualifications, possess the required knowledge, and adhere to certain ethical standards. Through its registration process, FINRA administers licensing exams—such as those for the Series 6 and 7 registrations—that test candidates' understanding of securities laws, regulations, and industry practices. Registration also allows FINRA to track and monitor individuals working in the industry, enabling action against misconduct.

SIE Exam

Prior to introduction of the SIE exam, students would first obtain a job at a FINRA member firm like Morgan Stanley, Wells Fargo, Bank of America, etc. and then as an employee study for the appropriate FINRA exam for their job function like the Series 7 General Representative exam. The time required for employees could be many months and ultimately take more than a year if the employee needs several attempts to pass the exam. Not all employees pass the exam which means that hiring and training new employees incurs the risk that employees are unable to advance or need to separate from the firm.

In October 2018, FINRA split its qualification exams into two parts. All applicants for the different exams would first take one, common core qualifying exam called the SIE, whose test takers do not need to be affiliated with a FINRA member firm - i.e., it allows finance students or graduates to take the exam.

The new SIE (FINRA, 2023) covers core concepts while the follow-on qualifying exam covers role-specific knowledge, thereby reducing redundancy if an applicant is taking multiple qualifications, as specialized qualification exams now focus only on advanced material. Once the second exam is passed the person is allowed to become registered.

Table 1
FINRA Registrations and Required Exams

FINRA Registrations	Qualifying Exams
Representative-Level	
Series 6 - Investment Company and Variable Contracts Products	SIE + Series 6
Series 7 - General Securities	SIE + Series 7
Series 57 - Securities Trader	SIE + Series 57
Series 79 - Investment Banking	SIE + Series 79
Series 86/87 – Research Analyst	SIE + Series 86 + Series 87
Principles-Level	
Series 4 – Registered Options Principal	SIE + Series 7 + Series 4
Series 9/10 – General Securities Sales Supervisor Exam	SIE + Series 7 + Series 9 + Series 10

Table 1 shows a sample of FINRA registrations and the required exams from FINRA (FINRA, 2024).

For students to take the SIE exam, they need to be at least 18 years old. US citizenship is not required. Passing the SIE does not guarantee employment or allow one to engage in the securities business. It does, however, make the hiring of a finance graduate potentially less risky for a FINRA member firm.

If a student, or anyone else for that matter, passes the SIE, their passing grade remains valid for four years, which means that they have four years to be hired by a FINRA member firm and take a certifying exam. After four years they will need to retake the SIE in order to sit for the certifying exam.

The remainder of this paper covers a literature review followed by alternative strategies for implementing SIE content learning objectives into finance courses/degree programs with specific benefits and challenges.

Literature Review

In contrast to the traditional focus in finance programs on corporate finance theory, capital structure, valuation, and portfolio theory, numerous studies have highlighted the opportunities to include professional certification exam content into finance curriculum. Examples include the CFA, CFP, and other finance-industry credentials (Biktimirov, 2012; Girard, 2024; Goetz et al., 2011; Melhorn & Hatch, 2023; Pittenger et al., 2020; Smith & Mansinghka, 1999).

These certifications and their exams serve as a form of industry validation, signaling competence in specific areas of finance. In comparison to the CFA and CFP, the SIE does not require multiple courses of content, offering a lower stakes certification for students and a lower hurdle for program implementation. Ashour et al. (2020) propose integrating the SIE Exam content into a student managed investment fund program.

SIE Content and Learning Resources

The SIE covers some, but not all, of the topics in a traditional investments course. It can be viewed as a practical complement to the more theory-driven investments course and could be a step forward in aligning academic programs with industry expectations (FINRA, 2023). While there is overlap in content in terms of basic definitions, the SIE tends to go more in depth in terms of the mechanics and behind-the-scenes of market operations and how they vary by equities, mutual funds, government and agency bonds, and municipal bonds. In addition, it goes into more detail on the regulatory framework and financial representative responsibilities and prohibited practices and how they vary by security type.

Tables 2 through 9 highlight differences between a typical undergraduate investments course (see Waggle and Moon, 2009) using the topic outline of the textbook, “Essentials of Investments,” by Bodie et al. (2022) and the SIE content. Table 2 specifically focuses on content related to asset classes and financial instruments. In addition to what is covered in an investments course, the SIE covers goes into more details about municipal bonds, shareholder rights and voting procedures, and outstanding share calculations.

Table 2
Asset Classes and Financial Instruments

Investments Course Content	SIE Content
Money Market <ul style="list-style-type: none"> • Treasury bills, certificates of deposit, commercial paper, bankers' acceptances, Eurodollars, repos, reverses, brokers' calls, federal funds, LIBOR market, and yields 	Money Market <ul style="list-style-type: none"> • Covers investments course content • Brokered certificates of deposit and liquidity risk, money market default ratings systems
Bond Market <ul style="list-style-type: none"> • Treasury, inflation-protected, agency, international, municipal, corporate, and mortgage-backed securities 	Bond Market <ul style="list-style-type: none"> • Covers investments course content • Many different types of municipal bonds and their characteristics
Equity Securities <ul style="list-style-type: none"> • Common stock, stock market listings, preferred stock, depository receipts, indexes, index calculations 	Equity Securities <ul style="list-style-type: none"> • Covers investments course topics but not index calculations. • Authorized, issued, treasury, and outstanding share calculations, voting rights and procedures, statutory and cumulative voting, shareholder meeting versus proxy voting
Derivatives <ul style="list-style-type: none"> • Options and futures contracts 	Derivatives <ul style="list-style-type: none"> • Covers investments course content • Warrants and rights

Table 3 highlights securities markets content. In this area the SIE adds more content related to the issuance of many types of new issues including rules and market practices around those issuances, additional content on how market transaction data is recorded via the first, second, third, and fourth markets, and more content related to market regulations and market participant legal and ethical responsibilities by securities type since each type has a unique regulatory body and market participant requirements.

Table 3
Securities Markets

Investments Course Content	SIE Content
<p>How Firms Issue Securities</p> <ul style="list-style-type: none"> Investment banking, shelf registration, private placements, initial public offerings 	<p>How Firms Issue Securities</p> <ul style="list-style-type: none"> Letter of intent, underwriter spread, investment bank negotiated syndicate, lead bank, syndicate agreement, share allocations, management fees, profit sharing, western and eastern syndicates, selling groups, municipal general obligation competitive bid underwriting, best efforts (all or none, mini-max, stand by), negotiated underwriting, due diligence, book entry certificates, market out clause, prospectus timing, trading on primary and secondary markets, insider purchase restrictions, green shoe and penalty clauses, sticky issue, combined primary and secondary offerings, municipal offering official statement, US Government/agency underwritings, yield auction process, treasury bill dutch auctions, competitive/noncompetitive bidding, agency debt selling groups concessions, prospectus delivery rules, 144, 144A, 145, 147, Regs D/S exempt issues
<p>How Securities Are Traded</p> <ul style="list-style-type: none"> Types of markets, types of orders, trading mechanisms 	<p>How Securities Are Traded</p> <ul style="list-style-type: none"> Covers investments course content
<p>Securities Markets</p> <ul style="list-style-type: none"> NASDAQ, New York Stock Exchange, electronic communication networks, bond market, international exchanges, consolidation of stock markets 	<p>Securities Markets</p> <ul style="list-style-type: none"> Covers US exchanges and markets
<p>Trading</p> <ul style="list-style-type: none"> Trading costs, margin, short sales, regulations, self-regulation, recent scandals, circuit breakers, insider trading 	<p>Trading</p> <ul style="list-style-type: none"> Covers investments course content First, second, third, and fourth trading markets, trade settlement timelines for different securities, over the counter trading of debt, market manipulation, proxy rules, creation of new exchanges, reporting requirements, new issue price stabilization rules, penny stock sales rules, Trust Indenture Act of 1939, Investment Advisers Act of 1940, SIPC Act, Federal Telephone Consumer Protection Act, Sarbanes-Oxley Act, Blue Sky Laws, broker-dealer state registration, FINRA account, trading and communications rules, MSRB account, advertising, and trading rules, tax rules, cost basis adjustments, FIFO versus specific identification

Table 4 shows differences in investment company content. SIE content in particular here, puts more focus on regulations and ethical responsibilities of market participants as it relates to sales of brokered mutual funds that charge sales loads. The many variations and details on sales loads leave an opportunity for unethical behavior on the part of market participants to increase their own compensation at the expense of their clients. In addition, more information is given on types of private funds.

Table 4
Mutual Funds and Other Investment Companies

Investments Course Content	SIE Content
Types of Investment Companies <ul style="list-style-type: none"> • Unit investment trusts, managed investment companies, other investment organizations, mutual funds, exchange-traded funds 	Types of Investment Companies <ul style="list-style-type: none"> • Covers investments course content • Fixed and non-fixed unit investment trust purposes, holdings, structures
Mutual Funds <ul style="list-style-type: none"> • Investment policies, fund sales, fee structure, mutual fund returns, late trading and market timing, taxation of mutual fund income, mutual fund investment performance, information on mutual funds 	Mutual Funds <ul style="list-style-type: none"> • Prospectus and rules, diversified fund rule of 75-5-10, custodian banks, selling groups, prohibited practices, shareholder rights, public offering price, forward pricing, in-kind redemption, breakpoints, letter of intent, rights of accumulation, share class types, business development corporations, direct participation programs, limited partnerships for real estate and oil/gas investments

Table 5 condenses several investments course chapters on asset pricing and portfolio theory into one table entitled portfolio theory. Evident here is the lack of investment theory coverage in the SIE.

Table 5
Portfolio Theory

Investments Course Content	SIE Content
<ul style="list-style-type: none"> • Returns and risk calculations, history, inflation, risky assets, risk-free assets, optimal risky portfolio, capital allocation line, diversification, portfolio risk, capital market line, risk premium, security market line, Capital Asset Pricing Model, beta, alpha, regression, factor models, random walk, Efficient Market Hypothesis, implications, forms of market efficiency and evidence, behavioral finance, information processing, behavioral biases, limits to arbitrage, technical analysis 	<ul style="list-style-type: none"> • Not covered

Table 6 compares content on bond securities and portfolios. The SIE covers more details behind debt features and market operation but does not cover bond portfolio theory and practices.

Table 6
Bond Prices, Yields, and Portfolios

Investments Course Content	SIE Content
Bond Prices and Yields <ul style="list-style-type: none"> • Bond features, corporate bonds, treasury bonds/notes, preferred stock, international bonds, bond pricing between coupons, Excel bond pricing, yield to maturity, yield to call, holding period returns, bond prices over time, zero-coupon bonds, Treasury STRIPS, after-tax returns, default risk and determinants, junk bonds, bond indentures, yield to maturity and default risk, yield curve, expectations theory, liquidity preference theory 	Bond Prices and Yields <ul style="list-style-type: none"> • Extensive review of bond features, detailed claim priority in liquidation for various types of debt, unpaid claims, and equities, quote differences for each type of bond, registration of bonds, book entry of owner, transfer agents, paying agents, convertible debt parity price and arbitrage, municipal revenue sourcing and risks, municipal regulatory and tax structures
Bond Portfolios <ul style="list-style-type: none"> • Interest rate risk, duration, immunization, cash flow matching, convexity, active strategies, passive strategies, immunization 	Bond Portfolios <ul style="list-style-type: none"> • Not covered

Table 7 reviews investments course and SIE coverage of equity analysis and valuation topics. The SIE only gives a cursory overview of this area with no coverage of discounted cash flow valuation models.

Table 7
Equity Analysis and Valuation

Investments Course Content	SIE Content
Macroeconomic and Industry Analysis <ul style="list-style-type: none"> • Global economy, domestic macroeconomy, Gross Domestic Product, employment, inflation, interest rates, budget deficit, sentiment, demand and supply shocks, government policy, fiscal policy, monetary policy, supply-side policies, business cycles, economic indicators, industries, business cycle sensitivity, sector rotation, industry life cycles 	Macroeconomic and Industry Analysis <ul style="list-style-type: none"> • Business cycle and sector rotation
Equity Valuation <ul style="list-style-type: none"> • Valuation by comparables, intrinsic value, market price, dividend discount model, constant growth model, growth opportunities, multistage growth models, PE ratios, free cash flow model, comparing valuation models, stock market valuation 	Equity Valuation <ul style="list-style-type: none"> • Dividend yield, PE ratio, mature versus growth companies

Table 8 covers options and futures which Waggle and Moon (2009) note that coverage of these extra chapters, which go beyond the basics covered in Table 2, depends on whether a finance

program offers a separate derivatives course. If they do not offer a separate course, investment courses cover these more detailed chapters. Also, if the investments course is an honors level course, it is likely to cover these extra chapters. The SIE covers basic options related terms and strategies also covered in the investments course. However, the SIE goes into more detail about options account rules, the disclosure statement, and the processes of exercise notices and settlement of exercised options. The SIE provides no additional information on futures.

Table 8
Options and Futures

Investments Course Content	SIE Content
<p>Options</p> <ul style="list-style-type: none"> American and European options, Option Clearing Corporation, other options, value at expiration, call and put options, option strategies, collars, option like securities, callable bonds, convertible securities, warrants, collateralized loans, leveraged equity and risky debt, exotic options, Asian, barrier, lookback, currency-translated, digital, option valuation, intrinsic and time values, determinants, binomial option pricing, two-state option pricing, Black-Scholes option valuation, put-call parity relationship, hedge ratios, portfolio insurance 	<p>Options</p> <ul style="list-style-type: none"> Option types and terminology, rules for options trading accounts, Option Clearing Corporation options disclosure statement, assignment process of exercise notices, settlement of exercised options, process of setting of option strike prices, speculative, hedging, and income trading strategies
<p>Futures</p> <ul style="list-style-type: none"> Mechanics of trading, Clearinghouse, open interest, mark to market, margin account, cash versus actual delivery, regulations, taxation, hedging and speculation strategies, basis risk and hedging, futures prices, spot-futures parity, spreads, stock index futures, synthetic stock positions, index arbitrage, foreign exchange futures, interest rate futures, swaps, balance sheet restructuring, swap dealer 	<p>Futures</p> <ul style="list-style-type: none"> Not covered

Table 9 covers areas not covered by investments courses including annuities and investor account types and details.

Table 9
Other Content Areas

Investments Course Content	SIE Content
<p>Annuities</p> <ul style="list-style-type: none"> Not covered 	<p>Annuities</p> <ul style="list-style-type: none"> Fixed versus variable annuities, equity versus life insurance components, inflation effects, payout options, guaranteed minimum income benefit, purchase and sales process and rules

Investments Course Content	SIE Content
Investor Accounts <ul style="list-style-type: none"> ● Not covered 	Investor Accounts <ul style="list-style-type: none"> ● Know your customer, FINRA, SIPC, business disruption procedures, best interest, suitability, fiduciary, customer relationship summary document, various account types (option, margin, joint, convenience, corporate, partnership, prime brokerage, discretionary, custodial, employees of financial services firms, numbered and fiduciary), third party trading authorization, transfer on death, durable/non-durable power of attorney, void power of attorney, senior citizen rules, brokerage firm types and departments, anti-money laundering, Reg T accounts and rules, savings plans (IRA, ROTH IRA, 401K, 457, 403(b), profit sharing, private pension, Keogh, defined benefit, ERISA), education/health savings plans (Coverdell, 529, LGIP, ABLE, HSA)

While textbooks for traditional investments courses are well established, SIE learning materials are less so. Materials are generally practitioner focused. FINRA firms often provided learning materials for their employees as they prepared for the examinations. As such, many of the same firms that offered educational content for FINRA firms, now offer materials for the SIE.

The advantage of the established publishers is that some of them have relationships with FINRA firms and these FINRA firms may be interested in sponsoring college students by paying for the exam preparation package. Besides eliminating the cost of materials for students, the advantage of this is that the FINRA firm's employees may make themselves available to speak with students about careers in financial services or the SIE exam itself. This arrangement is typically coordinated by the publisher who arranges for the firm to pay for the materials, provides access to online systems to the students, and coordinates discussions between the college and the firm.

There are other, newer learning resources as well including alternative online learning platforms and books available through booksellers. See Appendix A for a sample of learning resources and a weblink to study notes available for free student and instructor use.

SIE Curriculum Integration Options and Hurdles

Several options exist to incorporate SIE content into the finance curriculum, but potential hurdles to adoption should be considered. Specifically, curriculum overload, resource limitations, and the tension between academic, theory-based rigor and industry-focused credentialing should be considered. An analysis of these hurdles may help to determine whether incorporating the SIE content makes sense and if it does which option for incorporating the content would be best.

Curriculum overload is a potential risk in that an emphasis might be placed on covering more material, SIE content in this case, at the expense of students' deeper understanding and application

of existing material. The reward of taking this risk might be dependent on the number of program students potentially interested in a FINRA related career. In this case, offering the SIE content as an extracurricular activity or a separate, new class given program availability might mitigate this risk.

Resource limitations could include the availability of program units to offer a new course or faculty time to advise students and to develop and teach new content. Some programs may have few elective courses and adding a new course would impact other courses. It could be seen as a zero-sum game that hurts other program offerings or makes the program less efficient. In this case, offering the SIE content as an extracurricular activity or integrating the content into an existing course may be the best alternative.

Adoption of the SIE content could also bring about a concern that there might be a shift in focus from academic, theory-based rigor and to industry focused credentialing. Many graduate-level finance programs have already confronted this tension by aligning with the Chartered Financial Analyst certification curriculum which encompasses a broader scope of curriculum than the SIE and is better aligned with academic programs than the SIE, but it also covers industry-specific content not traditionally taught in finance courses like ethics rules and practitioner standards. Perhaps offering the SIE content as an extracurricular activity would make this a non-issue or integrating the content into an existing course would allow the content to be taught in an academic context.

The three potential methods for integrating the SIE content are investigated in more detail below.

Extracurricular Offering

Several options exist to help students prepare for the SIE. The first decision is how to promote the opportunity and the second is what resources students should use to prepare for the SIE. Student finance clubs are a common way to promote the SIE opportunity as members have a common interest in finance careers and already meet outside of the classroom. In addition, or as an alternative in case no finance club exists, announcements can be made to finance students electronically or within finance classes. Students would need to understand how the SIE fits into certain career paths – namely careers at broker/dealer and investment advisory firms – in order for them to understand if it helps them achieve their career goals.

There are several resources available to students to prepare for the SIE. Some of these resources can be grouped together as online learning publishers with written and video content and practice problems. A few of these publishers have established relationships with FINRA firms to provide their employees learning content for all the FINRA exams. The other resource is books available from online bookstores. See Appendix A for more information.

Students can either sign-up with one of these resources on their own or purchase a book, perhaps as part of a finance club's activities. However, if the school or student finance club works with an established SIE publisher who has a relationship with a FINRA firm, the firm may pay for the cost of the SIE publisher's content and the FINRA firm may hold a career information session for students and discuss the importance of the SIE. If not, the publisher will at least offer a discount to a group of students.

Overall, the benefits of making the SIE an extracurricular offering is that it is easy to implement in a crowded finance curriculum where adding SIE-specific content could result in less time

devoted to other areas. Also, most faculty are not prepared to teach SIE material, and making the content an extra-curricular activity relieves faculty of these extra duties.

However, the considerable extra study time outside of the normal class makes it less likely students will take the time to learn the content, which is equivalent to roughly a 1.5-2 semester unit class or a little more than half of a regular 3-unit class. With other student activities and a regular full load of classes, it can be difficult for students to find the needed time.

Additionally, if the college partners with a publisher and a FINRA firm, these firms have an expectation that students who sign-up for the package will actually learn the material and take the SIE test. The firm is ultimately sponsoring the content with the hope of being able to conduct employment interviews with students who pass the SIE. If students fail to follow up and take or pass the SIE, firms may be no longer willing to work with finance programs.

Existing Course Integration

The SIE content is an obvious companion to an existing investments course. The difficulty lies in that investment courses may already have a full semester's worth of content so adding new content may necessitate removing some content. If this is possible, faculty could incorporate the extra content within each section of their existing investments course outline as shown in Tables 2-9. Appendix A includes a web link to detailed study notes organized into content chapters which faculty can customize to facilitate course coverage of this new content.

Another solution is to offer SIE learning resources for students to review on their own outside of class, but perhaps offer some form of incentive like course extra credit. The advantage of this option is that it requires very little work on the part of faculty, while also providing students with more motivation to learn the content and take the exam.

If the school using this option chooses to offer extra credit while also partnering with a publisher and FINRA firm to reduce the cost of the materials, adequate student participation may need to be ensured to maintain long-term support from the FINRA firm.

New Course Offering

This option is the most labor intensive for faculty and administration in terms of creating a new course and adding it to the program curriculum. However, it also offers the most benefits in that students can focus on the unique content and potentially provide the focus to dedicate class time toward an industry speaker.

Preparing a new course is not an insignificant hurdle, and convincing finance faculty of the merit of a new course that could impact other finance courses could be difficult. The other issue is that the SIE content does not take up a whole 3-unit semester course; it covers approximately 1.5 to 2 semester units of material. If the proposal is for a new 1.5 or 2 semester unit course then this greatly simplifies the course design as the SIE content can be taken directly. However, if a 3-unit course is desired to match the units of other courses, then a decision has to be made about what content to include.

One option is to combine the SIE content with CFA content that is not covered in the SIE or in other finance courses. Faculty would need to compare their finance curriculum to the CFA content (CFA Institute, 2023) in order to identify gaps in the curriculum as detailed by Girard (2024). Table 10 below maps some common courses within undergraduate finance curriculum to

the CFA Level 1 content. Much of the CFA content, but not all, is covered by existing finance courses.

Table 10
CFA Level 1 Content

Finance Program Courses	CFA Level 1 Content
Business Statistics	<ul style="list-style-type: none"> ● Quantitative Methods (8-12%)
Microeconomics	<ul style="list-style-type: none"> ● Economics (6-9%)
Macroeconomics	<ul style="list-style-type: none"> ● Economics (6-9%)
Financial Accounting	<ul style="list-style-type: none"> ● Financial Statement Analysis (11-14%)
Managerial Accounting	<ul style="list-style-type: none"> ● N/A
Managerial Finance	<ul style="list-style-type: none"> ● Financial Statement Analysis (11-14%) ● Corporate Issuers (6-9%) ● Equity Investments (11-14) ● Fixed Income (11-14%) ● Portfolio Management (8-12%)
Corporate Finance	<ul style="list-style-type: none"> ● Financial Statement Analysis (11-14%) ● Corporate Issuers (6-9%) ● Equity Investments (11-14) ● Fixed Income (11-14%) ● Portfolio Management (8-12%)
Investments Analysis	<ul style="list-style-type: none"> ● Corporate Issuers (6-9%) ● Equity Investments (11-14) ● Fixed Income (11-14%) ● Portfolio Management (8-12%) ● Derivatives (5-8%) ● Alternative Investments (7-10%)
Derivatives	<ul style="list-style-type: none"> ● Derivatives (5-8%)
N/A	<ul style="list-style-type: none"> ● Investment Policy Statement (Portfolio Management (8-12%)) ● Ethical and Professional Standards (15-20%)

This author identified the CFA Investment Policy Statement and the ethical and professional standards as content missing from the undergraduate finance curriculum and the SIE content. The Investor Policy Statement breaks down the portfolio planning process into detailed steps to identify and quantify client needs, constraints, risk tolerance, and portfolio goals. The ethics and professional standards include the CFA Code of Ethics, the Seven Standards of Professional Conduct, the Global Investment Performance Standard, and the Asset Manager Code.

The Seven Standards of Professional Conduct include specific rules on professionalism, capital market integrity, duties to clients and employers, investment analysis, conflicts of interest, and responsibilities as a CFA member or candidate. For each of these areas, students learn what constitutes violations and how to prevent them. The Global Investment Performance Standard covers a voluntary industry wide standard for calculating and presenting historical investment results to ensure honesty and comparability. The Asset Manager Code ensures that client interests are put before those of institutional asset managers. Lastly, these rules are applied though the several case study assignments.

These areas were then added to the SIE content to create a new 3-unit course. To name this new course, the author chose to build off of the existing undergraduate Investment Analysis course by titling the new course Advanced Investments and Ethics. The new course thus covers both SIE and CFA learning outcomes to prepare students for both certifications. Appendix A covers a sample course outline, discusses a supplement to this paper with course notes, and provides alternative course resources for students.

Conclusion

As the financial services industry continues to evolve, academic programs must adapt to ensure students are not only well-versed in finance theory but also prepared for the practical demands of the industry.

The integration of the SIE exam into finance curricula represents a shift toward a more applied and industry-oriented approach to finance education. By equipping students with knowledge that aligns with the expectations of employers in the financial services industry, universities can enhance the employability and preparedness of graduates. Moreover, the SIE exam's broad coverage of financial products, market operations, and regulations allows students to build a solid foundation for future certifications such as the CFP, CFA or Series 7 licenses.

However, careful consideration must be given to how the exam content is incorporated without displacing other critical areas of finance education. Blending traditional theoretical instruction with practical industry insights through case studies, simulations, and exam preparation modules could offer a balanced approach. Faculty training and development, alongside curriculum revision, would also help ensure successful implementation.

Offering the SIE content in self-study packages as an extracurricular activity through a finance club or similar is a low risk, low faculty effort method for introducing the content. Offering the content on an extra credit basis within an existing class is another option. A final option is to offer a new stand-alone class for 1.5 or 3 units. The choice between these three options depends on student and program constraints.

Regardless of the option chosen, the potential payoff of putting the SIE credential on a student's resume could mean more job interviews due to the positive signaling of student motivation and ability.

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Appendix A – SIE/CFA Course Resources

This appendix provides an example of a new SIE/CFA course outline as discussed in the paper and course study notes organized using the same outline. Also, a few published SIE study resources from two publishers used by brokerage firms and one book from a popular series are provided. These resources include example questions and exams which can be highly valuable for students.

SIE/CFA Course Outline

1. Equities
2. Debt
3. Packaged Products
4. Trading Markets
5. Options
6. Customer Accounts
7. Retirement Accounts
8. New Issues
9. Regulations
10. CFA Level 1 Ethics and Professional Standards and The Investment Policy Statement

SIE/CFA Course Notes

Course notes that instructors or students can use to prepare for the SIE and CFA exams are organized using the course outline above and available in Microsoft Word format at the following website in the publications section:

<https://www.csueastbay.edu/directory/profiles/acct/frickeeric.html>

Published SIE Study Resources

The Cerifi, PassPerfect SIE online study resources were reviewed by the author and considered high quality. They are available at the publisher's website shown below. The STC SIE online study resources were anecdotally not as well liked by myself and one student who reviewed Cerifi and STC. The STC resources are available at the publisher's website. A relatively new book on the SIE with online problems is part of the popular Dummies series of books and is available at any online bookstore. While not reviewed by the author, it could be a viable alternative to the above publishers given its reputation for being well written.

Cerifi (2026, March) Pass Perfect SIE. <https://www.passperfect.com/securities/sie>

STC Securities Training. (2026, March). SIE. <https://www.stcusa.com/securities/licensing/us/sie/>

Rice, S.M. (2024). SIE Exam 2025/2026 For Dummies, 4th Edition. John Wiley & Sons, Inc.

Teaching Incremental Cash Flows Through Financial Causality: A Staged Instructional Model

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Incremental cash flow analysis is a foundational component of capital budgeting but is often taught procedurally rather than conceptually. This paper introduces a structured instructional method that emphasizes financial causality and incrementality as core principles. Using a staged, example-driven approach, students first analyze a baseline scenario before evaluating proposed changes. This framework improves understanding of opportunity costs, tax effects, and working capital adjustments. A quasi-experimental classroom study involving 480 students demonstrates that the method significantly improves performance on complex cash flow estimation tasks, supporting its effectiveness as a pedagogical intervention in undergraduate finance education.

Keywords: *Capital Budgeting, Finance Pedagogy, Incremental Cash Flows, Cash Flow Estimation, Financial Management*

Introduction

Incremental cash flow analysis is more than a computational step—it is the conceptual lens through which all capital budgeting decisions should be interpreted. Rather than asking “*what are the project’s cash flows?*”, the more meaningful question is “*how will this project alter the firm’s cash flows?*” This comparative framing isolates the true economic impact of proposed actions and distinguishes relevant changes from irrelevant data. Despite its centrality, undergraduate finance instruction often downplays incrementality as a foundational principle. Students are introduced to project components—capital outlays, operating cash flows, working capital adjustments—but are rarely taught *why* these elements matter. The economic reasoning behind inclusion or exclusion (e.g., opportunity cost, relevance, sunk cost) is often left implicit. As a result, students may master the mechanics of estimation while failing to grasp the financial causality that gives those numbers meaning.

This pedagogical gap becomes acute in real-world settings, where textbook templates break down. Decisions involving sunk costs, accounting income, or non-cash expenses often require conceptual judgment rather than procedural recall. To address this gap, we propose cultivating a disciplined habit of inquiry in students, framing analysis around the central question: “*How does a firm’s cash flow actually change when it takes a specific action?*” This question reframes project

evaluation as an exercise in tracing cause and effect, anchoring topics such as tax shields and opportunity costs within a common logic.

To operationalize this causal question in the classroom, we introduce a structured, staged instructional model that treats financial causality as the organizing principle of capital budgeting. Using a progressive, example-driven approach, students first establish a baseline “steady state” for a firm before analyzing changes introduced by a proposed project. The method is then implemented as a sequence of short decision points in which students must explain, in plain language, whether a proposed item changes cash flows and through what mechanism, before adding it to a project cash-flow model. Each stage adds complexity, such as taxes, depreciation, working capital, and salvage values, requiring students to justify inclusion or exclusion of each cash-flow item.

To assess the approach empirically, we conducted a quasi-experimental study involving 480 undergraduate finance students, 82 of whom received this staged instruction. All students completed a complex cash flow estimation problem incorporating depreciation, salvage, and opportunity costs. Controlling for prior performance, treated students scored between 2.6 and 10.7 percentage points higher, indicating that the concept-first method improved both comprehension and application.

Literature Review

While leading corporate finance textbooks recognize the importance of incremental thinking, they often treat it as a supporting clarification rather than the organizing logic of cash flow estimation. *Principles of Finance* (Brealey et al., 2022), *Corporate Finance* (Ross et al., 2022), and *Fundamentals of Corporate Finance* (Berk, DeMarzo, & Harford, 2021) each provide clear frameworks for estimating project cash flows. Yet in typical presentation, the economic rationale for *why* certain items matter (e.g., relevance, opportunity cost, and sunk cost logic) is embedded within specific examples rather than emphasized as a unifying principle. The definition of incremental cash flows is typically introduced only after students have already encountered multiple technical inputs. For example, Berk et al. (2021) defines incremental free cash flow after students learn how to incorporate depreciation into cash flow estimations. This can leave students to infer the “why” through repeated exposure rather than explicit instruction.

Prior pedagogical studies have certainly addressed elements of cash flow estimation, such as depreciation and tax shields (McDaniel, 2002), inflation in DCF analysis (Fairchild, 1988), and the framing of replacement versus expansion projects (Chen and Mayes, 2012), but tend to treat the identification of incremental effects as an assumed competency. Instructional strategies like spreadsheet modeling (Yip, 2009) or valuation techniques (Ogden et al., 2017) similarly focus on technique, not conceptual framing. The contribution of the present paper is to make that competency explicit by organizing instruction around causality-first reasoning and requiring students to justify inclusion and exclusion decisions before calculation.

This gap also aligns with a common instructional progression described by Bloom’s taxonomy: students often succeed at remembering and applying formulas yet falter when asked to analyze and evaluate which cash flows are economically relevant. The staged, causality-first approach is designed to scaffold that progression by building from a clear baseline and requiring students to justify inclusion and exclusion decisions before computation. The following section operationalizes this rationale with a class lecture example that instructors can implement directly.

Methodology

Lecture Outline

The following example lecture outline provides a structured, step-by-step framework for teaching incremental cash flow estimation using the staged approach. It is designed to help instructors implement the example over one to two class sessions while emphasizing causal reasoning and relevance, including why specific items belong in incremental cash flows.

Lecture 1 (75 minutes): Establish the baseline business and introduce the expansion scenario without taxes or depreciation to reinforce the baseline-versus-change comparison. Students compute baseline cash flows and then compute incremental operating cash flows from the proposed change, with brief written justification for each included item.

Lecture 2 (75 minutes): Extend the example by integrating taxes and depreciation, then incorporate working capital and terminal cash flows. Use the staged prompts to reinforce relevance and causality, including how to treat sunk costs, opportunity costs, and indirect (spillover) effects.

Implementation note: Stages 1 and 2 are presented in full to establish the template; later stages are presented more briefly but can be implemented using the same structure.

Optional adaptation: Replacement (cost-savings) projects. The primary classroom narrative used in this paper is that of an expansion project, where value is generated through changes in sale price, costs, and capacity. Instructors can apply the same staged structure to a replacement, cost-savings project instead, where incremental cash flows are driven by operating cost reductions rather than new revenues. We provide additional guidance on adapting the staged approach to replacement projects in a brief section at the end of the lecture example.

Stage 1: Introducing the Baseline Scenario

Objective: Familiarize students with a simple cash flow model to establish a baseline for future comparisons.

Narrative Setup: Our proposed strategy relies on an easily digested narrative and financial setup. For instance, consider Vikram, a craftsman who produces and sells synthetic leather belts using existing tools. (We note that the narrative elements of the example can be easily adjusted to what an instructor assesses to be optimal for their students.) Present the details of his business model:

- Vikram produces 5 belts per day, works 250 days a year, and sells each belt at \$105.
- The cost of materials per belt is \$15.
- Vikram already owns the necessary tools, which have no salvage value.

Use the following table to visualize Vikram's cash flows:

Production Details	Units/Value	Revenue and Cost Details	Per Unit	Annual Total
Belts made per day	5 belts	Selling price	\$105	\$131,250
Days worked per year	250 days	Cost of supplies	\$15	\$18,750
Annual production	1,250 belts	Net Cash Flow		\$112,500

Discussion Questions:

1. What profit does Vikram make every year? (What is his annual net cash flow?)
 - \$112,500.
2. What else could Vikram be doing? What assumptions are we making regarding his other opportunities?
 - Vikram could be doing many other things, but we assume there is no other option he considers preferable or more financially viable. (For instance, a job at some other company)

Explanation: This step ensures students grasp the mechanics of simple cash flow estimation. The simple narrative setup aims to help students understand “what will be changing and why we care that it is changing”. Discussion on the original cash flow’s magnitude, superficial as it may be, may help focus student attention on what is at stake for the economic agent (Vikram).

Stage 2: Introducing the Expansion Scenario

Objective: Introduce incremental cash flow analysis by comparing Vikram's baseline operation with a proposed expansion.

Narrative Setup: Vikram is considering an expansion, which involves purchasing new tools and a machine for \$40,000 (upfront). This investment doubles his production capacity to 10 belts per day, but introduces changes:

- Selling price per belt decreases to \$70.
- Cost of supplies increases to \$20 per belt.
- The equipment has a 5-year life.

Use the following table to visualize Vikram’s annual cash flows in the expansion scenario:

Production Details	Units/Value	Revenue and Cost Details	Per Unit	Annual Total
Belts made per day	10 belts	Selling price	\$70	\$175,000
Days worked per year	250 days	Cost of supplies	\$20	\$50,000
Annual production	2,500 belts	Net Cash Flow		\$125,000

Compare the new cash flows to the old cash flows to calculate the **incremental cash flows**:

	0	1	2	3	4	5
Old Cash Flow	\$0	\$112,500	\$112,500	\$112,500	\$112,500	\$112,500
New Cash Flow	(\$40,000)	\$125,000	\$125,000	\$125,000	\$125,000	\$125,000
Incremental Cash Flow	(\$40,000)	\$12,500	\$12,500	\$12,500	\$12,500	\$12,500

Discussion Questions:

1. What are Vikram’s profits each year once the machine is put in place?
 - \$125,000
2. What is the incremental cash flow in each period?
 - See table above
3. Why is there a “year 0”, with nothing but the machine cost?
 - These are set up, or “initial investment” costs. We often assume they happen immediately, whereas other, “operating” cash flows are measured at the end of a period. So, we are assuming Vikram is paying immediately for the machine, will work from now until the end of the year, and then will log his profits of \$125,000.
4. Why does the project end at year 5?
 - The equipment is stated to have a 5-year life. We therefore expect this expansion project to end after 5 years of operation. It is completely possible that Vikram may repair or purchase new machinery at that time, but we consider that action as a separate project.

Explanation: At this point, the students are provided a simple example of how the actions of a firm (i.e. a project) affect a firm’s cash flows. We suggest noting to the students that, while there is often more nuance to real-world cash flow estimation, they have already accomplished the primary goal – to identify the incremental cash flow.

Stage 3: Expanding the Example – Incorporating Taxes and Depreciation

Stage 3A: Adding Taxes (holding depreciation aside)

Up to this point, Vikram’s expansion has generated incremental pre-tax cash flows of \$12,500 per year. Stage 3A introduces corporate taxes for the first time by assuming a 20% tax rate and asking students to convert these operating cash flows into after-tax cash flows. For now, the exercise intentionally ignores depreciation so students can see the direct effect of taxes in isolation; the resulting after-tax cash flows are shown in the table below.

	0	1	2	3	4	5
Pre-tax NCFs	(\$40,000)	12,500	12,500	12,500	12,500	12,500
Taxes (20%)	?	(2,500)	(2,500)	(2,500)	(2,500)	(2,500)
After-tax NCFs	?	10,000	10,000	10,000	\$10,000	10,000

Teaching note: Stage 3A is intentionally simple mechanically. Its purpose is to reinforce that taxes are a real cash outflow that reduces what the project contributes to owners. Students typically compute the after-tax operating cash flow quickly once they apply the 20% tax rate, but the stage also introduces an important “why” question in capital budgeting. If the project required a \$40,000 investment at time 0, why doesn’t that generate an immediate tax benefit equal to 20% of \$40,000? Posed in class as “What about the \$40,000 at time 0?”, this question naturally motivates Stage 3B, where students see that the tax benefit of a capital expenditure is generally realized over time through depreciation rather than as an upfront tax credit.

Stage 3B: Taxes with Depreciation

Note: At this point, it can be helpful to briefly define depreciation (accounting allocation of a capital cost) and to confirm the depreciation method being used (e.g., straight-line versus MACRS). The exact placement and time spent can be adjusted based on course pacing.

Vikram’s expansion requires a \$40,000 equipment purchase. Because capital investments are not typically deducted immediately for tax purposes, Vikram now needs to incorporate annual depreciation into the tax calculation and re-compute after-tax project cash flows. In doing so, students often make a predictable mistake: they subtract depreciation directly from cash flow as if it were a cash expense, which produces the “Incorrect Version” shown below. The “Correct Version” then demonstrates the proper treatment, where depreciation affects cash flow only through its impact on taxes.

Incorrect Version:

	0	1	2	3	4	5
Pre-tax NCFs	(40,000)	12,500	12,500	12,500	12,500	12,500
Depreciation	0	(8,000)	(8,000)	(8,000)	(8,000)	(8,000)
Taxable Income	0	4,500	4,500	4,500	4,500	4,500
Taxes (20%)	0	(900)	(900)	(900)	(900)	(900)
After-tax NCFs	(40,000)	3,600	3,600	3,600	3,600	3,600

Correct Version:

	0	1	2	3	4	5
Pre-tax NCFs	(40,000)	12,500	12,500	12,500	12,500	12,500
Depreciation	0	(8,000)	(8,000)	(8,000)	(8,000)	(8,000)
Taxable Income	0	4,500	4,500	4,500	4,500	4,500
Taxes (20%)	0	(900)	(900)	(900)	(900)	(900)
After-tax NCFs	(40,000)	11,600	11,600	11,600	11,600	11,600

Teaching note: Stage 3B delivers the core conceptual point of depreciation in capital budgeting: depreciation is not a cash outflow, but it reduces taxable income and therefore reduces taxes, which is a cash flow. The clean way to frame this for students is that depreciation creates a “tax shield.” In this example, annual depreciation is \$8,000 and the tax rate is 20%, so depreciation reduces taxes by \$1,600 per year. Equivalently, students can see that taxable income falls from \$12,500 to \$4,500, taxes become \$900, and the after-tax operating cash flow becomes $\$12,500 - \$900 = \$11,600$. The incorrect table is useful because it makes visible the intuition error: treating depreciation as if it were a cash expense effectively double-counts the initial investment by expensing it once at time 0 and again through annual depreciation, which is why the “after-tax cash flow” collapses to an implausibly low figure. This stage also closes the loop on the Stage 3A “why” question about the \$40,000 at time 0: the tax benefit of the investment is realized over time through depreciation deductions rather than as an upfront tax credit.

Optional addition: The instructor may wish to include several additional tables showing how different depreciation schedules (shorter, longer) influence incremental net cash flows. While the aggregate cash flows remain unaffected, the timing of their receipt is affected, thereby influencing the project's net present value.

Stage 4: Expanding the Example – Incorporating Salvage Values

Up to this point, Vikram’s project cash flows reflect the initial investment and after-tax operating cash flows. Stage 4 introduces a terminal cash flow by assuming the tools and machinery can be sold for scrap at the end of Year 5. Specifically, suppose Vikram can receive \$1,000 for the tools and machinery after five years. To keep the focus on terminal cash-flow logic, assume depreciation is taken over five years to a book value of zero, and the tax rate remains 20%. Students are then asked how the possibility of selling the asset changes the project’s cash flows at the end of the project.

	0	1	2	3	4	5
Salvage Value						1,000
Tax on Sale of Tools and Machinery						(200)
New, Salvage-included, Net Cash Flows	(40,000)	11,600	11,600	11,600	11,600	12,400

Teaching note: Discussion in this stage can emphasize why salvage value must be attributed to the project that creates it, and why the relevant value of an asset is its economic value whether it is sold or redeployed. This naturally leads to opportunity cost: if Vikram keeps the machinery for another purpose instead of selling it, the foregone sale proceeds still represent a real cost of choosing that alternative. This stage also works well for clarifying tax intuition, including the fact that selling an asset below book value generates a tax credit rather than an additional cash loss, and for reinforcing how depreciation schedules affect disposal taxes by trading earlier tax shields for potentially higher taxable gains at the end of the project. More broadly, salvage values provide a clean extension of financial causality because students can see how a project's existence creates a disposition decision and how that decision affects after-tax cash flows.

Stage 5: Expanding the Example – Incorporating Working Capital

For Vikram, managing working capital primarily involves managing inventory. Specifically, he needs an extra \$10,000 of leather (inventory) to be available. Is he going to use it? Possibly, but not necessarily. If it gets used it will be replaced to maintain that inventory level. In expectation, the leather is there *just in case*. Try to imagine what is happening, *physically*:

1. Vikram needs \$10,000 worth of leather for operations in years 1-5. He goes out, (let's assume at the beginning of year 1, so end of year 0) and purchases \$10,000 worth of leather.
2. He puts this leather in his workspace, ready and available if he needs it.
3. He works for the next five years, with the leather sitting in his workspace. Remember – the leather is there *just in case*. So let's say that in expectation he doesn't use any of it.
4. At the end of the project, the machinery is salvaged. Therefore, the need for that inventory is gone – so Vikram sells the leather. We will assume he sells it without any appreciation (i.e. inflation), so he gets \$10,000 back.

Note how this process must look on a balance sheet over time:

	0	1	2	3	4	5
Extra Inventory	10,000	10,000	10,000	10,000	10,000	0

Working capital represents the net amount of current assets and liabilities required to sustain the project. Specifically, we calculate net working capital as current assets minus current liabilities. Based on Vikram's scenario, calculate the changes in working capital:

	0	1	2	3	4	5
Extra Inventory	10,000	10,000	10,000	10,000	10,000	0
Change in inventory	10,000	0	0	0	0	(10,000)

We observe that the change in net working capital more accurately reflects the movement of resources. We can easily transform this into cash flow terms, as to increase net working capital, you must spend cash. Inventory is a natural example, as you are literally spending cash to purchase items. These changes in working capital affect the project's total cash flows. Adding this to the previously calculated incremental cash flows:

	0	1	2	3	4	5
Extra Inventory	10,000	10,000	10,000	10,000	10,000	0
Change in inventory	10,000	0	0	0	0	(10,000)
Cash flow of this change	(10,000)	0	0	0	0	10,000
Old cash flows	(40,000)	11,600	11,600	11,600	11,600	12,400
NWC cash flows	(10,000)	0	0	0	0	10,000
New cash flows, with working capital added	(50,000)	11,600	11,600	11,600	11,600	22,400

Teaching note: The instructor can emphasize that working capital is not an operating expense, but a cash commitment required to keep the project running. A useful move is to redirect students from the *level* of inventory to the *change* in net working capital, because the change is what identifies when cash is actually tied up or released. In Vikram’s example, the project requires a one-time \$10,000 cash outflow to build the inventory buffer at the start, followed by a \$10,000 cash inflow when the project ends and the inventory requirement unwinds. This stage also helps address a common misconception: even if working capital is fully recovered, it still matters for project value because cash committed early carries an opportunity cost and reduces present value through the time value of money.

Stage 6: Introducing more nuanced effects such as indirect, opportunity, and sunk costs

Given the already robust length of our write-up, we leave the remaining portion and specific direction of lecture 2 to the instructor. However, we do note several examples that can be easily added to the Vikram example below.

Sunk cost: Another piece of machinery purchased online, but before it is delivered, Vikram realizes it is not what is needed (a point of pivot being whether it can be returned)

Opportunity cost: Vikram needs to expand, and he already owns some land for the expansion. Vikram erroneously assigns it as a “free asset” to be used for an expansion project

Indirect cost: Vikram considers adding a new type of belt to his portfolio. However, he must discern what effect the new belt’s introduction will have on the current sales (be it price of quantity effect) of his current belt products

Alternative Project Type: Replacement (Cost-Savings) Decision

Instructors can adapt the staged approach in this manuscript to replacement decisions by presenting the analysis as a comparison of two alternatives: retaining existing equipment versus replacing it with new equipment that improves efficiency.

We provide a brief and generalized narrative setup. Vikram’s business faces a replacement decision in which new equipment becomes available that produces the same output and does not change sales. The replacement aims to improve internal efficiency, perhaps by reducing maintenance and repair spending, lowering energy usage, or improving labor productivity. As in our main example of staged instruction, we suggest establishing a baseline scenario with existing

machinery. For the richest set of elements within the project’s counterfactual, we suggest including an ongoing depreciation schedule into the baseline case. Students then analyze the decision by comparing this baseline, a “keep the existing machine” scenario to a “replace” scenario that incorporates these cost changes.

The replacement project can incorporate multiple types of cash flows: at the replacement date, Vikram pays for the new machine and sells the old machine; during operations, the benefit is the after-tax cost savings each period, potentially combined with differences in depreciation tax shields; and at the end, the analysis includes after-tax salvage value differences and any working-capital effects that differ between the two alternatives. These elements can be introduced in staged fashion as in the main example. We provide a generalized template of potential cash flow effects below.

<i>Incremental component</i>	<i>Replacement date (t=0)</i>	<i>Operating periods (t=1...T)</i>	<i>Terminal (T)</i>
Cost of new equipment	– Cost(new)		
After-tax salvage of old equipment	+ After-tax proceeds		
Change in NWC	– ΔNWC (if increase)		+ Recovery of ΔNWC
After-tax cost savings		+ (Cost savings) × (1 – T)	
Depreciation tax-shield difference		+ [Dep(new) – Dep(old)] × T	
After-tax salvage value difference			+ [Salv(new) – Salv(old)] after tax

Empirical Analysis of Effect on Student Performance

We test for changes in student performance on assessments tied to cash flow estimation. Specifically, we examine how students who receive the recommended staged instruction perform compared with those who do not. We note that our comparisons rely on several important controls. First, the examinations used for both treated and untreated students utilize short-answer-based prompts featuring the same economic concepts. Specifically, we provide a question that requires the incorporation of depreciation, salvage values, and net working capital, as well as either a sunk cost or indirect cost.

We argue that such questions are complex and difficult enough that a significant difference in scores can be attributed to a deeper understanding of incremental cash flow analysis. Second, the application of the instruction, question-writing, and assessment for both treated and untreated students was conducted by an instructor blind to this study. Finally, we account for unobserved student talent in two ways. In our main specification, we control for students’ scores on an unrelated examination from the same course. In a secondary specification, we calculate the difference between students’ cash flow exam scores and the average cash flow exam score of students who have not received treatment but did receive the same general letter grade on an unrelated exam. Our sample consists of 480 students, 82 of which receive the staged instruction. We regress students’ exam scores on treatment, both with and without semester term fixed effects. We present these results in Table 1 below.

Table 1: Analysis of Student Scores with Staged Instruction

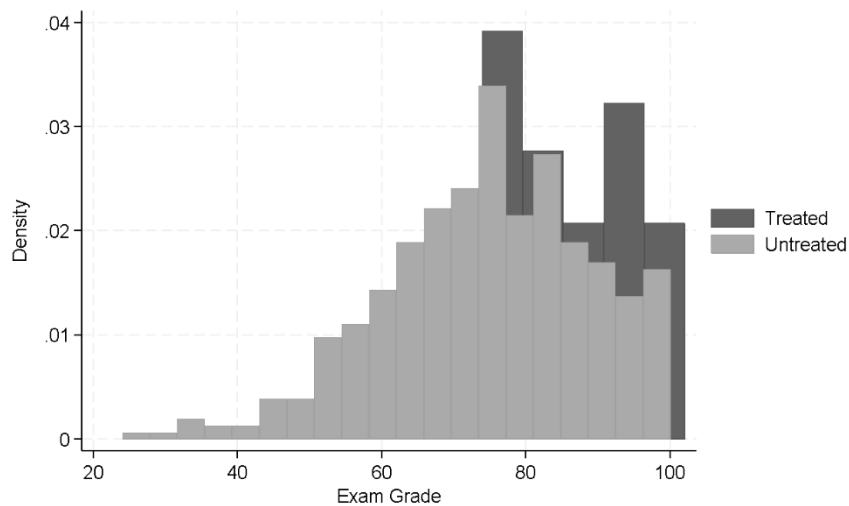
This table presents OLS regressions of student exam grades on receiving staged instruction on incremental cash flow analysis. “Exam Score – Cash Flow Estimation” is a student’s exam score on the exam tied to cash flow estimation, i.e., incremental cash flow analysis. We use this as our dependent variable in columns 1-4. Our dependent variable for columns 5-6, “Matched Score Difference”, is the difference between a student’s cash flow exam score and the average cash flow exam score by non-treated students with similar grades on a prior exam. We define similar grades as having made the same letter grade (D-F, C, B, A) on an earlier, unrelated exam. “Treatment” is an indicator equal to one when a student receives staged instruction on this topic. “Unrelated Exam Score” is the student’s score on an unrelated examination in the same course. “Semester FE” are semester fixed effects. T-statistics are reported in parentheses. *, **, and *** represent significance at 10, 5, and 1% respectively.

Variables	Exam Score – Cash Flow Estimation				Matched Score Difference	
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	8.07*** (4.63)	10.72*** (4.80)	2.64* (1.81)	7.45*** (4.07)	2.77* (1.90)	7.94*** (4.25)
Unrelated Exam Score			0.77*** (15.64)	0.78*** (15.54)		
Constant	74.54*** (106.85)	71.89*** (45.27)	15.57*** (4.08)	10.14** (2.43)	0.00 (0.00)	-5.17*** (-3.89)
Semester FE	N	Y	N	Y	N	Y
Observations	480	480	480	480	480	480

Our results suggest that students receiving the staged instruction score between 2.64 and 10.72 percentage points higher on relevant exams, specifically on nuanced, complex versions of assessments tied to cash flow estimation. In addition, we examine the distribution of scores alongside our regression estimates. We perform a Kolmogorov-Smirnov equality-of-distributions test on the treated and untreated distributions. Our test rejects the null hypothesis that the distributions are equal; our results indicate that the treated group distribution is larger, with a p-value < 0.0001. We present the histogram of students’ scores in Figure 1.

Figure 1: Histogram of Student Exam Scores between Treatment and non-Treatment

This figure presents the density plots of students' exam grades, specifically the exam covering cash flow estimation methods. "Treated" represents students who receive the staged-approach to teaching incremental cash flows, whereas "Untreated" represents students who do not receive an accentuated, staged introduction to incremental cash flow analysis.



Conclusion

The staged instructional approach presented in this paper, centered on the Vikram example, provides a pedagogically grounded and empirically supported method for teaching incremental cash flow analysis. By moving from a clear baseline to progressively more complex project evaluations, the approach shifts students beyond procedural memorization toward causal understanding and better financial reasoning. The narrative structure also helps make abstract concepts more accessible and engaging.

Introducing topics such as depreciation, taxes, and working capital within a scaffolded framework allows students to learn not only the individual components, but also how they interact within a unified model. This structure reduces common modeling errors and better prepares students to apply incremental cash flow analysis in applied settings.

Evidence from classroom implementation supports the approach's effectiveness. Students exposed to staged instruction performed better on complex assessment tasks and demonstrated stronger conceptual understanding. Overall, the method offers a replicable and flexible model for instructors seeking to improve both comprehension and application in corporate finance by deliberately building complexity and reinforcing financial causality.

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Implementation of a Commodity Trading Game in Introductory Economics Courses

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Trading games are a popular way to enforce student learning and increase student engagement in introductory and upper-level finance courses. In this paper, I introduce how a commodity trading game can be implemented in introductory economics classes using commodity-based exchange-traded funds (ETFs) and exchange-traded notes (ETNs). I further present the survey results from running this game in an introductory economics class. The survey results strongly suggest that commodity trading games enhance student learning and motivation and that they have a positive impact on the financial literacy of students.

Keywords: *commodity trading, simulation games, pedagogy, financial literacy*

Introduction

Trading games are quite popular in finance courses, but not so much in introductory economics courses. At first glance, this makes intuitive sense. Students learn about the stock market and investing in finance classes, not typically in introductory economics classes. Students in introductory economics classes primarily learn about foundational concepts such as supply and demand. However, since economics students understand supply and demand, they can apply their understanding to the commodities markets, which are heavily influenced by the market forces. In other words, I argue that the foundational concepts of supply and demand are sufficient to introduce students to investing in the financial markets. The challenge, however, is to create an experiential learning opportunity for introductory economics students without assuming knowledge or familiarity with the stock market. In this paper, I show that economics instructors can solve this challenge by having their students trade commodity-based exchange-traded funds (ETFs) and exchange-traded notes (ETNs) at no cost to students by using a free platform (MarketWatch).

Games and experiments in the economics classrooms have a long history. For example, Holt (1996) describes how instructors can embed a “pit”, a trading floor, in the classroom to teach students the supply and demand model. Lew and Saville (2021) show that instructors can incorporate an enriched version of the popular game *Monopoly* to teach students economics and financial concepts such as inequality, risk, leverage, and herd mentality. A more recent study by Cartwright and Cartwright (2024) shows the benefits of running experiments to teach students about key economic concepts such as supply, demand, and equilibrium price.

We see games and experiments implemented in the finance classrooms as well. For example, Damianova and Damianov (2018) describe and present experimental results for a futures trading game that is designed to teach students basic and advanced topics such as entering into futures positions and the convergence of futures and spot prices (see Pavlik and Nienhaus (2004); Root and Lien (2005); Hunsader et al. (2011) for more examples on derivatives-based games and

experiments in the classroom). How about trading simulation games that use online platforms, mimicking actual trading experience? Pedagogical research from finance/business classrooms demonstrates that these trading games have a positive impact on student learning and engagement (Moffit et al., 2010; Karadas & Hoffer, 2017; Krause & Robbins, 2018).

It is important to elaborate why trading games are less common in introductory economics courses despite their pedagogical benefits. This could be related to general teaching practices in the field of economics with respect to games and similar tools. For example, a survey of instructors teaching principles of economics courses reveals that 61% of them prefer lectures over other teaching methods (Goffe & Kauper, 2014). Some in this group (about 46% of them) do not consider lectures as the best pedagogical tool but stick with them since they consider them as “cost-effective”. Overall, the median time spent lecturing among the survey respondents stands at 70% of class time. The authors document a positive association between the use of non-lecture-based teaching practices and the participation in a teacher training program. Asarta et al. (2020) find in a 2020 survey (part of the national quinquennial survey on teaching economics) that traditional methods of teaching (lectures and whiteboard) have remained as the dominant method of delivery in introductory economics courses over the last 25 years. They surprisingly find that the use of games and simulations has declined in more recent years. Using the same survey data, Harter et al. (2022) examine the assessments of learning in economics courses. They find that “games, simulations, or experiments” account for 1% of a student’s grade on average in introductory economics courses based on the 2020 survey data, which is similar to the 2000 survey data but below the levels observed in the 2010 survey data. Analyzing the same 2020 survey, Ahlstrom et al. (2023) find a negative association between the use of classroom experiments and teaching experience of the instructors. Ahlstrom et al. (2023) argue that “[i]nstructors with more experience may be less familiar with the growing body of classroom experiments for undergraduate economics courses or may perceive that using classroom experiments is too costly in terms of preparation or the use of course time.” (p.10).

Overall, the literature on teaching economics suggests that relatively less common use of games, simulations, and experiments in the economics classrooms might be related to instructors not being familiar with recent pedagogical innovations and techniques and/or believing that such innovations and techniques may take too much time and effort to implement. The commodity trading game that I describe in this paper helps with both of these potential reasons. First, it helps raise the awareness of a commonly used pedagogical tool (trading games) in a new context (introductory economics courses). Second, it shows that implementing the game is very straightforward with the use of a free website and a list of ETFs and ETNs appropriate for the activity. Third, it reduces the preparation time for instructors by applying students’ knowledge and understanding of supply and demand, a topic that lies at the heart of introductory economics courses, to the commodities markets. This represents an application of fundamental analysis in the commodities markets, which is an examination of a commodity’s price based on the demand and supply for this commodity (CME Group, n.d.).

In this study, I use a survey to measure the impact of the commodity trading game on student learning and engagement. I provide evidence that the game had a positive impact on student learning outcomes. For example, over 91% of the students expressed that the game helped them improve their understanding of foundational economics concepts such as supply and demand and that the game improved their understanding of how the commodities markets work. Also, the same percentage of students suggested that the game be kept in the future sections of the course, but only less than 40% expressed that they would be more engaged with the game if there was real

money (instead of play money) involved. It is important to note that the sample size in the survey is small (23 students). Therefore, the results should be viewed as preliminary and interpreted with caution.

The rest of the paper proceeds as follows. Section 2 discusses the setup of the commodity trading game, and Section 3 walks the readers through the survey design and summarizes the results. Section 4 concludes the paper.

Commodity Trading Game Setup

I used a free platform (MarketWatch) to set up the commodity trading game. This free platform does not support trading in commodity futures. I was able to navigate around this limitation by providing the students with a list of commodity exchange-traded funds (ETFs) and exchange-traded notes (ETNs) tickers to choose from (see Table 1). It is important to note that trading ETFs and ETNs is simpler than trading commodity futures, as students do not need to know about concepts such as expiration of futures contracts and margin requirements. This turned out to be an ideal setup for introductory economics students with no background in finance.

MarketWatch allows students to trade equities. To ensure that students focus on commodities, I did not allow them to trade stocks. The game lasted approximately three months. During the game, students were required to submit three interim reports and one final report, summarizing the financial news and detailing their trades and portfolio performance. Further, students were required to make a minimum of three trades per report. To help students document and report their trades and to facilitate grading, I used a template for the interim trading reports (see the appendix). This template is similar to the ones used in the stock trading game by Karadas and Hoffer (2017) and the foreign-exchange trading game by Seiver (2013), and it is found to be beneficial to students in documenting their trades (Karadas & Hoffer, 2017). The template has three components: Market Report, Trading & Portfolio Report, and Learning Experience. For Market Report, I asked students to share news and latest developments on the overall economy and commodities markets such as gross domestic product (GDP) and gold prices. This section gave the students the opportunity to take a broader look at the trends in the marketplace (beyond their individual positions). In Trading & Portfolio Report, students entered basic information about their trades and provided reasoning behind their trading decisions. This part of the portfolio report allowed students to keep track of their trades and their portfolio performance. The Learning Experience part provided a space for students to document and share their learning journey throughout the game. The final trading report and interim trading reports have the same structure, except that the final trading report has an expanded Learning Experience section (see Section 3 for more details).

The securities in Table 1 contain regular ETFs and ETNs as well as leveraged and inverse leveraged ones (i.e., geared exchange-traded products). It is very important that instructors explain to students the difference between leveraged (e.g., +2x) and inverse leveraged (e.g., -2x) securities, and how students can trade them depending on their convictions in the marketplace. Also, students may not be familiar with ETNs. Instructors can use resources from the web such as FINRA (2022) as a primer on ETNs. Another important point is liquidity. Some of the ETFs/ETNs in Table 1 are thinly traded, and the trades involving them on MarketWatch sometimes may not go through.

It is very important that instructors present real-world examples to students for the successful implementation of the game. To this end, they can use newspaper articles on how supply and demand impact commodity prices. For example, WorldOil (2021) highlights the impact of weather (hence energy demand) on commodity prices. The first sentence of this article makes this

relationship very clear for students: “Freezing weather that’s gripped large parts of the northern hemisphere is delivering a winter blessing for oil, gas and coal prices as suppliers meet a surge in heating demand.”

Table 1
Exchange-Traded Funds (ETFs) and Notes (ETNs) in the Commodity Trading Game

Category	Commodity	Ticker	Full Name	Exposure
Precious Metals	Gold	GLD	SPDR Gold Trust	+1 x
	Gold	UGL	ProShares Ultra Gold	+2 x
	Gold	GLL	ProShares UltraShort Gold	-2 x
	Silver	SLV	iShares Silver Trust	+1 x
	Silver	AGQ	ProShares Ultra Silver	+2 x
	Silver	ZSL	ProShares UltraShort Silver	-2 x
	Platinum	PPLT	Aberdeen Standard Physical Platinum Shares ETF	+1 x
	Palladium	PALL	Aberdeen Standard Physical Palladium Shares ETF	+1 x
Energy	Crude Oil	USO	United States Oil Fund LP	+1 x
	Crude Oil	UCO	ProShares Ultra Bloomberg Crude Oil	+2 x
	Crude Oil	SCO	ProShares UltraShort Bloomberg Crude Oil	-2 x
	Natural Gas	UNG	United States Natural Gas Fund LP	+1 x
	Natural Gas	BOIL	ProShares Ultra Bloomberg Natural Gas	+2 x
	Natural Gas	KOLD	ProShares UltraShort Bloomberg Natural Gas	-2 x
Agriculture	Corn	CORN	Teucrium Corn Fund	+1 x
	Wheat	WEAT	Teucrium Wheat Fund	+1 x
	Sugar	CANE	Teucrium Sugar	+1 x
	Coffee	JO	iPath Series B Bloomberg Coffee Subindex Total Return ETN	+1 x
	Soybean	SOYB	Teucrium Soybean Fund	+1 x
	Livestock	COW	iPath DJ AIG Livestock TR Sub-Idx ETN	+1 x
	Cotton	BAL	Dow Jones-UBS Cotton Total Return Sub-Index ETN	+1 x

Survey Design and Results

To test the pedagogical effects of the commodity trading game, I ran a survey in an Introduction to Microeconomics class (synchronous online modality) after receiving approval from the local Institutional Review Board (IRB). The survey had two parts: questions about learning and motivation (12 in total) and questions about design (9 in total). The survey had a 5-point Likert scale with the following potential answers: strongly disagree, somewhat disagree, neither agree nor disagree, somewhat agree, and strongly agree.

I structured the survey as an extra credit opportunity. Due to the nature of the IRB approval process (the approval documents are available upon request), I provided students with an alternative extra credit opportunity if they chose not to participate in the survey. There were 35 students enrolled in this class, and 23 students completed the survey. Among the survey

participants, there were 11 first-year students, 9 sophomores, 2 juniors, and 1 senior. Furthermore, there were 10 female and 13 male students.

Table 2
Academic Information

Major Name	Number of Students
Accounting	3
Biology	1
Business Administration	7
Communications	2
Computer Science	2
English	1
Information Systems Security	2
Legal Studies	1
Management Information Systems	2
Political Science & Public Administration	1
Psychology	1
Total	23

Table 2 presents academic information about the students. The most common major is Business Administration. However, the course had students from a diverse array of majors such as English, Psychology, and Computer Science. The institution where I implemented the commodity trading game does not offer a major in finance (students can pursue a concentration in finance), and the economics class where the survey participants were enrolled in is a prerequisite for the first finance course offered at the institution.

Table 3 presents the survey results about learning and motivation, and Table 4 presents the results on the design of the commodity trading game. It is important to reiterate that the sample size in this survey is small (23 students), and the survey results need to be interpreted with caution. The survey results in Table 3 suggest that the game had an overall positive impact on student learning and motivation. Over 90% of the students indicated that the game had enhanced their knowledge on the key economics concepts, operations of the commodities markets, and trading. 87% of the students reported that the game had a positive impact on their engagement with the course and that they had a better understanding of the financial news and how the economy works as a result of participating in the game. Over 80% of the students reported increases in their financial literacy skills and their general interest in economics and finance.

Around 65% of the students reported an interest in taking more economics and finance classes as a result of participating in this game, and around 44% of the students reported a higher interest in seeking short-term and long-term career opportunities in economics and finance. These low numbers were surprising, and they could be related to first-year students still exploring their academic and career interests. Another possibility is that the game in its current form does not provide students with a sufficient understanding of career options available to them. This creates an opportunity for instructors. For example, instructors can provide students with information on careers that are related to the stock market and investing such as quantitative analyst, financial

analyst, portfolio manager, consultant, and financial advisor. This additional information may show students that a good understanding of the stock market has the potential to lead to good career opportunities for them. Instructors can also bring in guest speakers with degrees in economics or finance who can share their own career journey and discuss with students on potential career paths available to them.

Approximately 78% of the students indicated readiness to trade stocks and ETFs with real money in general after participating in the game. If realized, this participation rate would exceed the household stock market participation rate, which is currently at 62% (Gallup, 2025).

Table 3
Survey Questions about Learning and Motivation

Survey Questions	Somewhat or strongly agree
Participating in the Commodity Trading Game helped me understand key economics concepts such as supply and demand better.	91.3%
Participating in the Commodity Trading Game improved my understanding of the financial news.	87.0%
Participating in the Commodity Trading Game improved my understanding of how the economy works.	87.0%
Participating in the Commodity Trading Game improved my understanding of how the financial markets work.	82.6%
Participating in the Commodity Trading Game improved my understanding of how the commodities markets work.	91.3%
Participating in the Commodity Trading Game increased my financial literacy skills.	82.6%
Participating in the Commodity Trading Game increased my engagement with the overall course.	87.0%
Participating in the Commodity Trading Game increased my interest in economics and finance in general.	82.6%
Participating in the Commodity Trading Game made me more interested in taking another course in economics and finance.	65.2%
Participating in the Commodity Trading Game made me more interested in seeking a job or internship in economics and finance.	43.5%
I feel more knowledgeable about trading after participating in the Commodity Trading Game.	91.3%
I feel more comfortable with the idea of trading stocks and ETFs using real money after participating in the Commodity Trading Game.	78.3%

Table 4
Survey Questions about Design

Survey Questions	Somewhat or strongly agree
I regularly checked what my classmates were buying and selling.	60.9%
I would have been more engaged with the Commodity Trading Game if I had been given real money to invest with.	39.1%
Instructor should allow students to trade stocks in addition to commodity ETFs.	52.2%
Students should be asked to make more trades than the current requirement in the course.	34.8%
Students should be asked to submit more reports than the current requirement in the course.	21.7%
Students should participate in the Commodity Trading Game as teams rather than individual participants.	13.0%
The Commodity Trading Game should last for a longer period than the current length in the course.	60.9%
The Commodity Trading Game should be used in future sections of this course.	91.3%
If given the opportunity, I would still be interested in participating in the Commodity Trading Game after I finish this course.	60.9%

Table 4 presents the survey results about the design of the commodity trading game. Over 60% of the students were monitoring their classmates' portfolios. Only around 39% of the students indicated that having real money instead of play money would have increased their engagement with the game. In a sense, this result is reassuring because it suggests that play money is quite effective in engendering student engagement. Students were not allowed to trade stocks in this game, and there appears to be a split in their desire to trade stocks in the game.

The majority of the students reported that both the frequency of the reports and the trades were appropriate. Only 13% of the students indicated a willingness to participate in the game as a team project, which may have been driven by the fact that this was an online class. Over 60% of the students indicated willingness to have a longer trading period and to participate in the game after they finished the course. Over 90% of the students reported that the trading game should be kept in the future sections of this course. This suggests that students saw value in the game in terms of their learning and engagement.

In addition to the survey, the final trading report also asked students about their engagement and experience with the trading game in the Learning Experience section. This section of the report

gave students the opportunity to reflect on their performance in the game, which course materials they found helpful for the game, and their interest in the stock market among other topics. Some of the comments from the final trading report are as follows:

“One part of the course that helped me with this commodity trading game was the supply and demand in the market. This is beneficial because if it is seen that a good will become more valuable and demanded, it is a good idea to invest in that stock since it will increase. It is also important to know when a good is being demanded less so you do not invest in it.”

“This game actually caused me to look into stocks and caused me to sign up for robinhood to try to invest in stock with my actual money. This game has taught me tendencies I would have while working with stocks, and caused me to be more aware of my decisions while working with stocks.”

“I have not invested at all before, and with not knowing much about ETF’s I think this opened my eyes to investing. As someone who is not in the economics program, I feel this has enlightened me a significant amount to the realism of the world of stocks. I will most likely seek guidance from those who use the stock market more frequently in order to gain insight on what to invest in, whether that be family, friends, or a broker.”

“The commodity trading game encouraged me even more into trading in the future which is something I always had in the back of my head but now I am thinking about it more. The commodity trading game is a perfect way to practice trading ETF’s with zero risk so that you learn from your mistakes without losing out on real money that could hurt you.”

The anecdotal evidence from the final trading report also lends support to the positive impact of the game on student learning and engagement.

Conclusion

This paper presents the implementation of a commodity trading game in an introductory economics class and discusses the survey results from the students who participated in the game. The survey results indicate that the game offers pedagogical benefits to students in both economics and financial concepts. Future research can build on this key result in several different directions, some of which I discuss below.

The setup in this paper uses commodity-linked exchange-traded funds and notes. Future research may investigate the potential adoption of commodity futures-based trading games in introductory economics classes. Another future direction can be related to the decision-making units in the game. As a way to engender more interaction among students, forming groups and having groups of students compete against each other was one of the suggestions in the final trading report. A future study can implement this suggestion and compare how a team-based game differs from an individual-based game (the model adopted in this study) in terms of student learning and engagement.

Relating the survey results to granular student-level data could be a promising direction as well. For example, researchers can examine how students’ learning and engagement with the game may change depending on their demographics. For example, will there be a difference in reported benefits from playing the game between students from low-income families and those from high-income families? This is an empirical question that a new survey can attempt to answer. Similar to

their demographics, students also differ in terms of learning styles. For example, will there be a difference between visual learners and kinesthetic learners in terms of the game's benefits for financial literacy skills? This is yet another empirical question that future research can shed light on as well.

The starting balance in the competition (\$1 million for each student) may have intimidated some of the students, and there is anecdotal evidence of this in the final report. A new study can give students a lower amount of money to start with and measure the impact of the game on their learning. The nature of learning gains represents another potential new direction. For example, future research can implement a financial/economic literacy quiz at the end of the game and re-measure the same students over time. This will help answer whether the learning gains from the game are short-term or long-term.

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**Appendix
Template for Interim Trading Reports**

Word Count:

Name:

Report Number:

1. Market Report

2. Trading & Portfolio Report

**Table 2.1
Trading History & Decisions**

ETF Name	Ticker	Shares	Trade	Reason

**Table 2.2
Portfolio Performance**

	Name	Ticker	Return (%)	Profit (\$)
Best ETF				
Worst ETF				
Overall Portfolio				

3. Learning Experience

A Simple Yet Comprehensive Goals-Based Investment Policy Statement Assignment for the Investments Course²

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This paper provides the motivation for and outlines the steps of a comprehensive experiential-based project for the investments course that links a goals-based framework and applied investment analysis with theoretical investments. Students will develop an investment policy statement (IPS), evaluate macroeconomic and industry conditions, and must consider “real-world” issues that impact personal investment decisions. The students also apply the constructs of Nobel Prize winning work to identify optimal portfolios given risk and return constraints. This semester-long assignment bridges the gap between investment theory and applied investment analysis, and will give the students a glimpse into practical investment decision making.

Keywords: Policy statement, efficient frontier, optimal asset allocation, Excel solver

Introduction

Many investment textbooks support the notion that the goal of most investors is to maximize end-of-period wealth, including Elton and Gruber (1987). Determining the relevant time horizon for an investor is often difficult, but determining the time frame that constitutes a relevant actual end-of-period can be even more challenging. One common “end-of-period” identified for individual investors is the expected retirement age. Having a single time horizon, however, fails to account for other possible goals, such as education funding, planned giving, or the purchase of a vacation home that investors commonly possess.

Currently, a wealth management approach is being advocated that aligns a series of goals that span various time periods. The Chartered Financial Analyst® (CFA) Institute has included goals-based wealth management as a critical component of its Learning Outcome Statements. A goals-based approach reformulates the investment performance evaluation from a relative analysis against a benchmark to a more personal analysis of meeting specific objectives. Retirement goals continue to be a key part of the goals-based process, but other critical life goals are planned for as well. Blanchett (2015) shows that a goals-based financial plan can increase the portfolio alpha substantially over the lifespan of an individual investor.

College and university finance programs require its majors to enroll in a general Investments course. Most investment textbooks contain chapters that cover a wide variety of topics: Equity and fixed income securities, alternative investments, derivative securities, portfolio optimization,

² The authors are grateful for the helpful comments by the late Emily Cope, Associate Professor of Rhetoric and Writing at York College of Pennsylvania. This article is dedicated to the memory of Anne Forjan.

and performance evaluation, and other investment-related topics. A comprehensive assignment for the investments course that links a goals-based framework with the various topics included in investments textbooks would be invaluable for the students. It will bridge the gap between theoretical investments and applied investment analysis, and will give the students a glimpse into practical investment management.

To add value to the learning experience for students and to integrate their knowledge base with real-world issues facing the investment community, the goals-based approach is coupled with a project-based model, much like Funck, et al. (2016) propose. Their research suggests that student engagement is dramatically improved during and after completion of the project, but perhaps more importantly student confidence levels in their understanding of the basic course material was strengthened. Shu, et al. (2022) indicate that experiential learning and therefore project-based learning transforms students from a passive acceptance of professor lectures to a much more productive active learning outcome. The purpose of this paper is to outline the design of an assignment that engages, enhances, and broadens a student's skill set.

This paper offers a comprehensive review of the theoretical support for the value of the Investment Policy Statement (IPS) as well as an experiential-based project that can be used as a model for practical application. The semester-long project introduces students to the importance of professional development beyond their degrees while reinforcing the value of spreadsheet analysis to solve difficult problems. There is high student engagement among technology, the critical role that professional designations might play in student future career paths, and the application of multiple financial theories learned from professors.

The Investment Policy Statement

The Investment Policy Statement (IPS) is a formal, tailored, and complete document that outlines the risk and return objectives of the client as well as security selection process, asset allocation and liquidity decisions that help the client achieve those objectives. Black (1976) outlines the importance of the policy statement for individuals and suggests that the most important decision is the risk management decision. The IPS also includes an outline of the responsibilities of the wealth manager.

One of the hallmarks of the Chartered Financial Analyst (CFA) program is the development and application of the Investment Policy Statement. The CFA Institute is an organization that grants a professional designation to those individuals who demonstrate proficiency and meet certain requirements. Bracker and Shum (2011) show that college and university professors place a high value on the designation and that students who are exposed to the CFA program as undergraduates have greater appreciation for wealth management and are more likely to pursue careers in the investment management field.

The Certified Financial Planner Board of Standards (CFP Board) also stresses the importance of the IPS. The CFP Board promotes competent and ethical financial planning and grants the CFP® certification to professionals who meet the certification requirements. One of the 72 Principal Knowledge Topics promoted by the board is: Portfolio development and analysis - Develop and communicate an appropriate Investment Policy Statement (IPS) for a client.

This assignment serves the dual function of advancing the importance of the policy statement at least for individuals and encouraging students to investigate the value of pursuing professional designations, even before they graduate.

Optimal Allocation within the Investment Policy Statement

There exists in the literature instructive classroom-based approaches to teach students the basics of optimal asset allocation. Stephens (1998) and Roychoudry (1998) show the manner in which students can form the efficient frontier using matrix algebra. Carter, et al. (2002) provide a spreadsheet-based solution to graphing the Markowitz (1952) efficient frontier. Not only does their research offer a streamlined way of arriving at the efficient locus of points, it provides students with an excellent application of the solver function tool. This paper builds on their application and addresses one minor issue. Carter, et al. (2002) rely on the correlation function to locate points along the efficient frontier. If the correlation coefficients between the efficient portfolios produced by the methodology are highly positive, the resulting curve looks more like a straight line. The extra steps this paper offers almost guarantees the efficient frontier will appear as a curve.

There are multiple extensions of the original Markowitz (1952) frontier. The most relevant for this study is Kim, et al. (2022) in which they develop a portfolio optimization structure that considers individual investor goals. The objective function in their model is to maximize the present value of consumption according to a ranking system of each goal.

Semester-Long Comprehensive Assignment

The assignment should be given to students very early in the semester with the following directions: The IPS assignment includes, but is not limited to, the creation and description of a fictional client, a brief macroeconomic and industry analysis, the identification and selection of appropriate financial assets (fixed income, equity, alternative, and derivative), an equity asset allocation decision using the Markowitz model, and production of an efficient frontier, and finally a benchmark against which to compare performance.

Professors are encouraged to adjust their syllabi to reflect the timing of the policy statement assignments, according to the stages outlined in Table 1.

Table 1
Semester Outline for Policy Statement Assignment

Stage	Textbook Topic	IPS Content	Assignment Elements
Stages 1-4 Weeks 1-3	Introduction to the Policy Statement	Client constraints, risk and return objectives	Craft fictional client with sufficient information to develop an entire IPS; establish three client goals
Stage 5 Week 4	Economic and Investment Analysis	Macroeconomic Analysis and Industry Analysis and Security Analysis	Use AI to analyze the entire macro environment as well as one selected industry
Stage 6 Weeks 5-6	Fixed Income Securities	Bond valuation, interest rate risk, default risk, immunization with duration and convexity	Select one bond that will achieve the intermediate goal and show the immunization strategy
Stage 7 Weeks 7-10	Equity Securities	Stock valuation, systematic risk, efficient frontier, SML, CML	Select ten assets and use spreadsheet to draw the efficient frontier for client to achieve long-term goal

Stage 8 Weeks 11-12	Derivative Securities	Option contracts, futures contracts, swap contracts	Use one derivative security to adjust portfolio risk
Stage 9 Week 13	Alternative Securities	Hedge funds, commodities, collectibles, private equity	Select one alternative investment and show how it adds value to the portfolio
Stage 10 Week 14	Market Indexes	Benchmarking, CFA Institute	Select an appropriate benchmark

Stage 1: Introduction to the Policy Statement and Creation of Fictional Client

Students can be introduced to the policy statement in a variety of ways. They can be referred to the CFA ® webpages, directed to textbook examples, or provided with real world examples.

Perhaps the most critical initial component of the assignment is to create a fictional client. Necessary variables include age, employment status, expectations for retirement, number and ages of dependents, annual income earned coupled with spending requirements, and the present value of financial assets. On the risk side, students should provide enough background information to determine the client's risk tolerance. Students should be creative and make this fictional client interesting, although many students select actual people, either famous or within their personal networks. Professors who have incorporated this assignment into an investments class have found that students often write policy statements for their relatives, but also for musicians, professional athletes, actors and actresses, poker players, Marvel comic heroes, and historical figures. For the professor grading the policy statements, the more interesting the client, the greater is the commitment from the students in producing a valuable document.

After these initial items are created, the student must identify a minimum of one short term, one intermediate term, and one long term goal for the client consistent with the idea of utilizing goals-based approach to portfolio management. Fictional client information should be limited to one or two pages.

The policy statement format follows the general outline suggested by the CFA ® Institute. These items can be arranged in a summary table for ease of grading.

Stage 2: Determination of Client Constraints

All investors face limiting constraints that restrict their capacity to become fully invested. The assignment requires students to describe six investment constraints that impact the investment decision.

Liquidity

There are two liquidity issues in this constraint. One is a general liquidity requirement for the client and the second is a list of one-time short-term liquidity cash outflows. Examples include down payments for first or second homes, the present value of education expenses, substantial family one-time events such as weddings, purchase of durable assets such as automobiles or motorcycles, as well as significant gifts to relatives.

Time Horizon

The remaining life stages of the client are explained in this part of the assignment, using typical textbook outlines for each phase. Of course, these can be general statements. Examples include early and rapid accumulation stages and financial independence stage.

Tax

Each current and potential future tax liability is explained. The upcoming year's tax liability should be estimated. Major tax liabilities include income tax, total state and local taxes, capital gains tax, and any other tax imposed on the client. One common tax implication is for those students who create a client that has recently won the lottery.

Legal/Regulatory

Investors are regularly limited by various contractual issues or regulations. Examples include upper management of publicly held companies being forbidden to invest in the equity securities issued by competitors but also being required to invest in their employer's securities, government employees being prohibited from investing in defense contracting firms, and other employment contract related items.

Unique

Constraints that are not a part of the first four constraints and typically include issues such as health, marital status, estate planning issues, and unusual dependent circumstances, are addressed here.

Behavioral

An integral part of this assignment is for students to be exposed to the complex issues of behavioral decision making. Kahneman and Tversky (1972, 1979) and Tversky and Kahneman (1974) offer a critique of utility theory by developing an alternative to decision making under uncertainty. Kahneman and Tversky's research has advanced a more complete explanation of investment decisions that are in opposition to utility theory, namely, Prospect Theory, Heuristics, Framing, and Representativeness. This part of the assignment provides students with the opportunity to investigate how behavioral decisions can impact their client's goals. In addition, Kane (1982) identifies skewness in stock returns and Corroda and Su (1996) show that both skewness and kurtosis are present in stock returns using implied volatilities of the Black-Scholes-Merton option pricing model. Perhaps this is evidence of the effect that behavioral investors have on market prices. Even Markowitz (Kritzman and Markowitz (2017, p.19)) himself admits "I never assumed Gaussian distributions. I assumed what was then - and still is now to a great extent - the standard theory of rational decision making in the face of risk and uncertainty". This assignment is designed to provide students with an opportunity to couple the original Markowitz model with some behavioral factors that might present themselves in skewness or fat tails. This assignment requires students to create one emotional bias and one cognitive error for their fictional client and to recommend a strategy to manage the behavioral issues.

Stage 3: Identification of Ability and Willingness to Take Risk

Students must create risk and return objectives with an emphasis on the client's ability and willingness to take risk. The ability to take risk is dependent on age, income, and asset base. The willingness to take risk is dependent on the client's personal attitudes toward risk and the possibility of loss. Students should describe the client's risk characteristics when creating the client's profile.

Stage 4: Computation of the Return Objective for the Long-Term Goal

The return objective should be a ratio of portfolio income needs to the total amount of investable assets for the coming period with a measure of expected inflation added as a premium.

Stage 5: Macroeconomic, Industry, and Security Analysis

This section is designed to promote financial research skills for students. It really is a simple part of the assignment mostly because little or no original research is required. In the first part of Stage 5, students are encouraged to use Chat GPT or other free artificial intelligence sources and published analyses from the United States Federal Reserve or financial institutions regarding the current state of the economy and one selected industry. The purpose of this part of the assignment is to gauge economic activity to aid in selection and allocation decisions. Suggested page length for this section of the IPS is a maximum of two pages for the economic analysis and one page for the industry analysis, but should cover important topics the students learned in their economic courses.

In the second part of Stage 5, a quick security analysis is performed to identify ten assets (stocks, mutual funds, or ETFs) the student expects to fulfill the long-term return objective. The purpose of this part of the assignment is not to identify undervalued assets, which is very likely an assignment in a Security Analysis course. Best practice is to advise students to select companies they support or that are hot topics on social media that operate in multiple industries with low or very low correlation between and among each other. A table of relevant financial information for each asset is appropriate. This becomes critical when constructing the Markowitz efficient frontier.

Stage 6: Meeting Short and Intermediate Objectives with Fixed Income Securities

Short Term Goal

Short term goals are typically met by investments on very low risk securities, such as money market mutual funds or treasury bills. Students identify one short term goal and show how the goal can be achieved. Examples include the purchase of automobiles, motorcycles, boats, down payment on house, and wedding expenses that are expected to occur within a short-term time horizon.

Intermediate Term Goal

This is an immunization assignment. The student must find an appropriate default risk level bond to finance the goal. Students identify one intermediate term goal and use a spreadsheet to show how the goal will be achieved if interest rates rise or fall by the end of the investment period. Examples include those short-term liquidity needs plus any other intermediate needs that are expected to occur generally within a one-to-five-year time horizon, but to make this more realistic, it is suggested to students they select a four- or five-year horizon.

Stage 7: Meeting Long-Term Objective with Equity Securities

In this part of the IPS project, the student will construct the efficient frontier using the assets selected in stage 5, and the related financial information. Using spreadsheet analysis, the student will construct a lifetime equity portfolio that meets the long-term goals of the client. Examples of long-term goals could include funding retirement, supporting philanthropic goals, estate and succession planning, and bequests. In this stage the student will find the combination of the ten assets that forms an efficient portfolio that will meet the client's long-term risk and return objectives. An efficient portfolio is defined in the classic mean-variance Markowitz (1952) sense and as related to the individual investor in Black (1976).

Stage 8: Alternative Investment

In an effort to teach students even more about diversification and the possibility of investing in multiple asset classes with low correlation to traditional securities, client portfolios should include an alternative investment. Students have substantial freedom in alternative asset selection, and can include hedge funds, private equity, collectibles, and luxury items, as long as they are consistent with the risk and return objectives of the client.

Students should describe the alternative investment, discuss the appropriate measures of risk, and assign a reasonable allocation. Liquidity-related issues or lack of liquidity should be addressed and its purpose should be linked to the long-term goals.

Stage 9: Derivative Security

Students are required to layer a portion of the portfolio with a derivative security to hedge a specific type of short-term risk. Examples include a protective put to hedge unsystematic risk of one of the ten assets in the equity portfolio, linking the alternative investment with a futures contract, and using a swap contract to manage interest rate risk of the fixed income security in the portfolio. This component has a simple calculation requirement to show the impact of the hedging strategy under both favorable and unfavorable spot results. Students should also select an amount of hedging that is material.

Stage 10: Benchmark

Students should select several indexes to include as part of the client's benchmark. Three equity indexes, one treasury index, one fixed income index, and an alternative investment index is

sufficient. Students should explain how the components of the index have similar risk characteristics as the entire client portfolio.

Sample Fictional Client Creation and Investment Policy Statement

The following is a typical example of the input and output for this assignment. Will Johnson founded and operates a billboard and advertising business. Johnson recently received a \$12 million unsolicited bid for his business which came with an offer to continue as a paid consultant. Johnson and his wife, Eva, both 55 years old, are in excellent health and have three children, two of whom are independent and the youngest has one more year of higher education. All education costs are fully funded in a 529 plan.

Eva is employed as a dental hygienist and plans on continuing her work for at least five more years. The dentist office purchases all its equipment from a national dental supply company and the terms of Eva's employment contract require her to hold a minimum of 25 shares in that company. Will plans on accepting the offer to sell his business and will retire as soon as the acquisition is complete, but he has not ruled out returning to work as a consultant. Will and Eva enjoy annual vacations in which they have scuba dived to watch for great white sharks, bungee jumped off the Stratosphere bridge in Las Vegas, and are experts in white water rafting. They also visit wineries throughout the world and consume several bottles of wine per month.

The Johnsons have annual combined income and retirement spending needs after the sale of the business of \$500,000 before taxes, \$75,000 of which is Eva's salary. Will intends to purchase a Harley Davidson motorcycle as soon as the acquisition is complete, the expected cost is \$60,000. Will plans to exclude Harley Davidson as part of his equity portfolio because he lost a substantial amount investing in a competitor motorcycle stock a few years ago. Will and Eva will create a trust fund for each of their children for \$1 million when the acquisition is complete. The total tax liability for the sale of the business, their current income and property tax liability is expected to be \$4 million.

The couple has developed short-term, intermediate-term, and long-term goals. In the short term, they want to provide a minimum of \$50,000 for the youngest child for a down payment on a house after graduation. In the intermediate term, they want to purchase a vacation home for a minimum of \$2 million in five years. Their long-term goal is to invest in an equity portfolio that will fund their retirement and provide future support for their children. A secondary long-term goal is to contribute substantially to medical research for childhood cancer.

Both describe themselves as having moderate risk tolerance for their investments but insist on including publicly held advertising companies in their lifetime equity portfolio. Both sets of their parents are still living and in good health, with the exception of Will's father who is facing substantial health challenges.

Will is covered under Eva's health insurance policy, but believes they will need additional life insurance and estate planning. Eva insists the equity portfolio include her health insurance company because it treated her extremely well during a cancer scare a few years ago. Eva continues to read all the good reports about this company. Current inflation expectations are 2.5%, while the relevant tax rate is 25%.

The Johnson couple's balance sheet and constraints are shown in Tables 2 and 3.

Table 2
Johnson Balance Sheet

Short Term Investments	\$800,000	Short Term Debt	\$800,000
Equity Securities	\$1,000,000	Mortgage Debt	\$200,000
Personal Assets	\$1,200,000		
Business Valuation	\$12,000,000		
Retirement Assets	\$800,000	Net Worth	\$14,800,000

Table 3
Johnson Constraints

Liquidity	Motorcycle, trust funds for a total of \$3,060,000
Tax	Sale of business, income taxes, property taxes total \$4 million
Investment Horizon	Early Retirement Phase for Will, continue employment for Eva of 5 years. Active Retirement: 10 years Passive Retirement and Estate Planning: 10 years
Legal and Regulatory	Eva must hold 25 shares in the dental supply company
Unique	Potential return to work for Will; The health of Will's father
Behavioral	Eva exhibits familiarity and confirmation bias by reading only positive reports about the health insurance company and insisting it be included in the portfolio; Will exhibits recency bias and experiential bias by insisting motorcycle manufacturing firms be excluded from the portfolio. They both insist on investing in advertising companies which is another example of familiarity bias.

Risk Objective

The couple has substantial net worth of nearly \$15 million with most of it associated with Will's business. The couple's ability to take risk before the sale of the business was most likely moderate to high, but with the sale of Will's business, their ability is high. The couple has indicated a moderate willingness to take on investment risk, but they are adventuresome as evidenced by scuba diving, bungee jumping and water rafting. The large portion of their investments in short-term securities indicates low risk willingness. Taken together, the couple's willingness is likely to moderate to high. Combining the ability and willingness to take risk results in the couple's overall risk tolerance to be high.

Goals Based Return Objectives

Short-Term Goal

The youngest child is expected to graduate in one year, which means the couple should easily find a short-term investment with very little or zero default risk. The couple intends to give the child \$50,000 as a down payment on a home. Acceptable securities for this investment include a money market mutual fund, a US treasury bill, or even a certificate of deposit.

Suppose the yield on one of these short-term securities is 5%, the present value compounded annually is a quick calculation: $\$50,000 \div (1.05)^1 = \$47,619$. The couple would purchase \$47,619

in short-term securities today and would have \$50,000 for the gift one year from today upon graduation.

Intermediate Term Goal

The couple hopes to purchase a vacation home in approximately five years and they have moderate to high tolerance for risk. An investment grade bond would very likely be appropriate here, one with a duration of 5 years and a rating of BBB. The student can show how the immunization strategy works using a spreadsheet analysis.

A six-year bond with a coupon rate of 7.5% and a current market price of \$935 has a five-year Macauley duration. The yield to maturity is 8.95% and the bond makes annual coupon payments. To achieve immunization, the client will reinvest the coupons and then sell the bond at the end of the investment horizon, which is five years.

Table 4
Terminal Value for Intermediate Term Goal

Potential Reinvestment Rates	Future Value of Coupons	Future Selling Bond Price	Total Available for Intermediate Term Goal
8.85%	\$447.51	\$987.60	\$1,435.11
8.95%	\$448.41	\$986.69	\$1,435.10
9.05%	\$449.30	\$985.79	\$1,435.09

The calculations can be performed using a spreadsheet or a calculator. For the potential reinvestment rate of 8.85%, the calculations are shown as: The FV of the coupons: PMT = \$75; N = 5; I = 8.85; PV = \$0: Solve for FV = \$447.51. The future selling price at year 5: PMT = \$75; FV = \$1,000; N = 1; I = 8.85: Solve for PV = \$987.60

The sum of the two-year 5 cash flows is \$1,435.11. Regardless of the future interest rate path, the future value of the immunized investment is \$1,435 per bond. As the current price of the bond is \$935, the Johnsons will purchase 1,394 bonds for a total initial investment of \$1,303,390. This offers an internal rate of return of 8.95%, which is the yield to maturity on the bond. It is probably wise to remind students that immunization works only when there are parallel shifts in the yield curve, and this should be reflected in the IPS.

Long-Term Goal

The couple intends to use the equity markets mainly to provide financial support for living expenses, but also to have funding to support the children's future needs and for donations. The return objective will simply be the ratio of income portfolio needs to investable assets: Portfolio Income Needs = \$500,000 - \$75,000 = \$425,000.

Table 5
Johnson's Investable Assets and Known Cash Outflows

Investable Assets	Known Cash Outflows
Short-Term Investments: \$800,000	Liquidity Constraint: \$3,060,000
Current Equity Securities: \$1,000,000	Tax Liability: \$4,000,000
Sale of Business: \$12,000,000	Gift to Child for Home: \$47,619
Total: \$13,500,000	Vacation Home: \$1,303,390
	Total: \$8,411,009

Return Objective = $\$425,000 \div (\$13,500,000 - \$8,411,009) = 0.0835$ plus inflation of $0.025 = 0.1085$. Convert this annual return into a monthly return in the following manner: $(1.1085)^{1/12} - 1 = 0.0086$.

The next step is to download monthly stock prices for the ten stocks. This can be accomplished by following steps A through H which are outlined in precise detail by Carter, et al. (2002). It is recommended that students select ten stocks for this assignment.

Step A

Link to a web page that offers free downloadable monthly stock prices for a three-year period. Students will only need the adjusted closing price column. Repeat for the next nine stocks. Table 6 shows a partial ten-stock, four-month list of stock prices. Students will select their own ten stocks and collect thirty-six monthly prices. The example below consists of ten randomly selected fairly well-known stocks: Johnson and Johnson, Hershey Foods, Under Armor, McDonald's, AutoZone, PNC Bank, Brown Forman, Apple, Oracle, and Malibu Boats.

Table 6
Partial List of Monthly Stock Prices

	JNJ	HSY	UA	MCD	AZO	PNC	BFB	APP	ORCL	MBUU
9/1/21	149.38	158.86	17.52	226.56	1697.99	174.28	59.40	139.17	83.24	69.98
10/1/21	150.66	164.54	18.88	230.74	1784.84	187.99	60.85	147.33	91.65	70.61
11/1/21	144.23	166.54	20.07	229.84	1817.07	176.58	62.41	162.57	86.99	69.47
12/1/21	159.27	182.46	18.04	253.29	2096.39	179.74	64.42	174.90	83.60	68.73

Step B

Convert to monthly returns, as shown in Table 7. Once again, students will have ten stocks but thirty-five monthly returns: The calculation is a simple future value divided by present value and then subtract one to obtain the monthly return.

Table 7
Partial List of Monthly Stock Returns

	JNJ	HSY	UA	MCD	AZO	PNC	BFB	APP	ORCL	MBUU
9/1/21	0.0085	0.0360	0.0776	0.0184	0.0511	0.0787	0.0244	0.0587	0.1011	0.009
10/1/21	-0.043	0.0122	0.0630	-0.003	0.0181	-0.061	0.0256	0.1035	-0.050	-0.016
11/1/21	0.1043	0.0955	-0.101	0.1020	0.1537	0.0179	0.0323	0.0758	-0.039	-0.010
12/1/21	0.0071	0.0186	-0.114	-0.032	-0.053	0.0273	-0.059	-0.016	-0.069	-0.045

Step C

Compute mean monthly return and standard deviation of monthly returns for each individual stock as shown in Table 8.

Table 8
Average Monthly Stock Returns and Standard Deviation for Each of the Ten Stocks

	JNJ	HSY	UA	MCD	AZO	PNC	BFB	APP	ORCL	MBUU
AVG	0.0036	0.0071	-0.0111	0.0081	0.0188	0.0040	-0.006	0.0165	0.0186	-0.0113
STD	0.0468	0.0492	0.1384	0.0540	0.0604	0.0839	0.0547	0.0775	0.0949	0.1174

Step D

An equal-weighted portfolio is formed by multiplying equal weights (in this case, 10% in each stock) by the monthly return for each stock. This step is easily accomplished using the sumproduct function and partial result are shown in Table 8, while Table 9 shows a partial list of the sumproduct results.

Table 9
Row of Equal Weights for Ten Stock Portfolio

	JNJ	HSY	UA	MCD	AZO	PNC	BFB	APP	ORCL	MBUU	
EWP	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.0

Step E

Compute the mean return and standard deviation of return for the equally weighted portfolio.

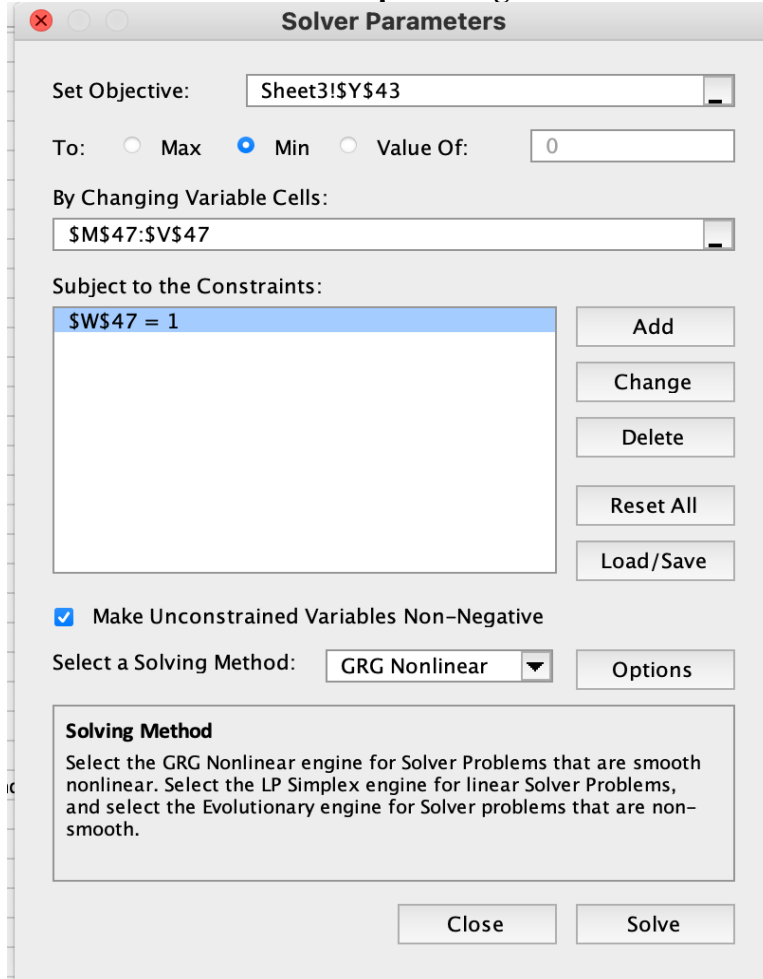
Step F

Create the minimum variance portfolio.

Step G

Compute the mean return and standard deviation of return for the minimum variance portfolio. In steps F & G steps we begin to identify the locus of points that comprise the efficient frontier. The objective function is set to minimize the standard deviation while changing the weights for each of the ten stocks. The only constraint required for the minimum variance portfolio is that the weights must sum to 1.0. The solver function for the minimum variance portfolio is shown in Figure 1:

Figure 1
Solver Window for Equal-Weighted Portfolio



At this point, the students will have determined the appropriate weights that form the minimum variance portfolio using Solver, and the resulting standard deviation of the minimum variance portfolio. The spreadsheet will show the allocations to each company in Table 10.

Table 10
Efficient Set of Weights for the Equally-Weighted Portfolio

	JNJ	HSY	UA	MCD	AZO	PNC	BFB	APP	ORCL	MBUU	
EWP	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
MVP	0.2580	0.4181	-0.011	-0.093	-0.039	0.1226	0.3107	-0.010	0.0706	-0.027	1

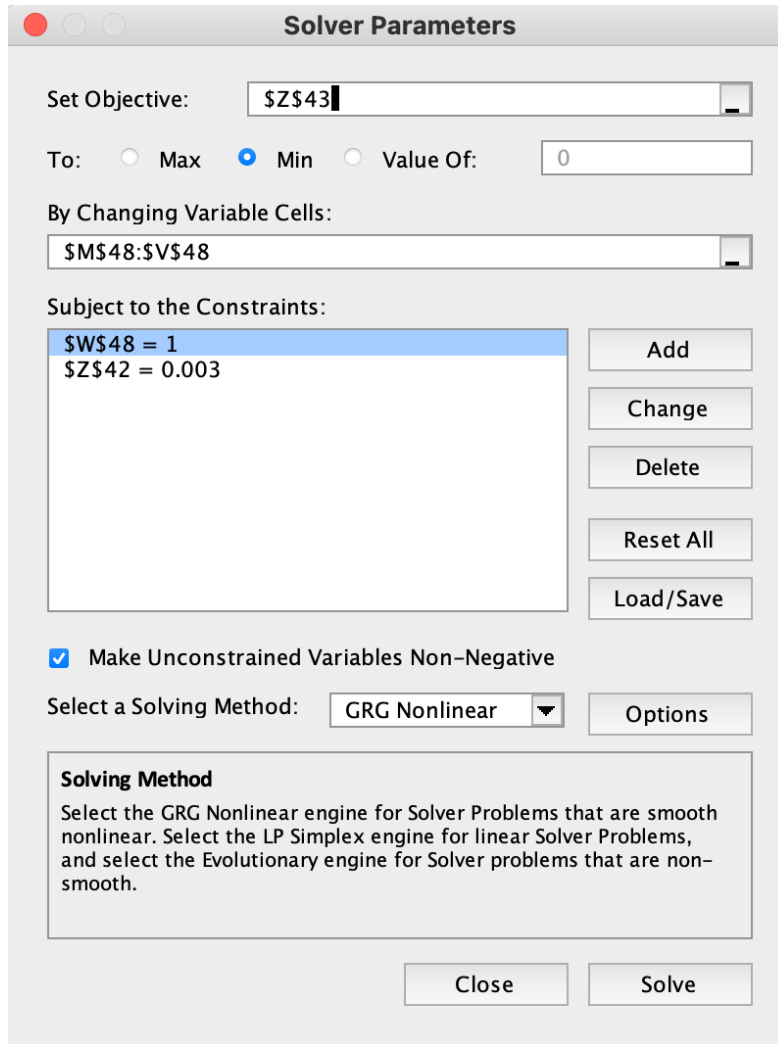
Solver produces a minimum variance average monthly return of 0.00264 and a standard deviation of 0.03635 for the ten stocks.

Step H

Repeat the process several more times to obtain a sufficient number of points of the efficient frontier. This requires the addition of a second constraint, which produces efficient weights at

continually increasing return objectives. A little creativity is required here. Students should be instructed to add a small premium to the minimum variance return, in this case, the extra constraint is to force the monthly return to be 0.003. Solver function for this step is shown in Figure 2.

Figure 2
Solver Window for Efficient Portfolio 1



For each subsequent solver iteration, simply add a small premium to the previous monthly return. It is suggested to increase by increments of 0.001 which translates into a 1.2% annual return. Solver is used to find the weights for additional efficient portfolios (EP) that minimizes risk for a specific return objective. The weights for each efficient portfolio are shown in Table 11.

Table 11
Optimal Allocation of Weights for Each Efficient Portfolio

	JNJ	HSY	UA	MCD	AZO	PNC	BFB	APP	ORCL	MBUU	
EWP	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1
MVP	0.2580	0.4181	-0.011	-0.093	-0.039	0.1226	0.3107	-0.010	0.0706	-0.028	1
EP1	0.2532	0.4166	-0.011	-0.093	-0.027	0.1233	0.3016	-0.003	0.0687	-0.029	1
EP2	0.2399	0.4115	-0.01	-0.093	0.0036	0.1260	0.2766	0.0194	0.0631	-0.035	1
EP3	0.2277	0.4066	-0.01	-0.094	0.0356	0.1278	0.2506	0.0417	0.0573	-0.039	1
EP4	0.2132	0.4013	-0.01	-0.093	0.0657	0.1314	0.2268	0.0636	0.0521	-0.046	1
EP5	0.1999	0.3963	-0.02	-0.092	0.0967	0.1341	0.2018	0.0857	0.0465	-0.052	1
EP6	0.1866	0.3912	-0.02	-0.092	0.1277	0.1368	0.1769	0.1078	0.0410	-0.057	1

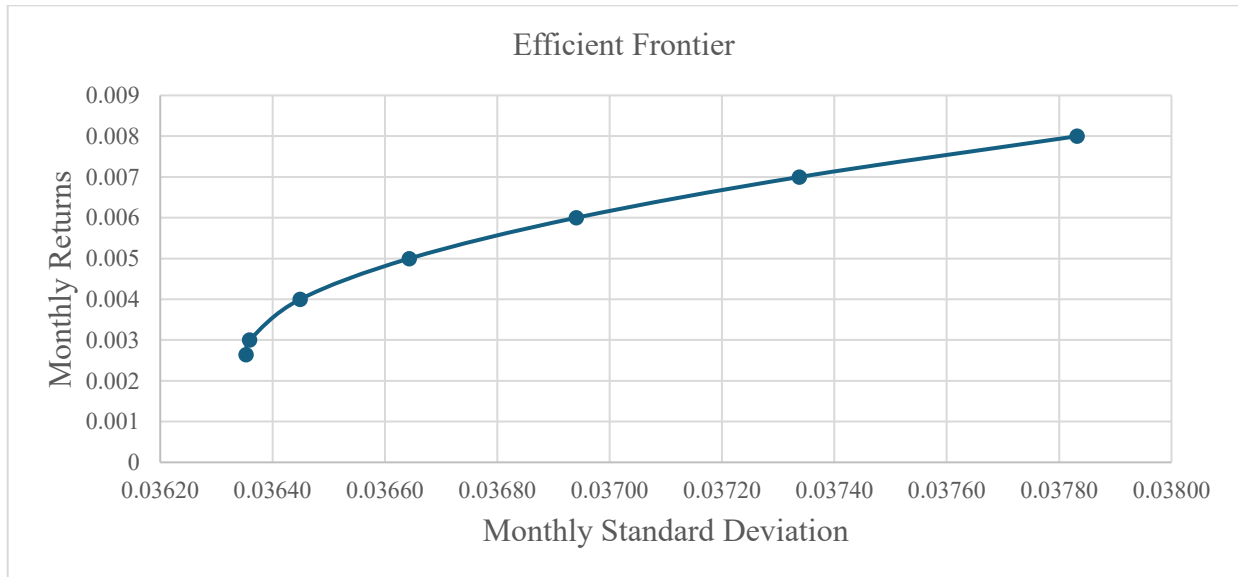
With the weights determined, we now compute the average and standard deviation for the minimum variance portfolio and for each efficient portfolio (EP 1 to EP 6) as shown in Table 12.

Table 12
Portfolio Average Monthly Return and Standard Deviation of Return

	EWP	MVP	EP 1	EP 2	EP 3	EP 4	EP 5	EP 6
AVG	0.00485	0.00264	0.00300	0.00400	0.00500	0.00600	0.00700	0.00800
STD	0.04955	0.03635	0.03636	0.03645	0.03664	0.03694	0.03734	0.03783

The weights will include both long and short positions as allowed by Carter, et al. (2002) even though the short positions might not present the ‘investable’ efficient frontier as pointed out by Johnson and Liu (2005). For an in-class assignment, this paper ignores those shortcomings. After completing these steps, the following efficient frontier is generated as shown in Figure 3.

Figure 3
Final Efficient Frontier for the Ten Stock Portfolio



The final part of this step is to locate the client’s exact position on the efficient frontier. Students will simply compute the monthly required return from the annual return objective. Recall for the Johnsons, the annual return objective is 10.85% which translates into a monthly return

objective of 0.86%. A simple eyeball test is likely sufficient to determine that the Johnsons would select the Efficient Portfolio 6 which produces their return objective and coincides with their overall high-risk tolerance.

Step I

In this step, an alternative investment is selected to include in the portfolio. Recall that a secondary long-term goal is to provide financial support for their children in the future. This is somewhat of a vague goal and could result in a variety of outcomes. To combine their interest in wine and travelling and their need for extra diversification in their portfolio, the Johnsons should purchase a rare bottle of Chateau Mouton-Rothschild 1945 vintage wine. A recent price is approximately \$300,000. The Johnsons can use \$300,000 of their current short-term investments to fund this investment. Massett and Henderson (2010) find that high quality wines have higher returns and lower standard deviations than poor quality wines and have low enough correlations with equity markets to advance diversification benefits.

Step J

In this step, a derivative security is added to the portfolio. The motivation in this component is to layer one of the securities chosen in the portfolio to hedge a specific type of risk. Suppose that after consideration of the portfolio content, the Johnsons express concern that a major competitor to Apple has emerged that challenges Apple's market share in smartphone market. The Johnsons believe that Apple will remain the market leader in the long run but is concerned about a substantial six-month drop in stock price. The Johnsons decide to use a put option to hedge this market risk. Apple's current price is approximately \$225 per share and the allocation according to Table 11 is \$548,593 which is 2,438 shares. A six-month put option with an exercise price of \$210 is available at a price of \$10.50. The Johnsons decide to purchase 2,438 options to hedge the entire allocation to Apple.

The price of Apple can rise or fall over the next six months, but suppose that future price could be either \$260 or \$170 or \$130. The hedging results are shown below:

- If Apple price is \$260: The value of the two-asset portfolio is $\$633,880 + \$0 = \$633,880$
- If Apple price is \$170: The value of the two-asset portfolio is $\$414,460 + \$97,520 = \$511,980$
- If Apple price is \$130: The value of the two-asset portfolio is $\$316,940 + \$195,040 = \$511,980$

Note if the price falls below the exercise price, the hedge will lock in a minimum value for the two-asset portfolio of \$511,980, but can realize any price appreciation if Apple price rises. This option strategy provides the Johnsons with an effective hedge against risk.

Step K

The final stage in the assignment is to develop an appropriate benchmark for the entire portfolio. The composition and characteristics of the benchmark should be representative of the

investor's assets. It may be necessary to construct a composite benchmark, depending on the allocation of funds to various asset classes.

A reasonable benchmark for the Johnson's portfolio might be three stock indexes, one fixed income index, and one money market index, and a wine index. This is a minor part of the assignment, and one that can be completed in a short time, but students should be made aware of the critical importance of the benchmark to evaluate the performance of the wealth manager over time.

Assessment and Future Research

Grading this comprehensive semester-long assignment is quite challenging for professors, mostly from a time perspective. Best practice for assessment would include a double reading of the client description to familiarize the professor with the expected contents of the policy statement. Emphasis should be placed on the identification of the constraints and the development of the objectives. Key output of the policy statement is the construction of the efficient frontier as well as the student's ability to link the frontier with the client's objectives.

Table 13 provides a summary of one potential distribution of assessment weights and a brief explanation of the grading process.

Table 13
Suggestions for Evaluating the Student's Policy Statement

Stage	IPS Content and Assessment Weights	Student IPS should be evaluated based on:
Stages 1-4	Client Constraints (10%) Risk and Return Objectives (20%)	A complete individual constraint description; Risk objective that includes ability and willingness to take risk; return objective that includes an inflation premium and is reflective of the contents of the client description.
Stage 5	Macroeconomic Analysis and Industry Analysis and Security Analysis (5%)	A description of at least six relevant macroeconomic factors; A brief analysis of industry growth rates and industry leaders; A brief description of the firm's product lines.
Stage 6	Bond valuation, interest rate risk, default risk, immunization with duration and convexity (10%)	The determination of an immunization strategy to achieve the intermediate term goal and a discussion on the level of interest rate risk.
Stage 7	Stock valuation, systematic risk, efficient frontier, SML, CML (30%)	The ability to use the Excel steps to illustrate the efficient frontier and locate the client's portfolio position on the frontier.
Stage 8	Option contracts, futures contracts, swap contracts (10%)	The use of one derivative to hedge a specific risk outlined in the client description.
Stage 9	Hedge funds, commodities, collectibles, private equity (10%)	The inclusion of an alternative investment and a link to the risk and return objectives of the client.
Stage 10	Benchmarking, CFA Institute (5%)	The selection of three or more indexes that possess similar risks as the portfolio.

The lectures and other semester assignments coincide with the stages of the assignment shown in Table 13. At each stage, or perhaps comingling a few stages, professors should offer feedback. Key risk indicators include skeletal client descriptions, poor use of artificial intelligence, incomplete constraint descriptions, difficulty with forming the Harry Markowitz efficient frontier, and a flawed derivative security application. The professor's guidance at each stage will help students avoid these common pitfalls. It is also recommended that a time sensitive schedule for submitting partial work at each stage should be reflected in the course syllabus. That time schedule should also include optional checkpoints for students who need extra guidance.

One possible method for professors to test the effectiveness of the assignment is to construct a survey on student knowledge base about the content of policy statements, how the assignment relates to other business courses, and how the assignment can impact the career search. Professors can create their own survey questions and compare the results of student responses at the beginning of the semester and after the assignment is submitted. The results of the survey should be helpful when providing feedback to students and listening to their concerns about the quality of their document. This process should allow the professor to gauge student confidence levels and provide a framework for student success.

Over several semesters, professors will judge the success or failure of each stage and the final document. Extensions and deletions to the assignment are very likely to occur. For example, the behavioral constraint was added after the 2008 financial crisis when the topics of the housing bubble and a herding mentality entered weekly current event discussions. In the 2020s, the reliance on artificial intelligence as an aid in crafting the macroeconomic and industry analysis sections was added for students to increase their awareness of the marginal costs and benefits of using Chat GPT.

Refinements to the policy statement assignment depend on which topics each professor might target during the semester. For example, some professors might want to exclude the derivative securities stage and replace it with a section requiring students to compute Sharpe ratios or draw the capital market line above the efficient frontier. Another possibility is to require students to expand the return objective to include a behavioral asset pricing model, thus directly linking the behavioral constraint with the return objective. One way to accomplish this is to have students search for at least one stock in their client's portfolio that exhibits positive momentum. Zakamulin and Giner (2022) provide strong evidence of short-term momentum in US stocks. Although students are not likely to use the AR(p) models shown in Zakamulin and Giner (2022), they can use simpler methods such as identifying one their client's ten stocks that has substantially increased in price over a specified time period. Students could then add a constraint in Solver to overweight that particular stock. Finally, other professors might prefer their students to maximize the geometric return rather than the arithmetic return in the second constraint outlined in the Excel Solver process. Johnson and Hatem (2000) show that maximizing terminal value using geometric means adds an important layer to student's understanding of portfolio optimization.

Concluding Remarks

This paper provides the motivation for and outlines the steps of a comprehensive assignment for the investments course that links a goals-based framework and applied investment analysis with theoretical investments. This semester-long assignment will give the students a glimpse into practical investment management.

Throughout the semester, the students are guided through the development of an investment policy statement (IPS), macroeconomic and industry analyses, and must consider “real-world” issues that impact personal investment decisions. The students also apply the constructs of Nobel Prize winning work to identify optimal portfolios given risk and return constraints.

The experiential-based project presented here bridges the gap between theoretical investments and applied investment analysis. The students will develop practical tools for use in their own investment programs. They may also be motivated to investigate the value of pursuing professional designations, even before they graduate.

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Trade Secrets: Launching the First Options Trading Practicum

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The first student-managed investment fund (SMIF) launched in the 1940s, focusing exclusively on equities. Since then, options trading has grown significantly, with the daily average notional value of single-stock options surpassing that of individual U.S. stocks. Despite this growth, most SMIFs either limit their use of options to risk mitigation strategies or avoid them altogether. In response to a recent donation, Northern Illinois University established the first U.S. SMIF dedicated solely to options trading, offering students a unique opportunity to gain hands-on experience in derivatives markets. This article details the process of designing, implementing, and delivering this cutting-edge course, highlighting the challenges, pedagogical innovations, and broader implications for student-managed funds.

Keywords: Options, Trading, Python, Data Visualization, Technology

Introduction

When the first university-sponsored student managed investment fund (SMIF) launched in the 1940s (Indiana State University, 2023), decades before the country's first organized options exchange (Poser, 2024), the fund understandably focused on equity instruments. However, since 1973, the average daily volume of U.S. options has grown faster than that of U.S. stocks at 20% annually versus 14%, respectively (Options Clearing Corporation, 2024; Russell Investments, 2023; United States Census Bureau, 2011). Although the daily notional value of all U.S. equities continues to overshadow that of U.S. options at 18:1 (CBOE Global Markets, 2024), the total market order flow attributed to U.S. options increased from 23% to 33% in 2021. That same year, the daily average notional value of single-stock options surpassed (and continues to exceed) that of individual U.S. stocks (Schwartz, 2022).

Despite the rise in stock option popularity, across today's 600+ student managed investment funds in the United States (Indiana State University, 2023), the role of options remains largely limited to risk mitigation or passive income generation (Intentional Endowments Network, 2021). While all funds surveyed by Kubik (2018) invested in equities, less than 20% were permitted to also invest in options. When these SMIF do incorporate options, the strategies follow conservative frameworks suggested by Saunders (2014), such as covered calls or protective puts or index options.

In contrast, after observing Northern Illinois University's equity-based SMIF, which permits such limited options strategies on its stock holdings, an alumnus recently earmarked funds for the creation of a new SMIF focused entirely on options speculation without underlying stock or index holdings (Table I summarizes the key difference between the two funds). The following sections detail the creation and development of this unique SMIF, the Jamrok Student Options Trading Fund, and its distinct educational value.

Table 1
SMIF Comparison

	Our Traditional SMIF	Our Options SMIF
Duration	Year-round	1 semester
Enrollment	Competitive entry	Competitive entry
Objective	Growth & Income	Growth
Holdings	Long stocks & ETFs Limited options (covered calls, protective puts) Limited cash	Long calls & puts Short puts Cash
Horizon	Long (1 year+)	Short (1 hour – 3 weeks)
Turnover	Low	High
Selection Criteria	Fundamental Analysis	Technical Analysis

Course Design and Development

Approval Process

It will come as no surprise for seasoned higher education professionals that the road to launching a new course delivery can be full of hurdles. Given the ground-breaking nature of this initiative, there were no existing models to follow, and every aspect of the course needed to be created from scratch. While the approval of any new course is often tedious and time-consuming, this particular course required additional steps to address unique concerns and secure its launch.

The first major challenge was securing university buy-in. Given the perception that stock options carry excess risk, the administration was initially cautious. Their understandable concern focused on the potential for unlimited downside exposure, posing a financial risk both to the portfolio and subsequently the university. Consequently, a comprehensive risk mitigation plan was developed and presented in multiple meetings (see Table 2).

First, risk exposure would be limited by restricting the types of strategies employed. Specifically, the course would avoid strategies with unlimited risk potential. Second, the brokerage account's options approval level was set to permit only cash-backed positions, ensuring that any losses would not exceed the account balance. Third, trading authority was restricted to two faculty members, preventing students from executing trades.

Fourth, subject to brokerage constraints, trades would be simultaneously entered with corresponding stop-loss orders to limit downside risk. Although not all brokerage firms offer simultaneous stop-loss and take-profit orders, alternatives such as Interactive Brokers support this functionality. While price alerts are a potential substitute, they are imperfect due to execution lags and the common conditioning on the underlying price rather than the option contract price. For those seeking option price-based alerts, Interactive Brokers and the Bloomberg terminal provide effective solutions.

Table 2
Risk Mitigation Measures

Risk Mitigation
Avoidance of strategies with unlimited risk potential
Account with cash-backed option trading level
Limited trading authority
Stop loss (and take profit) orders
Competitive entry selection process
Open only to undergraduate senior and graduate students
Introductory options crash course
Mandatory knowledge check

Fifth, to establish a solid foundation for participants, a “knowledge floor” was implemented. Admission to the course was competitive, limited to undergraduate seniors and graduate students with appropriate backgrounds. Before trading began, students were required to complete an options crash course and pass a proficiency exam to demonstrate competence.

Finally, to address any concerns that this might be perceived as a technical day-trading exercise without educational value, it was emphasized that the course would focus heavily on building transferable quantitative skills applicable across a range of financial and data-driven disciplines.

Learning Objectives

The course is designed to equip students with practical experience in advanced options trading, technical skill development, and professional communication, all within a real-money trading environment. As summarized in Table 3, key learning objectives include mastering a diverse range of equity options strategies, such as spreads and combination trades; conducting performance evaluation and benchmarking; and enhancing technical skills in financial databases, coding, and data visualization. Additionally, students develop critical teamwork and communication abilities by collaborating on problem solving and pitch selection. Emphasis is also placed on professionalism and ethical responsibility, ensuring students manage real-money trades with integrity.

Table 3
Learning Objectives

Learning Objectives

Apply Advanced Options Trading Strategies: Students will develop and execute a range of equity options trading strategies, including long single leg positions, back spreads, vertical spreads, strangles, straddles, butterfly spreads, and condor spreads using real money in a controlled, competitive environment.

Analyze and Evaluate Stock Performance: Students will research and pitch suitable underlying stocks for various options strategies, comparing holding period returns against relevant benchmarks to assess strategy effectiveness.

Develop Technical and Analytical Skills: Students will enhance their proficiency in financial databases, coding, data visualization, spreadsheets, and software integration, applying these skills to create trading dashboards and pitch presentations.

Collaborate and Communicate Effectively: Students work individually to develop and pitch trading recommendations, while collaborating to solve technical challenges and collectively evaluate to select the most promising ideas, honing their ability to communicate complex financial concepts and make data-driven decisions.

Demonstrate Professionalism and Ethical Responsibility: Students will uphold academic integrity, embrace the principles of diversity, equity, and inclusion, and manage real-money trades responsibly, reflecting the ethical standards expected by the client, university, and industry.

Technology Selection

The platforms selected for the course were chosen based on alumni and employer feedback, as well as institutional software availability. These include Python as the coding language, VS Code for text editing, Power BI for data visualization and dashboard creation, and PowerPoint for the final slide deck.

Python is currently regarded as the most relevant programming language for finance professionals, according to alumni and employers. In addition to its industry relevance, it is also free and open source. Within the course, Python is used to pull external data into the visualization software, perform a variety of functions (such as creating technical indicators, filtering and rearranging datasets, and calculating position statistics), and organize the requisite data into dataframes. However, the default Python text editor and output display are quite basic, lacking several features that are particularly useful for novice programmers.

To address these limitations, the VS Code text editor was selected. This freely available Microsoft product offers significant advantages, including syntax highlighting, error detection, debugging tools, and output display capabilities. It also allows for executing code subsets and integrates artificial intelligence features that help answer common coding questions, making it a valuable tool for students.

For data visualization and dashboard creation, Power BI was chosen. It uses Python code developed in VS Code as the basis for a Power Query, which pulls in dataframes and converts them into visual dashboards. Power BI's interface, with its ribbon and commands resembling other

Microsoft Office products like Word, Excel, and PowerPoint, presents a less steep learning curve compared to alternatives such as Tableau.

Finally, PowerPoint remains the preferred platform for creating presentation slide decks. After building dashboards in Power BI Desktop, students publish them to O365 and export the dashboards to PowerPoint for their presentations. This final step does, however, require a Power BI Premium subscription to properly display interactive graphics within PowerPoint.

Data Sources

The primary data sources for the course include both Bloomberg terminals and Yahoo! Finance. The Bloomberg terminal provides access to specialized information not readily available elsewhere, such as option Greeks and time-series data for option contract prices and stocks' historical implied volatility, short interest, and put-call ratios.

However, schools without access to Bloomberg terminals can still replicate most of the dashboards using freely available data. While equity-focused SMIFs may rely on Bloomberg for fundamental and macroeconomic analysis, the technical trading decisions in this course primarily draw from current stock metrics, price and volume history, and real-time option chain data—all of which can be accessed via Yahoo! Finance.

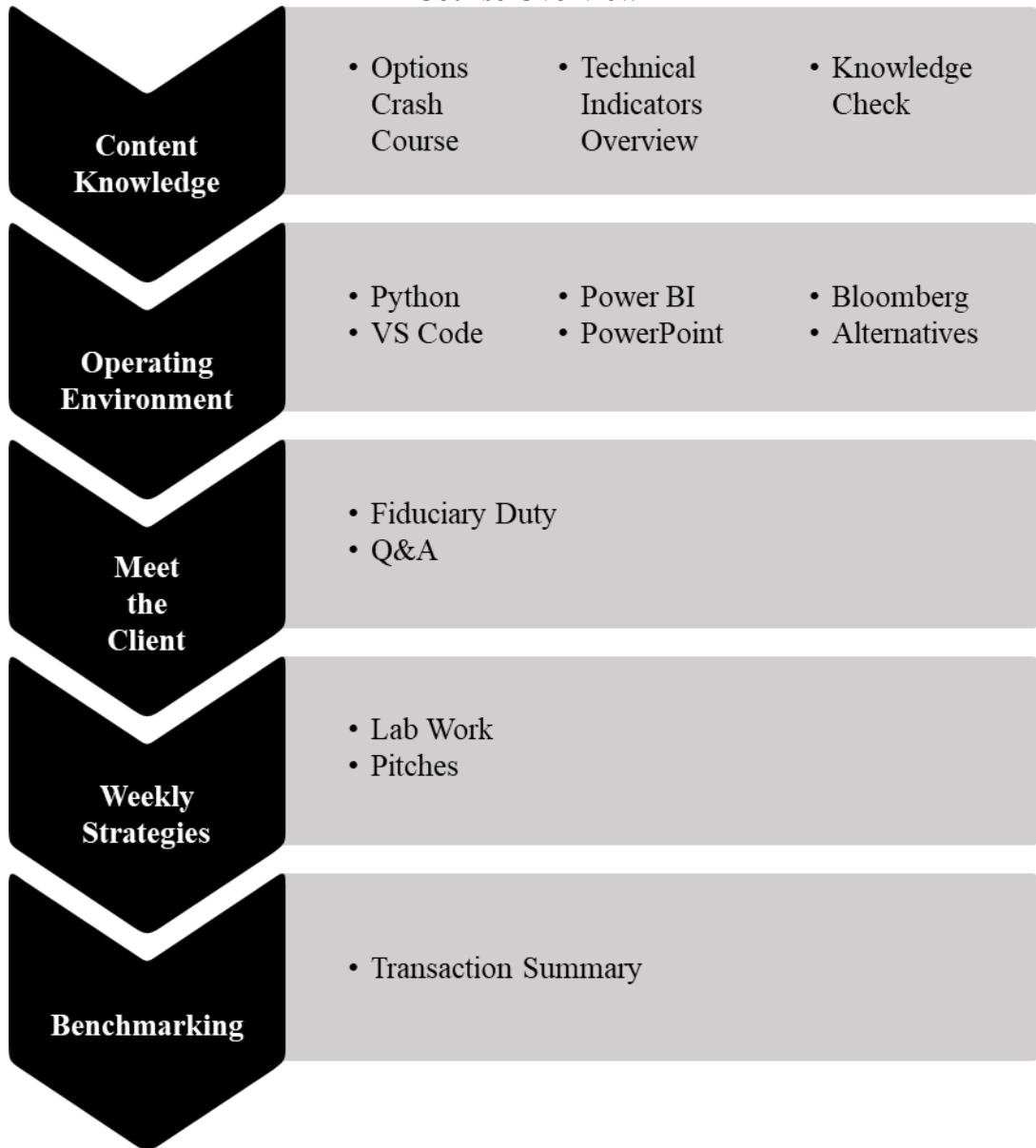
Students with access to the Bloomberg terminal lab utilize both Bloomberg and Yahoo! Finance to complete their dashboards. For students enrolled in the course remotely—due to employment, geographic constraints, or accommodations—the dashboards are constructed using only Yahoo! Finance data. Although this somewhat limits dashboard components, all students learn to use Python to scrape website data. To prevent such harvesting, websites often frequently change their layouts, rendering Python packages unusable (at least temporarily). Students are encouraged to investigate the packages' underlying structure, often via GitHub, and attempt to make the requisite modifications. These technical skills and the ability to nimbly adapt and problem-solve are highly transferable and valuable for future finance and data analytics roles in an ever-shifting technology environment.

Course Structure

Timeline Overview

After obtaining delivery approval, the course was structured as outlined in Figure 1. During the initial weeks of the semester, students work independently to achieve specific milestones. The first goal is to demonstrate a baseline knowledge of options terminology, pricing, trading mechanics, and technical indicators. After reviewing supplementary materials—including crash courses, lecture videos, and assigned readings—students must pass a knowledge check, which can be retaken if necessary.

Figure 1
Course Overview



At the same time, students prepare their operating environment. This involves ensuring the installation and functionality of the required software—VS Code, Power BI, and PowerPoint—on both personal and lab machines. While these Microsoft products integrate well, differences in settings, permissions, program versions, and operating systems across machines can introduce complications. This stage often requires significant support to troubleshoot and standardize the working environment.

Once the operating environment is in place, students develop their base programs. Once trading begins, after students have individually selected their recommendations' parameters, they will modify their base code to efficiently generate their slide deck. Together with the software installation and coordination above, these are by far the most instructor-intensive portions of the course.

Finally, before trading begins, students are reminded of their fiduciary responsibility. During a “Meet the Client” session, the donor visits with the incoming analysts. While the students do not report directly to the donor, this interaction reinforces the notion of accountability. The session also provides an opportunity for students to receive advice and exchange ideas, while offering an inspiring example of philanthropy in action.

Option Trading Strategies

Once students have completed the technical and educational groundwork, the course transitions to strategy implementation, rotating through one strategy per week for the remainder of the semester. The sequence begins with single-leg directional strategies, as these are easier for students to understand conceptually and to implement in code. After mastering these foundational strategies, students progress to more complex multi-leg strategies, some of which include cash-covered short positions. From a speculative standpoint, the course moves from directional bets to volatility-based strategies.

The strategies covered include long calls, long puts, vertical spreads, back spreads, strangles, straddles, butterfly spreads, and condors. This progression is designed to gradually increase the level of complexity and expose students to a diverse range of option trading approaches, balancing conceptual understanding with practical execution.

Benchmarking Process

As the semester concludes, students summarize their performance by preparing a benchmarking report for the donor and Foundation. While the benchmarking process for the options-focused SMIF is not as extensive as that of the equity-based SMIF—due to the shorter holding periods associated with the options portfolio—it still provides meaningful insights into trade effectiveness. In contrast to the equity-based SMIF, which evaluates raw and excess returns, volatility, and risk/reward metrics (e.g., Sharpe ratio, Treynor ratio, and coefficient of variation) across various rolling time periods, the options benchmarking focuses on strategy-specific performance over matching short-term holding periods.

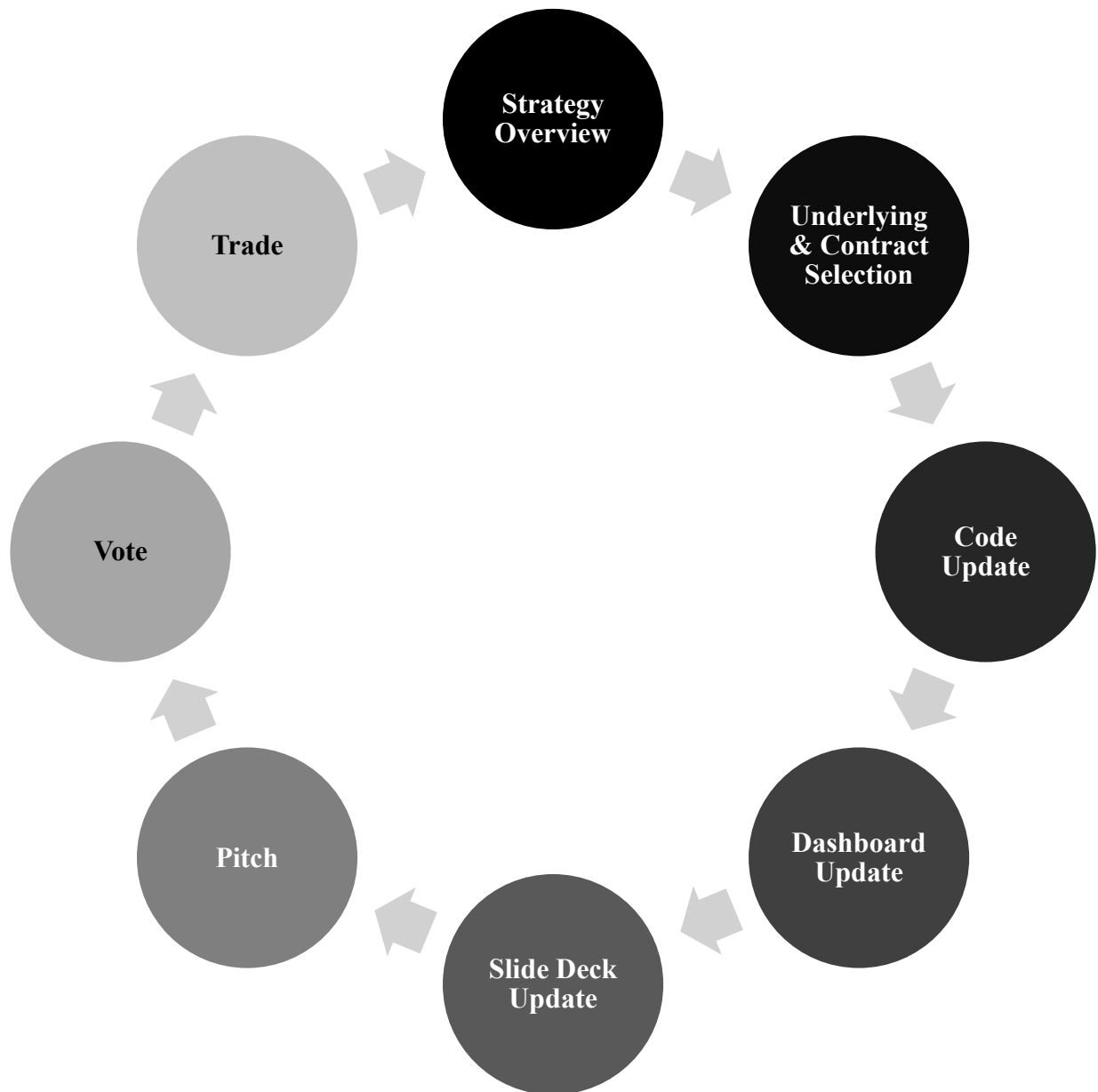
For students with access to Bloomberg terminals, performance analysis involves reconstructing each strategy using corresponding S&P 500 (SPX) options for the same entry and exit dates as their trades. For example, if a student entered an at-the-money call on March 5, 2025, with a March 21, 2025 expiration and exited on March 10, 2025, they would compare the performance of this trade on the pitched stock against an equivalent at-the-money SPX call for the same holding period. This comparison helps students evaluate whether their selected stock outperformed the overall market in that environment.

For students without Bloomberg access, benchmarking is performed using freely available historical CBOE data. CBOE provides strategy-specific indices, such as PUT, PPUT, CLL, SSTGK, BFLY, and CNDR, which track standard options strategies like cash-secured puts, protective puts, covered calls, collars, short strangles, butterflies, and condors. However, since not all strategies have a corresponding CBOE index, students use these indices selectively to benchmark trades whenever an appropriate benchmark is available.

Weekly Workflow

Each trading week consists of two sessions. During the first session, students engage in lab work to review the strategy and independently select contract details, including the underlying security, expiration, and strike prices. They also update their code and presentation decks. In the second session, each student presents a pitch, explaining why their selected contract is the most appropriate for that week's strategy. After these pitches, the students vote on the trade to pursue, and the selected trade is executed (see Figure 2).

Figure 2
Weekly Deliverable Process



Underlying Security Selection

The process for selecting the underlying security, expiration, and strike prices varies depending on the week's strategy. For directional strategies, students focus on identifying securities they expect to increase or decrease in the short term. In contrast, for volatility-based strategies, the emphasis shifts to securities likely to experience significant or insignificant price movement, regardless of direction.

The decision-making process draws heavily from guidance provided during the Client Meeting, where students engage with the fund's donor to discuss their approach to options trading. Factors commonly considered include share price, price-to-book (P/B) ratio, bid-ask spread, option contract volume and open interest, dividend yield, share trading volume, market capitalization, and a preference for short-dated expiries and credit over debit spreads. To aid in their analysis, students often consult widely available equity screeners and options data providers such as Yahoo! Finance, Bloomberg, Thinkorswim, and brokerage platforms.

Programming Updates

The approach utilized in this course contrasts sharply with traditional portfolio management classes, which focus on fundamental analysis and long-term outlooks. In the options trading practicum, technical indicators take precedence, and investment horizons are significantly shorter—ranging from a few weeks to less than one day. Given the speed required for day trading, the technology and processes used to create sample deliverables (see Figure 3) were selected to maximize efficiency.

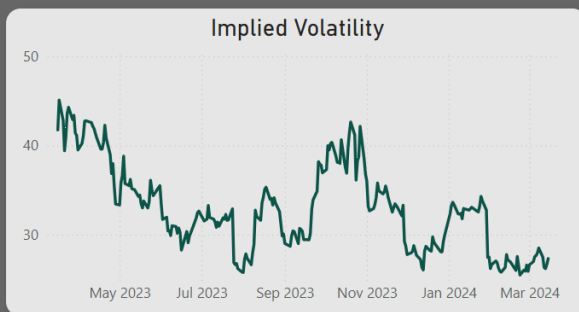
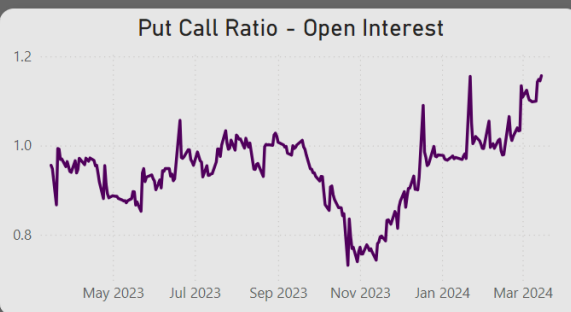
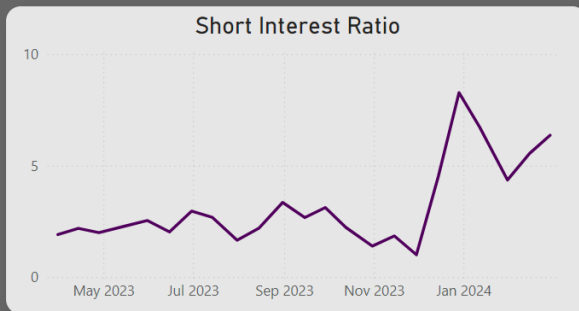
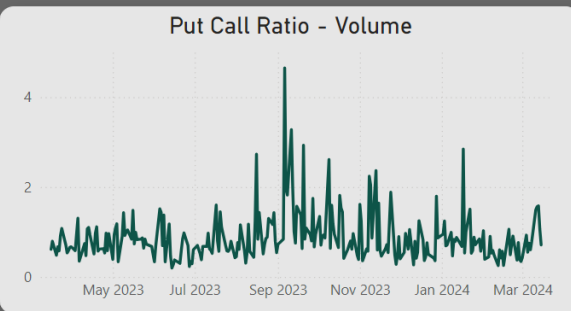
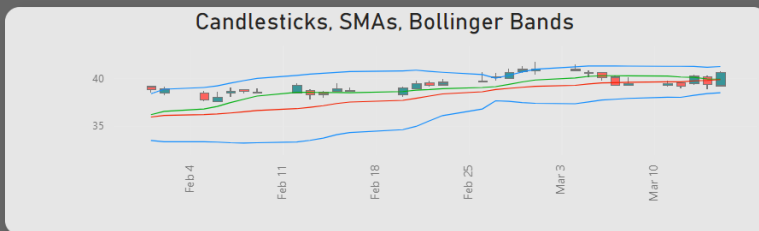
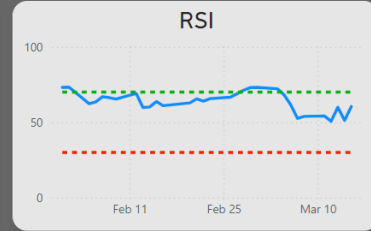
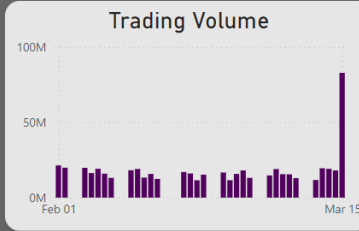
Figure 3
Sample Power BI Dashboard



GM dashboard

Current Price
\$40.69

SortID	Attribute	Value
0	Current Price	40.689998626708984
1	Market Cap	46.9748
2	Shares Outstanding	1.15B
3	Beta	1.50
4	D/E	179.94%
5	52-Week Change	21.03%
6	52 Week Range	26.30 - 41.80
7	Day's Range	39.27 - 40.82
8	Previous Close	39.38
9	Bid - Ask	40.60 - 40.69
10	1y Target Est	49.95
11	EBITDA	15.788
12	Sales (ttm)	171.848
13	BV Per Share	53.57
14	EV	143.168
15	EV/EBITDA	6.17
16	EPS (TTM)	7.32
17	EV/Sales	0.83
18	PE Ratio (TTM)	5.56
19	Forward P/E	4.52
20	P/B	0.73
21	P/S	0.32
22	FVE	Dec 31, 2023



GM option chains

Call Options

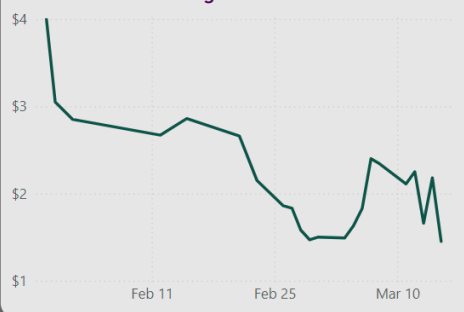
Contract Name	Strike	Last Price	Bid	Ask	Implied Volatility	Volume	Open Interest	Moneyness
GM240419C00039000	39.0	2.45	2.48	2.56	32.42%	116	5319	ITM
GM240419C00041000	41.0	1.27	1.29	1.32	29.54%	2432	11459	OTM
GM240419C00043000	43.0	0.57	0.57	0.59	28.76%	480	8637	OTM
GM240419C00040000	40.0	1.83	1.84	1.87	30.52%	631	11368	ITM
GM240419C00042000	42.0	0.9	0.87	0.9	29.05%	928	14350	OTM

Put Options

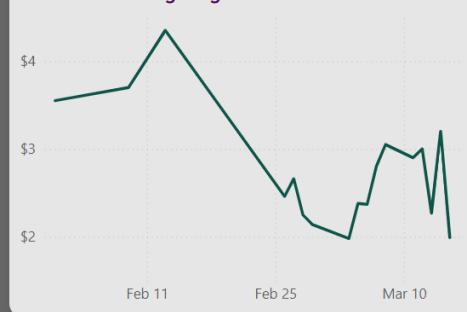
Contract Name	Strike	Last Price	Bid	Ask	Implied Volatility	Volume	Open Interest	Moneyness
GM240419P00039000	39.0	0.62	0.6	0.63	26.91%	3709	7287	OTM
GM240419P00040000	40.0	0.95	0.95	0.98	26.39%	2111	5968	OTM
GM240419P00041000	41.0	1.45	1.41	1.45	25.93%	440	2972	ITM
GM240419P00042000	42.0	1.99	1.99	2.04	25.44%	46	193	ITM
GM240419P00043000	43.0	2.68	2.38	2.74	24.81%	28	63	ITM

Bear Put Spread dashboard

Short Leg Historic Price



Long Leg Historic Price



Short Leg Greeks

Contract	delta	gamma	ivol	opt_theta	rho	vega
GM US 04/19/24 P41 Equity	-0.50	0.05	26.95	-0.02	0.00	0.05

Long Leg Greeks

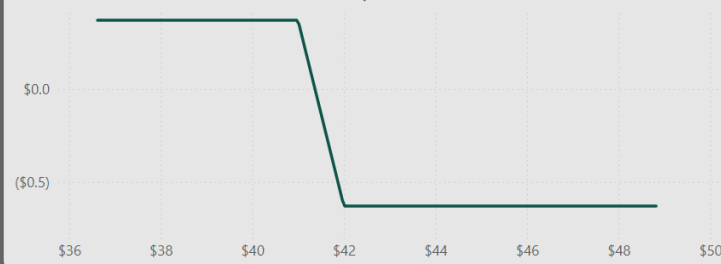
Contract	delta	gamma	ivol	opt_theta	rho	vega
GM US 04/19/24 P42 Equity	-0.62	0.05	26.69	-0.02	0.00	0.05

Bear Put Spread dashboard

Strategy Summary

Variable	Value
exit_price_profit	\$39.13
spot	\$40.69
exit_price_loss	\$41.11
delta_position	-0.12
reward_to_risk	0.59
PoP_BS	56.96%
PoP_MC	57.36%
PoT_MC	81.06%

Bear Put Spread Profit



Strategy Summary

Position	Initial Cost	Max Gain	Max Loss	Break-Even
Contract	-\$63.00	\$37.00	-\$63.00	
Share	-\$0.63	\$0.37	-\$0.63	\$41.37

Each trading week, students modify the skeleton Python programs developed at the beginning of the semester to reflect their selected underlying asset, contract terms, and strategy specifications. To optimize efficiency, variable inputs that change across strategies—such as ticker symbol, expiration date, strike prices, trade direction, option type, number of legs, and profit calculations—are organized at the top of the code to facilitate updating.

Several Python packages assist in data acquisition and metrics calculation. Yfinance retrieves information about the underlying asset—such as stock quotes, historical prices, current metrics, and trading volume—as well as real-time options chain data from Yahoo! Finance. This data, combined with packages like pandas_ta and optionlab, enables students to calculate technical indicators such as the relative strength index (RSI), candlestick patterns, simple moving averages (SMA), and Bollinger Bands as well as strategy measures such as profit and loss profiles.

For less publicly available data—such as short interest ratios for stocks or options-specific metrics like put-call ratios, option Greeks, implied volatility, and historical option contract prices—students use Bloomberg terminals. These datasets are accessed through Python packages such as blpapi and xbbg, integrating Bloomberg data into their analyses and expanding the range of metrics available for decision-making.

Visualization and Reporting

Students can update their Python code directly in Power BI or paste from VS Code into Power BI's Power Query Python script editor. Values and series from the imported dataframes are linked to Power BI visuals, allowing the dashboard to update automatically across all pages with a simple query refresh. While the initial setup of the Power BI dashboard requires a significant time investment, subsequent updates are streamlined, reducing the weekly workload to refreshing program queries without the need for manual editing of visuals, tables, or graphics.

Once the multi-page dashboards are proofread for potential connectivity or coding errors, students publish them to Power BI O365. From their online workspace, they can export any or all dashboard pages to PowerPoint for their final presentations. Each slide deck is required to include several key components. The title slide displays the student's name, presentation date, strategy of the week, selected underlying ticker, expiration dates, and strike prices. The second slide outlines the student's rationale for selecting the underlying security, listing the key factors that make it suitable for the week's strategy. The following slides provide an overview of the underlying stock's quotes, key metrics, and technical charts, followed by the options chain for the selected expiration. Additional slides display the Greeks and historical price charts for each leg of the strategy. The presentation concludes with a strategy summary slide containing a profit diagram, a cash flow summary table (including initial cost, maximum gain and loss, and break-even points), and a set of relevant statistics such as position delta, estimated profitability probabilities, probability of being touched, and prices for exit orders.

This workflow dynamically streamlines the creation of weekly pitch decks. Once the underlying specifications are determined, students can quickly open Power BI Desktop, update the inputs at the top of the Power Query script containing their skeleton Python code, refresh the queries, scan for errors, publish the updated dashboard to Power BI O365, and export it to PowerPoint. The only slide that requires manual editing is the rationale slide, where students explain their reasoning for the selected underlying security and strategy.

Concluding Thoughts and Future Considerations

The creation of this class was initially daunting, particularly given its focus on day trading, which may not align with the ideologies of all faculty members. Despite this, student interest has been high, and employers have expressed strong support for the skills the course fosters. From a pedagogical perspective, the technical learning objectives are highly transferable and offer significant value beyond options trading alone.

Comparative Analysis

An options-focused SMIF presents both unique advantages and significant challenges compared to a traditional equity-based SMIF. One of the key benefits is the exposure students gain to more complex and dynamic trading strategies, which enhances their understanding of derivatives markets and risk management. This experience is particularly valuable for students interested in careers in asset management, trading, or quantitative finance. Additionally, the shorter time horizons associated with options trades offer students frequent feedback on their strategies, accelerating their learning process.

However, an options-only focus also presents challenges. The increased complexity of options strategies requires students to develop a strong technical foundation, which may be intimidating for those without prior programming or quantitative experience. Moreover, the highly speculative nature of many options trades means that students must be constantly vigilant about risk management, adding another layer of difficulty. Despite these challenges, the skills acquired in an options-focused SMIF—such as coding, data visualization, and technical analysis—are broadly applicable across financial and data-driven industries, making the experience highly rewarding.

Instructor Workload

Faculty members should be aware that structuring a course reliant on web scraping, open-source programming packages, and personal student computers requires a substantial time commitment. Websites frequently update, code deprecates, and package compatibility issues arise due to multiple versions. Variations in file locations, paths, permissions, and environment variables across machines also introduce significant troubleshooting challenges. Faculty should expect to revise code regularly—often mid-semester—and dedicate considerable time to hands-on support for students. This process demands flexibility, persistence, and a willingness to adapt to the inevitable issues that will arise. Despite these obstacles, the rewards of such a program are immeasurable, providing students with highly valuable skills and real-world experience.

Long-Term Impact

The long-term impact of this options-focused SMIF has been significant, both in shaping students' career trajectories and in enhancing their understanding of financial markets. Several students have continued to apply the skills developed in the course, creating their own Python-based options portfolios post-graduation. Alumni from the university's traditional SMIF program have returned to campus specifically to enroll in this course, eager to gain exposure to the unique opportunities provided by options trading.

Student feedback, summarized in Table 4, highlights the program's ability to cultivate technical skills such as coding, data visualization, and quantitative analysis, all of which have broad applications beyond finance. Additionally, the focus on frequent presentations and real-time decision-making sharpens students' communication and problem-solving abilities. These transferable skills enhance their readiness for careers in finance and other data-driven industries, reflecting the broader educational value of an options-focused approach.

Table 4
Student Feedback

Select Written Comments

I found the options trading practicum to be very informative towards options market mechanics and fundamentals as well as trading technicals. More importantly the in-depth approach on programming using data pulls from the Bloomberg terminal and exports to Power BI was an incredibly good experience. Overall, the course touched on both technical and core information which will be extremely valuable in my career. The course is very well designed and the professor has been responsive to feedback for continuous improvement.

Participating in the options practicum significantly enhanced my technical and practical skills. My proficiency in coding, particularly with Python, improved substantially, especially in utilizing data visualization tools that have broad applications beyond trading. The practicum also honed my technical analysis skills, which I continue to apply in my investment strategies today. It provided an efficient framework for implementing knowledge in real-world scenarios, and the opportunity to trade regularly gave me hands-on experience. Additionally, presenting strategies and analyses improved my ability to communicate complex ideas effectively. However, there were areas for improvement. The practicum was an invaluable experience that significantly contributed to my growth in both technical and interpersonal skills.

Options was the second most relevant class to my career, with SMP (Student Managed Portfolio, our institution's traditional long-only equity portfolio) being the first. Understanding options and the language/thought process behind these trades tunes your brain, gets it acclimated by connecting the classroom concept to the career. I think beyond the content of the work, the discipline and routine the course follows provides great preparation for students stepping into entry roles.

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Valuation of Index-linked Guaranteed Investment Certificates: A Spreadsheet-based Approach

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Yi Feng

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Lewis University

We introduce students to a complex yet widely popular financial product: Index-Linked Guaranteed Investment Certificates (ILGICs). We first present a closed-form valuation using the option pricing model. To enhance student understanding, we incorporate a spreadsheet-based simulation that generates price paths for the underlying index, enabling students to derive the ILGIC's payoff and valuation. This approach not only highlights potential mispricing but also helps students visualize the inherent randomness in index movements, thereby reinforcing their grasp of the valuation process. Importantly, the method requires no advanced Excel techniques such as VBA or macros, making it accessible to students with varying levels of spreadsheet proficiency.

Keywords: Index-Linked Guaranteed Investment Certificates, Option Pricing Model, Spreadsheet Simulation, Payoff Visualization, Valuation Accessibility

Introduction

Index-linked Guaranteed Investment Certificates (ILGICs), also known as market-linked or equity-linked certificates of deposit (CDs), are structured financial products with payoffs linked to the underlying market indices. Investors are guaranteed the principal payment at maturity, along with the potential for additional returns if the linked index performs strongly over the investment period (typically three to five years). The specific payoff structures can vary significantly, incorporating features such as caps, floors, participation rates, contingent coupon payments, or average returns over the term (Deng, Dulaney, et al., 2014; Li et al., 2022). The principal is generally protected by government-sponsored deposit insurance agencies, such as the Canada Deposit Insurance Corporation (CDIC) in Canada and the Federal Deposit Insurance Corporation (FDIC) in the United States.

Since Chase Manhattan Bank first introduced this type of product in 1987, financial institutions have issued and sold billions of dollars' worth of ILGICs annually to retail investors in the United States (Deng, Dulaney, et al., 2014; Edwards & Swidler, 2005). Milevsky & Kim (1997) document that ILGICs gained popularity in Canada during the 1990s, with all six major Canadian banks offering some variant of these products since then.

Financial institutions have marketed ILGICs as zero-cost financial products that combine principal protection and the opportunity to participate in the equity market gains. The industry

often positions these products as attractive alternatives to traditional mutual funds, term deposits, and fixed-income securities. However, academic research presents counterarguments. Edwards & Swidler (2005) analyze a participating equity-linked CD using historical data and simulations, concluding that it underperforms a five-year treasury note and is less appealing than a replicating portfolio consisting of a zero-coupon bond and a call option on a stock index. Deng, Dulaney, et al. (2014) further document that structured CDs are valued below their face value, approximately 93% of the value of a fixed-rate CD. Similar trends are observed in Canada. Milevsky & Kim (1997) compute the Value per Premium Dollar for capped and participating ILGICs and find values consistently below one, indicating that these products are overpriced from an investor's perspective.

Given the complexity of ILGICs and their widespread presence in the financial industry, introducing such products to students poses a challenge and a necessity for finance instructors. This topic is often underrepresented in traditional finance textbooks. To address this gap, we begin with a simple numerical example illustrating how a typical capped ILGIC resembles a portfolio of a zero-coupon bond and a bull call spread. We then apply the Black-Scholes-Merton option pricing model to a real ILGIC issued by a major Canadian bank. Implementing the option pricing model in Excel is straightforward, i.e. using the NORM.S.DIST function to compute the required cumulative standard normal distribution. The closed-form valuation reveals that the fair value of the capped ILGIC is 97.64% of its face value, implying a hidden cost of 2.36% to investors.

While the option pricing model offers a convenient closed-form solution for valuing ILGICs, the process may appear opaque or overly abstract to many students. To address this issue, we introduce a more intuitive and accessible alternative - a spreadsheet-based approach. This method employs Monte Carlo simulations to generate price paths for the underlying index and maps each trail to the corresponding ILGIC payoff. By plotting the simulated index paths and computing the associated ILGIC payoffs, students can visualize the stochastic nature of the underlying asset and develop a deeper understanding of ILGICs as derivative instruments, whose payoffs at maturity are contingent upon the underlying index's value at that time.

In performing the Monte Carlo simulation, we employ an Excel-based approach that avoids the need for advanced macro or VBA programming. Randomness is introduced through Excel's *What-if Analysis* feature, making the method both straightforward and accessible to students with varying levels of spreadsheet proficiency. The simulation yields valuable outcomes. It offers an alternative valuation method, produces summary statistics, and generates histograms based on the simulation trials, enabling the students to analyze the distribution of potential returns. Furthermore, this approach is easily adaptable to more complex path-dependent structured notes.

The spreadsheet-based approach presented in this paper serves as an effective pedagogical tool for deepening students' understanding of complex financial products with embedded option features. This method is well-suited for undergraduate finance courses, particularly after students have been introduced to foundational concepts such as the time value of money, the characteristics of European options, and option strategies including covered calls and bull spreads. Toward the end of this paper, we offer pedagogical guidance for classroom implementation, including learning objectives and sample exercises. Preliminary evidence suggests that the spreadsheet-based approach enables students to grasp the mechanics of ILGIC without requiring engagement with advanced analytical techniques.

The remainder of the paper is organized as follows. Section 2 introduces the payoff structure and valuation of ILGICs using a simple numerical example. Section 3 derives a closed-form valuation based on the option pricing model and applies it to a real-world example. Section 4

presents the spreadsheet-based approach, which generates simulated index paths to provide an alternative valuation method and offer intuitive insights for students. Section 5 discusses strategies for classroom implementation. Finally, Section 6 concludes the paper.

A Numerical Example

Unlike a standard GIC, which provides investors with a fixed return over a predetermined investment period, an ILGIC offers a payoff contingent upon the performance of an underlying market index, while still ensuring principal protection. Given that its return profile mimics that of certain option strategies, an ILGIC can be replicated using a bond and option portfolio.

For example, consider an ILGIC that guarantees investors a minimum payment of \$100 in three months, with the potential for additional returns if the underlying stock index performs positively. Suppose investors are entitled to receive the full positive return of the index, up to a cap of 20%. In this case, the payoff at maturity will depend on the performance of the linked index, as illustrated in Table 1.

Table 1
ILGIC Payoffs with a 20% Cap Rate

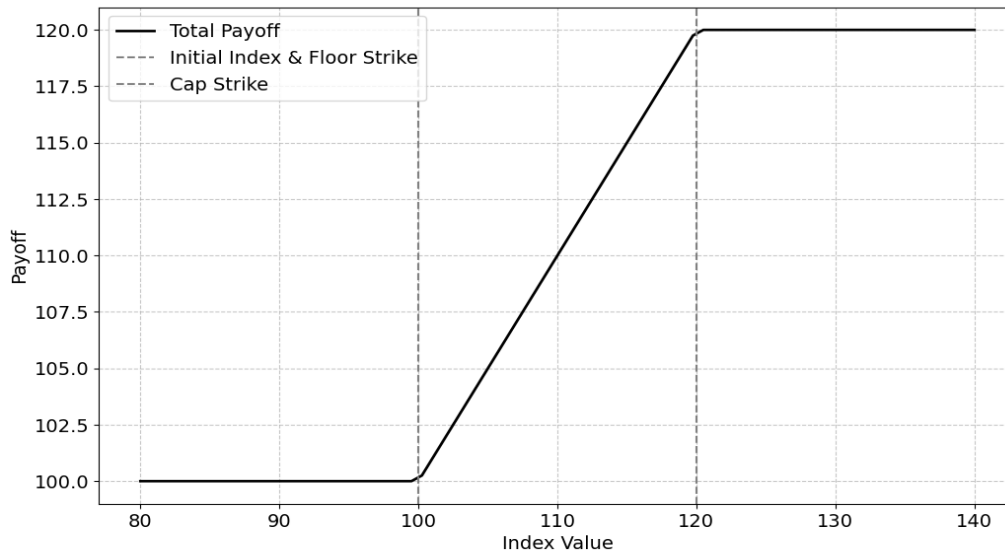
	Index Start Level	Index End Level	Index Return	ILGIC Return	ILGIC Payoff
Scenario 1	100	85	-15%	0%	\$100
Scenario 2	100	110	10%	10%	\$110
Scenario 3	100	130	30%	20%	\$120

For simplicity, we assume the initial value of the underlying index is 100. When the index yields a return less than or equal to zero, as in Scenario 1, the ILGIC return is zero, and investors receive exactly \$100 at maturity. When the index return falls between 0% and the cap rate, for example, 20% in this case, the ILGIC return matches the index return. Finally, when the index return exceeds the cap rate, the ILGIC return is limited to the maximum payout of 20%. This payoff at maturity can be expressed as follows:

$$V_T = 100 + \max(S_T - 100, 0) - \max(S_T - 120, 0), \quad (1)$$

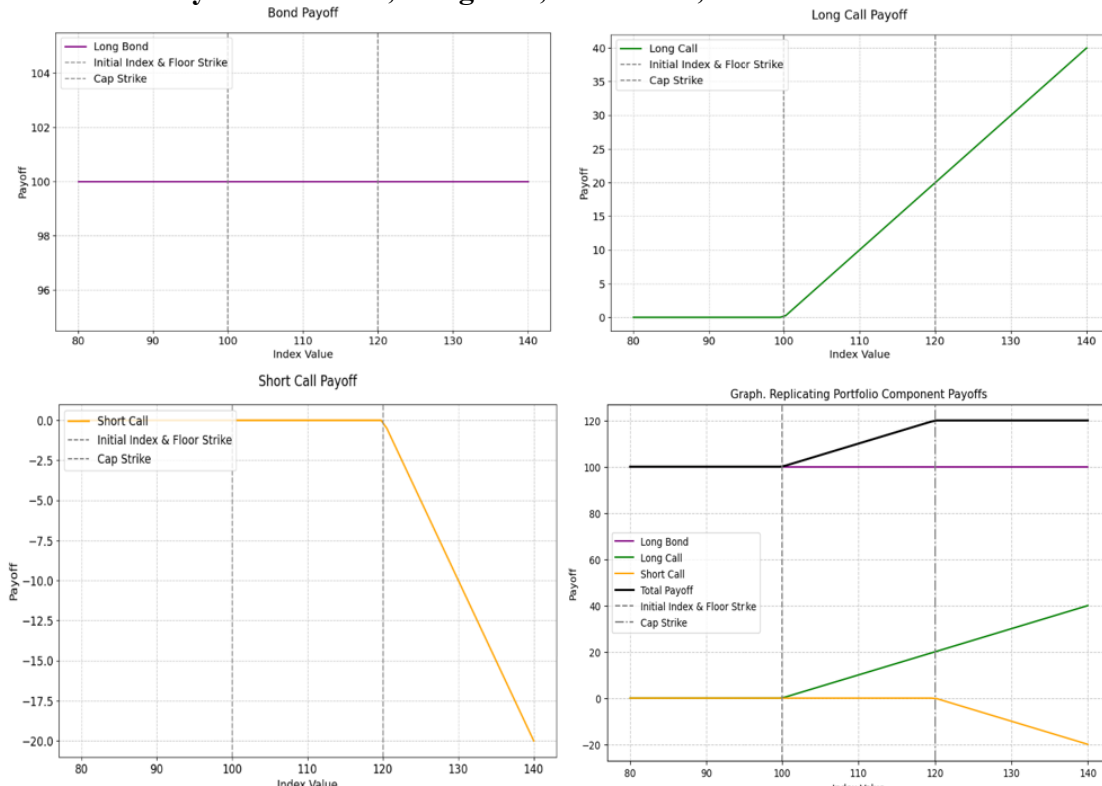
with V_T and S_T representing the terminal values of the ILGIC and the underlying stock index, respectively. Graphically, the ILGIC payoff resembles a flipped Z-shape, as illustrated in Figure 1.

Figure 1
ILGIC Payoff at Maturity
 Total Payoff



This Z-shaped payoff structure can be replicated using three components: purchasing a zero-coupon bond with a face value of \$100, buying a call option with an exercise price equivalent to the initial index value of \$100, and selling a call option with an exercise price of \$120. Their individual and combined payoffs are illustrated in Figure 2.

Figure 2
Payoffs for Bond, Long Call, Short Call, and All Combined



Valuing ILGIC with the Option Pricing Model

After establishing the fact that the capped ILGIC can be replicated using a bond and a bull call spread, we follow the literature to value this product (Deng, Dulaney, et al., 2014; Hernández et al., 2011; Milevsky & Kim, 1997) using the Black-Scholes-Merton option pricing model (Black & Scholes, 1973; Merton, 1973).

Black-Scholes-Merton's Model

Suppose an investor purchases $\$P$ of a capped ILGIC at $t=0$, when the initial level of the underlying index is S_0 . Such an ILGIC doesn't generate any cash flow until maturity, $t=T$. At that time, if the terminal level of the index, i.e. S_T , is below the initial level, S_0 , the investor receives $\$P$, as the principal is guaranteed. If S_T exceeds S_0 but the return is below the predetermined cap rate, cap , the investor receives a total payment of $\$P \times \frac{S_T}{S_0}$. When the return surpasses the cap rate, the investor receives $\$P \times (1 + cap)$. The terminal value of this capped ILGIC, V_T , can be summarized as follows:

$$V_T = \begin{cases} P, & \text{if } S_T \leq S_0 \\ P + \frac{P}{S_0}(S_T - S_0), & \text{if } S_0 < S_T \leq S_0(1 + cap) \\ P + \frac{P}{S_0}(S_T - S_0) - \frac{P}{S_0}(S_T - S_0(1 + cap)), & \text{if } S_T > S_0(1 + cap) \end{cases}$$

$$= P + \frac{P}{S_0} \max(S_T - S_0, 0) - \frac{P}{S_0} \max(S_T - S_0(1 + cap), 0). \quad (2)$$

The payoff function of the capped ILGIC is a combination of the following three components, i.e., a zero-coupon bond with a face value of $\$P$, a long position with $\frac{P}{S_0}$ units of call options C_1 , and a short position with $\frac{P}{S_0}$ units of call options C_2 . Consequently, the value of such a position at $t=0$ is equivalent to the cost of the replication portfolio such that

$$V_0 = P e^{-r_f T} + \frac{P}{S_0} C_1(S_0, S_0, r_f, q, T, \sigma) - \frac{P}{S_0} C_2(S_0, S_0(1 + cap), r_f, q, T, \sigma). \quad (3)$$

The six parameters in the parentheses represent the six variables in European call options on a dividend-paying asset. The long call C_1 has an exercise price equivalent to the initial value of the underlying index S_0 . The short call C_2 has an exercise price of $S_0(1 + cap)$. In addition to the individual exercise prices, the two call options are linked to the same underlying index and share the same parameters, including the risk-free rate, the dividend yield, the maturity, and the standard deviation of the underlying stock index, denoted by r_f, q, T , and σ , respectively.

With the function $N()$ representing the cumulative probability distribution function for the standard normal random variable, the two call options can be further expressed as follows:

$$C_1 = S_0 e^{-qT} N(d_1) - S_0 e^{-r_f T} N(d_2),$$

$$d_1 = \frac{(r_f - q + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}}, \quad (4)$$

and $d_2 = d_1 - \sigma\sqrt{T}$.

$$C_2 = S_0 e^{-qT} N(d_3) - S_0(1 + cap) e^{-r_f T} N(d_4), \quad (5)$$

$$d_3 = \frac{-\ln(1+cap) + (r_f - q + \frac{\sigma^2}{2})T}{\sigma\sqrt{T}},$$

and $d_4 = d_3 - \sigma\sqrt{T}$.

Applying Equations (4) and (5), the initial value of the capped ILGIC, i.e., V_0 , can be rewritten as:

$$V_0 = P e^{-r_f T} + P e^{-qT} N(d_1) - P e^{-r_f T} N(d_2) - P e^{-qT} N(d_3) + P(1 + cap) e^{-r_f T} N(d_4). \quad (6)$$

V_0 is independent of the starting level of the underlying index as long as the maximum return of the product, i.e. cap , is proportional to S_0 . Thus, the initial value to price ratio, $\frac{V_0}{P}$, is equivalent to

$$\frac{V_0}{P} = e^{-r_f T} + e^{-qT} N(d_1) - e^{-r_f T} N(d_2) - e^{-qT} N(d_3) + (1 + cap) e^{-r_f T} N(d_4). \quad (7)$$

A Real-world Example

With a foundational understanding of the Black-Scholes-Merton option pricing model, students can value a capped ILGIC using a closed-form solution. In this section, we apply the valuation framework introduced earlier to a real-world example.

On February 3, 2012, the Canadian Imperial Bank of Commerce (CIBC) issued a Canadian Market Return GIC, which matured five years later on February 3, 2017. This product guaranteed the return of the full principal amount at maturity and included a variable return component linked to the performance of the S&P/TSX 60 Index. The index return was computed based on the index level at issuance and at maturity, excluding any dividend yield from the underlying securities. On the issue date, the index closing price was 716.41. The ILGIC featured a capped return of 20% over the five-year term. Further details, including the product overview and offering documents, are available at: <https://notes.cibc.com/#/productdetail/1000570>.

We assign the following values to the parameters when applying Equations (6) and (7). The risk-free interest rate r_f is set to 1.50%, which was the 5-year benchmark bond yield on Government of Canada bonds in early 2012. The volatility σ is set to 15%, the standard deviation derived from the S&P/TSX 60 VIX index on the issue date. The dividend yield is set to 2.82%, equal to the dividend yield of S&P/TSX 60 in December 2011. The time to expiration in years, T , is five years, consistent with the offering information. The maximum return of this product is capped at 20%.

Implementing the option pricing model in Excel is relatively straightforward. The Excel function NORM.S.DIST can be used to compute the cumulative standard normal distribution, which is required in Equations (6) and (7). Table 2 summarizes the inputs and outputs for this numerical example.

Table 2
Inputs and Outputs in the Option Pricing Model

Inputs		Outputs	
r_f	1.50%	d1	-0.0291
q	2.82%	d2	-0.3645
σ	15%	d3	-0.5726
T	5	d4	-0.9081
cap	20%	V_0	97.6386
P	100	V_0/P	0.9764

Our analysis indicates that the fair value of the capped ILGIC on the issue date is 97.64% of its face value. This implies a hidden expense ratio of 2.36% for investors purchasing the product. In other words, when financial institutions sell the capped ILGIC to investors at \$100 and simultaneously construct the synthetic portfolio using bonds and calls, they effectively generate an arbitrage profit of \$2.36 per unit. This finding aligns with prior literature (Deng, Dulaney, et al., 2014; Milevsky & Kim, 1997), reinforcing the conclusion that ILGICs tend to be overpriced products designed for issuers at the expense of investors.

A Spreadsheet-based Approach

While the option pricing model provides a convenient method for valuing capped ILGICs, students may struggle to grasp the valuation process intuitively. To address this challenge, we present an alternative approach using spreadsheet-based simulations. Since the payoff of the ILGIC is contingent on the performance of the underlying stock index, simulating the index's price paths allows us to calculate the corresponding payoff for each scenario at maturity. By averaging these simulated payoffs and discounting the result back to the present, we obtain the fair value of the ILGIC at the issue date. This simulation-based method offers a more visual and hands-on understanding of the product's valuation.

Simulated Index Prices

Following the literature (Cox, 1977), we assume the underlying index prices follow a generalized Wiener process, also known as geometric Brownian motion. The natural logarithm of the index price also follows a generalized Wiener process such that

$$d \ln S = \left(\mu - \frac{\sigma^2}{2} \right) dt + \sigma dz, \quad (8)$$

where S stands for the index price, μ for the fixed drift, and σ for the volatility. t is time, and $dz = \epsilon \sqrt{dt}$, where ϵ is a random drawing from a standard normal distribution. Furthermore,

$$S_T = S_0 e^{\left(\mu - \frac{\sigma^2}{2} \right) T + \sigma \epsilon \sqrt{T}}, \quad (9)$$

where S_0 and S_T denote the index prices at time 0 and T , respectively.

We must transform the continuous-time to the discrete-time setting to simulate the underlying index prices. We intend to simulate the index prices for each trading day. If we further denote n as

the number of trading days in a year, we can connect the simulated index price on trading day $t + 1$ with the price of the day before using the following expression

$$S_{t+1} = S_t e^{\left(\mu - \frac{\sigma^2}{2}\right) \frac{1}{n} + \frac{\sigma}{\sqrt{n}} \epsilon} \quad (10)$$

As a result, the expected index price at maturity T becomes

$$E(S_T) = S_0 e^{\mu T} \quad (11)$$

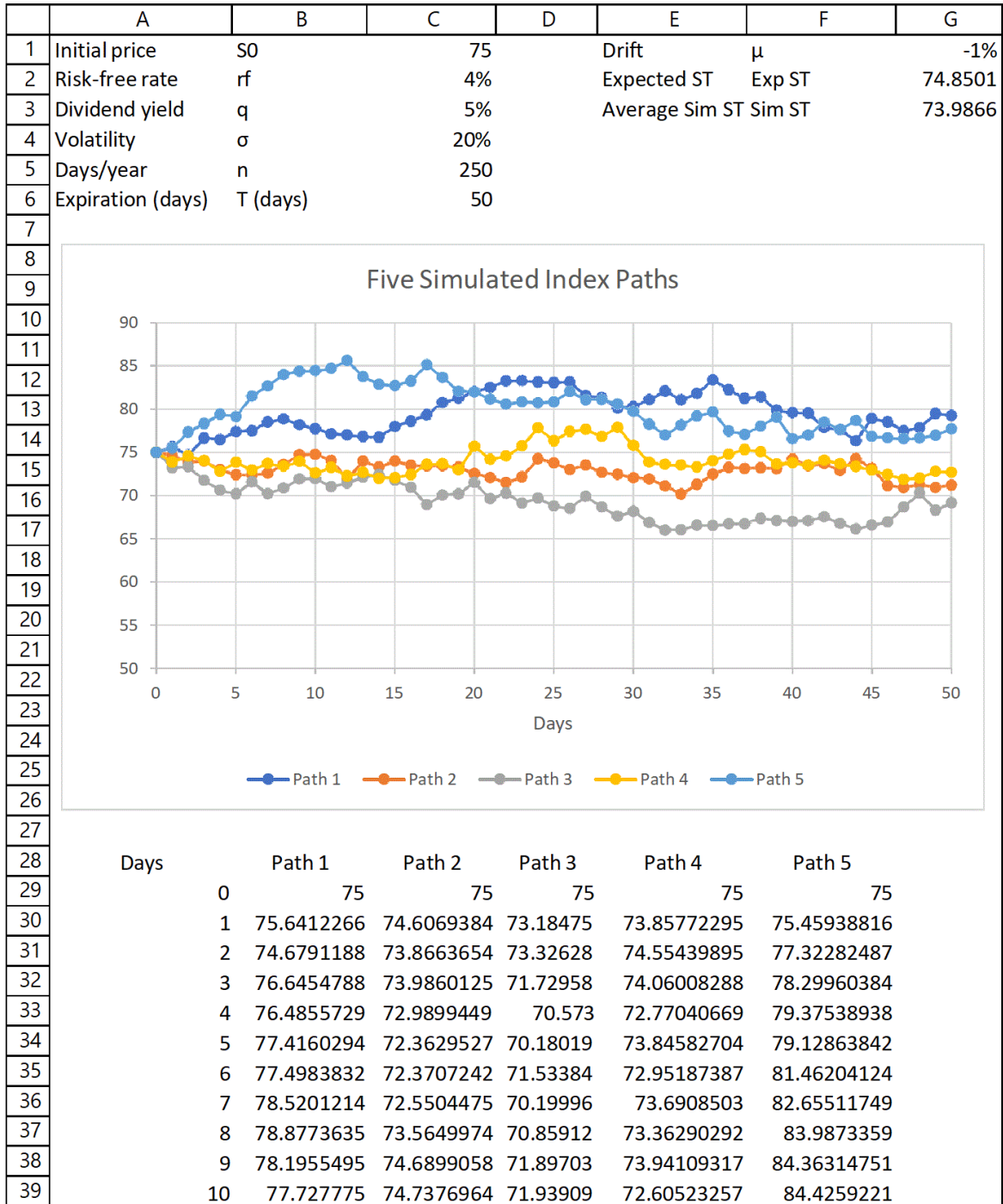
Since the ILGIC has embedded option features, we follow the Black-Scholes-Merton model to value the underlying index in a risk-neutral world, as Deng, Husson, et al. (2014). With r_f and q denoting the annualized risk-free rate and dividend yield, respectively, the drift term μ becomes $r_f - q$.

Figure 3 displays five simulated stock paths. The initial index level is set to 75. The annualized risk-free rate, dividend yield, and volatility are set to 4%, 5%, and 20%, respectively. We assume 250 trading days a year, and each simulation path lasts 50 days. Following the risk-neutral perspective, the annualized drift is -1%. The expected index price in 50 days, based on Equation (11), is estimated to be 74.8501, which is reported in Cell G2.

The daily simulated index prices are displayed in Rows 30 to 79, with Rows 40 to 79 trimmed in Figure 3 to save space. Each daily price is connected to the previous day's price following Equation (10). For example, the Day 1 index price of Path 1 in Cell B30 is set to $B29 * \text{EXP}((\mu - \sigma^2/2)/n + \sigma/n^{0.5} * \text{NORM.S.INV}(\text{RAND}()))$. The Excel function $\text{RAND}()$ creates a random draw from a uniform distribution between 0 and 1. Combined with the Excel function $\text{NORM.S.INV}()$, they will return the inverse of the cumulative standard normal distribution, capturing ϵ in Equation (10). As a result, each day's index price is a random walk from the previous day, and all five simulated index paths wind along all 50 days distinctively. The graph inserted in Rows 8 to 26 depicts the five simulated paths, which reveal the randomness in the underlying index movements.

The results presented in Figure 3 help students visualize the behavior of simulated index prices. However, a simulation based on only five index paths is insufficient to produce convincing and unbiased results. Therefore, in the next section, we develop a Monte Carlo simulation with 5,000 paths using Excel. Our approach avoids the use of advanced macro or VBA, making it accessible to students with basic Excel skills and allowing them to construct and explore Monte Carlo simulations independently.

Figure 3
Monte Carlo Simulation with Five Paths



Simulated ILGICs

Following the approach introduced in the previous section, we construct the simulated index paths and derive the corresponding payoffs for the ILGIC based on each simulated index path at

maturity. Let I represent the total number of paths, and i denote the i -th path. We rewrite the maturity payoff functions for the capped ILGIC in Equations (2) as follows:

$$V_T(i) = P + \frac{P}{S_0} \max(S_T(i) - S_0, 0) - \frac{P}{S_0} \max(S_T(i) - S_0(1 + cap), 0). \quad (12)$$

As a result, the fair value of the capped ILGIC at the issue date can be written as:

$$\text{and } V_0 = e^{-r_f T} \frac{\sum_{i=1}^I V_T(i)}{I}. \quad (13)$$

Figure 4 extends the previously explained index simulation over five years with 5,000 paths. To produce an alternative fair value for the ILGIC in the real-world example, we begin the simulation with the same set of parameters as in Table 2, including the risk-free rate, dividend yield, volatility, and maturity in years. Assuming 250 trading days a year, we simulate 1,250 daily index levels in each path. We set the initial price to the index level on the issue date, i.e. 716.41. To derive a comparable fair value estimate to the option pricing model, we follow the risk-neutral framework. Therefore, the drift value in the simulation is set to $r_f - q$, i.e., -1.32%.

Figure 4
Monte Carlo Simulation with 5000 Paths

	A	B	C	D	E	F	G	H
1	Initial price	S0	716.41		Drift	μ	-1.32%	
2	Risk-free rate	rf	1.5%		Expected ST	Exp ST	670.6535	
3	Dividend yield	q	2.82%		Average Sim	Sim ST	671.5342	
4	Volatility	σ	15%					
5	Days/year	n	250		Principal	P	100	
6	Expiration (days T (days)		1250		Cap rate	cap	20%	
7								
8								
9								
10	Day	Path 1		Path	Sim ST	Log Sim ST	VT	
11		0	716.41	1	904.232416	6.807086	126.217168	
12		1	714.285486	2	532.247458	6.277109	100	
13		2	715.231166	3	555.928411	6.32064	100	
14		3	709.708599	4	555.122142	6.319188	100	
15		4	718.069871	5	453.847702	6.117762	100	
16		5	725.449182	6	941.954903	6.847957	131.482657	
17		6	715.47634	7	531.093606	6.274938	100	
18		7	726.782788	8	521.491043	6.256692	100	
19		8	726.032841	9	816.370682	6.704869	113.952999	
20		9	713.36032	10	871.823245	6.770587	121.693338	
21		10	710.739965	11	481.279074	6.176447	100	

Cell B11 is the starting point of the simulated Path 1. From B12 to B1261, each daily price is generated based on the previous day's price following Equation (10). The simulated index price at maturity in the first path is reported in Cell B1261. Figure 4 truncates the spreadsheet beyond Row 21 to conserve space. Next, in Cells D11:D5010, we use Fill Series to generate path numbers 1 to 5,000 automatically. Since the payoff of the capped ILGIC only depends on the simulated index

price at maturity, we skip reporting daily index levels for the remaining 4,999 paths and only log the maturity index prices in Cells E12:E5010.

Generating the maturity index price for each of the 5,000 simulated paths can be a daunting task and often involves advanced Excel techniques such as macros or VBA. To simplify this process, we introduce an efficient and accessible approach that leverages Excel's *Data Table* function to automatically retrieve the final simulated index price along each path in a single column. Specifically, we highlight the range from Cells D11 to E5010, where Column D lists the 5,000 path numbers, and Cell E11 is set equal to Cell B1261, which references the simulated maturity index price from the first path. Next, we open the *Data Table* function under the *What-if Analysis* tab. In the pop-up window, we leave the *Row input cell* blank and enter an unused (empty) cell, e.g. Cell C11, into the *Column input cell*. Using a blank input cell prompts Excel to recalculate a new trial value for each row, filling in the results sequentially down Column E. After several minutes of processing, all 4,999 additional simulated maturity index prices will populate Column E. The average of the 5,000 simulated index prices at maturity is displayed in Cell G3, which closely approximates the expected index value at maturity, shown in Cell G2 and estimated using Equation (11).

For each simulated index price listed in Column E, we calculate the corresponding natural logarithm and record the 5,000 log-transformed values in F11:F5010. Next, we compute the payoffs of the capped ILGIC following Equations (12) and list them in G11: G5010. Finally, applying Equation (13), we find the fair value of the capped ILGIC at the issue date to be \$97.65 per \$100 face value, based on this specific set of 5,000 simulated paths. The simulation-based estimate is remarkably close to the option pricing value reported in Table 2. Moreover, this alternative valuation reinforces the conclusion that capped ILGICs are structured to benefit the issuers, often at the expense of the investors.

Further Analysis

Beyond providing a point-estimate valuation, the simulation approach generates a rich set of scenarios that allow for a deeper exploration of the payoff possibilities of this complex financial product. Table 3 presents the summary statistics, while Figure 5 illustrates the distribution of outcomes based on the 5,000 simulated paths generated in the previous section.

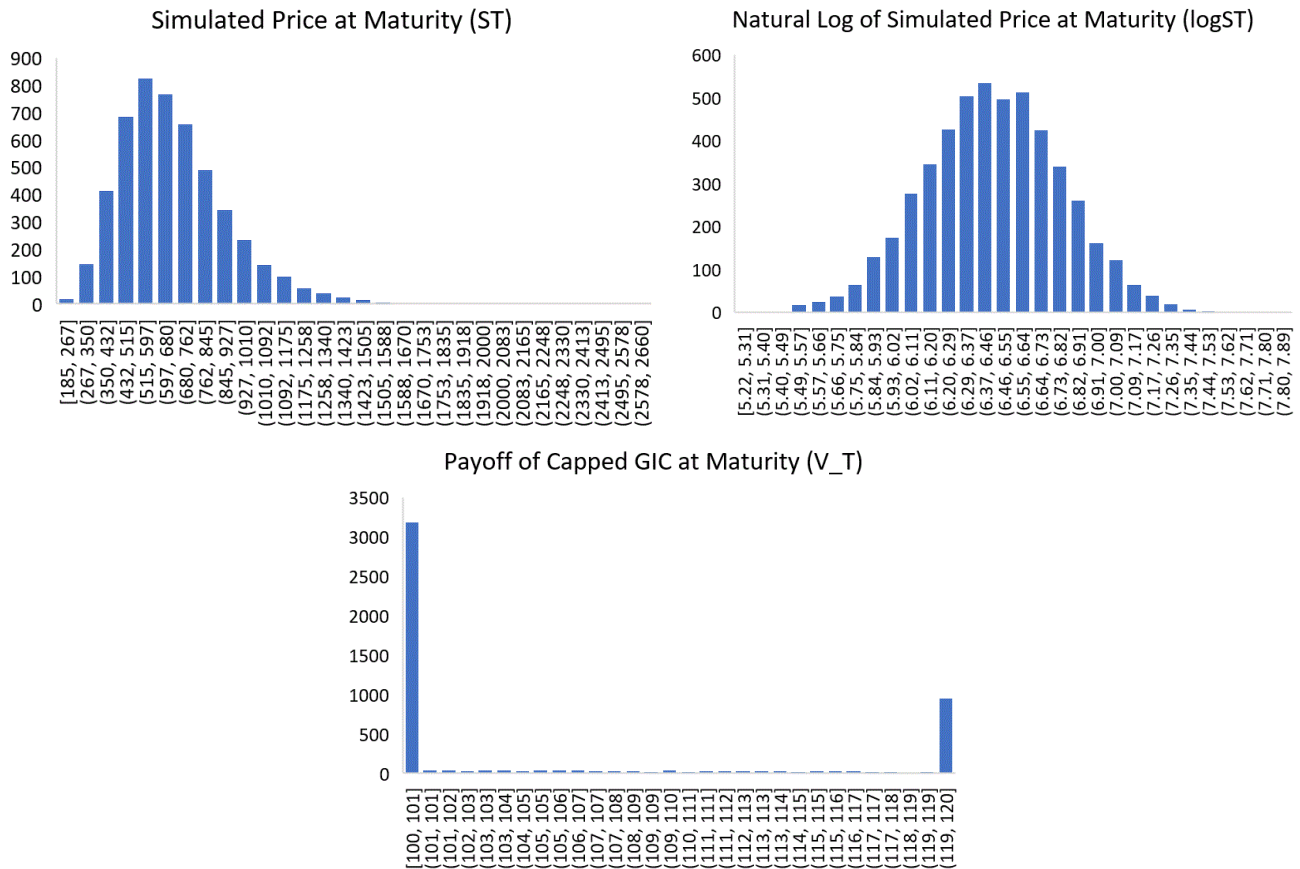
Table 3
Summary Statistics of Simulated ILGIC Payoffs

	Sim ST	Log Sim ST	VT
N	5000	5000	5000
Mean	671.53	6.46	105.21
Stdev	225.66	0.33	8.10
Skewness	1.06	-0.06	1.09
Kurtosis	13.54	0.10	-0.65
Max	2284.74	7.73	120.00
75%	796.36	6.68	111.16
Median	641.85	6.46	100.00
25%	512.33	6.24	100.00
Min	201.03	5.30	100.00
% with 100			64.72%
% with 120			17.96%

Columns 2 and 3 of Table 3 present the statistics of the simulated index prices at maturity and their natural logarithm. The distribution of the simulated index prices is far from being normally distributed. With skewness of 1.06 and kurtosis of 13.54, the distribution is positively skewed and contains heavy tails. Conversely, the natural logarithm-transformed index prices have skewness and kurtosis close to zero, indicating a symmetric distribution and thinner tails. The first two histograms in Figure 5 are consistent with Table 3. The graph for the simulated index prices displays asymmetry and fat tails, while the graph for the log value of the index prices resembles a symmetric bell-curved shape.

The last column of Table 3 shows that the average payoff of the simulated ILGIC at maturity is \$105.21 under a risk-neutral framework. Investors receive the minimum payoff of \$100 in 64.72% of the simulations. In 17.96% of the cases, returns are capped at the maximum 20% rate, while in the remaining 17.32%, investor returns fall between 0% and 20%. The final histogram in Figure 5 visually reinforces these findings, featuring two distinct spikes with one on each side. Together, these simulated results provide students with a more comprehensive understanding of the capped ILGICs. While the product guarantees principal protection, it does so at the expense of limiting upside potential beyond the capped rate.

Figure 5
Histograms of Simulated Prices and Payoffs



In addition to analyzing valuation and projecting payoff distributions ex-ante, students can also be guided to evaluate the actual return performance of this ILGIC over the five-year term in comparison with alternative investment products. During the holding period from 2012 to 2017, the underlying index, S&P/TSX 60, rose from 716.41 to 913.38, reflecting a price return of 27.49%, or an average annualized return of 4.98%. Moreover, the index generated a substantial dividend yield over the same period, which contributed to a total holding period return of 48.37%, equivalent to an annual total return of 8.21%.

Since the linked index delivered a price return exceeding the capped rate, and ILGIC investors were not entitled to receive the dividend yield, their total return was limited to 20% over the five-year period, equivalent to an annualized return of 3.71%. In comparison, a standard GIC during the same period offered an average annual return of 1.85%. While the ILGIC outperformed the standard GIC, its return was significantly lower than that of the underlying index, which achieved a total annual return of 8.21%. Given that the standard GIC is a risk-free investment and the S&P/TSX 60 index is subject to the higher volatility typical of equity markets, the capped ILGIC represents a middle-ground investment in terms of both risk and return. However, it offers limited diversification benefits. As such, this structured product may be suitable for certain investors whose risk-return preferences align with the characteristics of a principal-protected, equity-linked instrument.

Pedagogical Discussions

ILGICs are widely available financial instruments offered by banks to retail investors. However, their option-like payoff structures present challenges for instructors introducing these products to students. The spreadsheet-based simulation approach presented in this paper offers an effective pedagogical tool to enhance student learning of this complex financial product. This approach is well-suited for both Personal Finance and Financial Derivatives courses at the undergraduate level, particularly after students have been introduced to fundamental financial topics such as the time value of money, the characteristics of European options, and option strategies including covered calls and bull spreads. An additional prerequisite is that students possess basic proficiency in Excel.

One of the co-authors has implemented this approach in his undergraduate Personal Finance course when introducing ILGICs as a retail investment product. Students are required to complete a pre-lecture quiz consisting of multiple-choice questions that focus on the product's payoff structure and the factors influencing the profitability of financial institutions and the returns on investment. Following the lecture, students complete a similar post-test. They are also asked to evaluate which method—the analytical option pricing model or the spreadsheet-based simulation approach—better supports their understanding of the topic. The post-test results and student feedback indicate that the simulation approach is an effective pedagogical tool, helping students grasp the mechanics of ILGICs without requiring deep engagement with complex analytical models. Furthermore, this simulation-based approach can be equally valuable in a Financial Derivatives course. While the Black-Scholes-Merton model faces limitations in pricing exotic options such as path-dependent Asian options and digital options, the simulation method can be adapted to offer a practical alternative for these cases.

In summary, the spreadsheet-based simulation approach enables the instructors to achieve the following learning objectives:

- Understand the structure and payoff of complex financial products such as ILGIC,
- Apply the practical tools to model and analyze the dynamics of basic options and complex option portfolios,
- Bridge conceptual understanding and technical skills without relying solely on analytical pricing models,
- Assess practical financial products in a retail personal finance setting, and
- Understand the key design parameters of financial products that influence the profitability of financial institutions.

The simulation exercises described in earlier sections can be modified and extended in various ways. Below, we offer two sample exercises suitable for classroom discussions or student assessments in Personal Finance or Financial Derivatives courses. Spreadsheet-based solutions are available upon request.

Sample Exercise 1 - Design a Capped ILGIC for ABC Bank

You are employed by ABC Bank and tasked with designing a pay-at-maturity ILGIC to be issued next month. This product will offer full principal protection and a maximum return capped at 30% over the entire investment period. You may choose to issue a one-year, three-year, or five-year note. The risk-free interest rate is 2.75%, and the term structure is flat. Each note will have a

face value of \$10,000. You also have the option to link the ILGIC to one of four underlying assets. The characteristics of these assets are summarized in the table below.

Asset	Standard Deviation	Dividend Yield
S&P 500	19.40%	1.47%
S&P TSX 60	14.30%	3.62%
S&P TSX Capped Financials	14.50%	4.64%
Shopify	55.50%	0.00%

Construct a capped ILGIC for ABC Bank that would appeal to a conservative retail investor. Justify your selection of the underlying asset and the chosen note characteristics. Calculate the bank's profit from issuing this product, based on your design.

Sample Exercise 2 - Advising Seniors on a Participating ILGIC

It is January 3, 2025. Your grandmother is 70 years old and uses her investment income to supplement her pension income. She has previously invested in actively managed equity mutual funds and GICs. Your grandmother is considering purchasing an ILGIC product offered by XYZ Bank, and you—having recently studied various financial products in your Personal Finance course—offer to provide a second opinion. This ILGIC offers a fixed annual coupon rate of 0.5% over a 3-year term, along with full principal protection at maturity. Additionally, it enables investors to benefit from potential stock market gains by offering a variable interest component equivalent to 40% of the price return of an equally weighted portfolio of six Canadian stocks over a 3-year period. No variable interest will be paid unless the portfolio return is positive. The six stocks included in the portfolio are: Bank of Nova Scotia (TSX: BNS), BCE Inc. (TSX: BCE), Bank of Montreal (TSX: BMO), Emera Inc. (TSX: EMA), Power Corporation of Canada (TSX: POW), and Royal Bank of Canada (TSX: RY).

You notice that the six selected stocks forming the underlying portfolio are heavily concentrated in regulated industries and high-dividend-yield businesses. Recalling a key point from your Personal Finance course, you remember your instructor emphasizing that one of the major shortcomings of ILGICs is that investors are not entitled to the dividend income generated by the underlying assets. Additionally, you observe that a regular GIC offered over the same 3-year term provides a fixed return of 3%.

Explain to your grandmother the costs and benefits of investing in this participating ILGIC. Collect the monthly price return and total return data for the six underlying stocks over the past ten years, and calculate their historical volatility and average dividend yield. Based on your analysis, identify the hidden costs associated with this ILGIC. In addition to the guaranteed coupon rate and principal protection, what are the other benefits of investing in the ILGIC? Why is it unlikely that XYZ Bank would offer a plain vanilla ILGIC without a return cap and a 100% participation rate? Finally, recommend alternative investment options your grandmother could consider, taking into account her financial goals and risk tolerance.

Conclusion

In this paper, we introduce students to a complex yet popular financial product offered to retail clients by most financial institutions, i.e. Index-linked Guaranteed Investment Certificates. While

issuers promote ILGICs as providing principal protection along with the opportunity to benefit from rising equity markets, our analysis demonstrates that a typical capped ILGIC is an overpriced financial product.

Using the option pricing model, we first present a convenient closed-form solution for valuating ILGICs, which reveals that typical capped ILGICs are structured to favour the issuers. To enhance students' understanding of this product, we adopt a spreadsheet-based approach featuring Monte Carlo simulations, which further confirms the overpricing of capped ILGICs. Moreover, the simulation results enable students to visualize the distribution of potential payoffs. Given that the payoff function deviates significantly from a normal distribution, the resulting histogram offers valuable insights that can support more informed investment decision-making.

A key advantage of the spreadsheet-based approach is that it does not require advanced programming techniques such as VBA or macros. Instead, we leverage Excel's *What-If Analysis* tool to drive the simulation, making the method accessible to students with basic-level Excel skills. Moreover, this approach is highly versatile and can be adapted to value other ILGIC structures with more complex, path-dependent payoffs, such as average return ILGICs or contingent multiple-coupon ILGICs.

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A Choice Algorithm for Teaching Capital Structure Using Constrained Optimization

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This paper presents an adaptive linear programming model that utilizes Excel's 'Solver' function to optimize a company's level of debt using Standard and Poor's published median financial ratios by debt rating. Simple capital structure problems usually focus on a single ratio, such as interest coverage, and back solve for debt. This paper proposes a linear programming model to optimize these problems using multiple constraints. Teaching of this model is not explained in undergraduate and graduate corporate finance texts. The model explained in this paper is a simple, adaptable, and highly effective tool that can be used by both industry professionals and as a pedagogical aid to help students understand optimal capital structure and constrained optimization. This paper advances the pedagogical literature by offering a detailed Excel walkthrough using 'Solver.'

Key Words: Pedagogy, Capital Structure, Debt, Excel, Solver, Financial Modeling Pedagogical Tools

Introduction

The capital structure decision involves the selection and determination of sources and mix of debt and equity capital. This concept is one of the fundamental decisions of financial managers and is covered in every introduction to finance and corporate finance textbook (Benninga, 2008; Holden, 2012). Among the topics included in the teaching of capital structure are homemade leverage, the debt tax shield, bankruptcy costs, and firm valuation. The choice of sources and amounts of funding, or the cost of capital, is commonly called the capital structure decision (Modigliani & Miller, 1958). It serves as a cornerstone for understanding how firms balance risk and return to maximize shareholder value. The ability to optimize this balance is critical, as poor capital structure decisions can increase financial risk and reduce a firm's overall value.

This paper presents a simple linear programming model in Excel that can be used to solve single-period constrained optimization problems related to capital structure. Given information about cost of interest, EBIT, Depreciation, FCF, Market Value of Equity, and Sales, this model will select the optimal amount of debt that can be utilized at each Standard and Poor's (S&P) debt rating without falling below the median financial ratio for firms at that rating. Standard and Poor's regularly releases the Corporate Ratings Criteria which among other things explains how bonds are rated, and what ratios are considered, and their median values across firms at each rating. By simulating real-world conditions, this model provides students with a practical tool for understanding the complexities of capital structure decisions.

Teaching capital structure using this model as a pedagogical tool aligns with existing theory that interactive and complex decision making, encourages critical thinking, and provides a

platform for cost/benefit analysis. The model presented herein can be used as a companion to capital structure cases such as the Deluxe case in Bruner et. al. (2014), or as a standalone model for constrained optimization of capital structure. The process presented in this paper would be appropriate for intermediate corporate finance, graduate finance and financial modeling courses. By requiring students to navigate multiple variables and constraints, the model replicates the real-world challenges financial managers face when balancing risk and return. Its step-by-step framework allows students to deconstruct complex problems, fostering both technical proficiency and strategic thinking. Furthermore, this hands-on approach promotes active learning, where students engage with financial data directly, enhancing their ability to draw meaningful insights and make informed decisions.

This paper is organized as follows. The literature review presents a brief summary of the benefits of active, problem-based learning and the application of Excel tools contained therein. The problem of capital structure and the traditional model is explained. A model for selecting optimal debt level using Excel's 'Solver' is presented as a pedagogical tool. Next, the application, implementation, and benefits of the model for Technology Enhanced Active Learning is discussed. Finally, the learning outcomes for corporate finance and financial modeling are examined and the paper concludes.

Literature review

Student engagement has long been shown to deepen learning, as evidenced by increased retention and improved academic performance on assessments (Carini, Kuh, & Klein, 2006). The positive relationship between student engagement in educationally purposeful activities and outcomes such as critical thinking, retention, and academic performance, as demonstrated by Carini, Kuh, and Klein (2006), underscores the value of incorporating interactive, applied learning methods into finance education. Prince (2004) provides a comprehensive review of active learning methods, demonstrating that approaches such as problem-based learning and collaborative exercises enhance critical thinking, engagement, and the ability to analyze complex scenarios, which are foundational to the pedagogical effectiveness of financial decision-making models. Research reviewed by Prince (2004) broadly supports the effectiveness of active and problem-based learning, highlighting their role in enhancing educational outcomes. Technology Enabled Active Learning (TEAL), as demonstrated by Hassana, Saifullizam, and Buhari (2015), has been shown to correlate positively with student understanding, creativity, and innovation. Introduced at the Massachusetts Institute of Technology (MIT) in 2003 by John Belcher, the TEAL format was designed to bring innovative teaching strategies into physics classes and foster active learning. Morrison and Long (2011) describe TEAL as an environment that seamlessly integrates lectures, simulations, and hands-on activities to create a dynamic learning experience.

Colby et al. (2011) emphasize the value of engaging business students in "multiple framing," a skill that encourages analytic thinking by approaching complex or ambiguous problems from different perspectives. The application of analytical thinking and scientific inquiry requires students to formulate and rigorously apply abstract concepts, underscoring the importance of integrating theory and practice. Active participation in methodologies such as those described in Prince (2004) significantly improves academic outcomes and equips students with the ability to address real-world challenges with adaptability and rigor. Existing studies demonstrate that collaborative and cooperative learning environments enhance critical thinking and problem-solving skills while promoting deeper retention of knowledge (Johnson, Johnson, & Smith, 1998a,

1998b). Techniques such as Technology-Enhanced Active Learning (TEAL) go further by creating experiential learning opportunities that foster collaboration, innovation, and the development of transferable skills, preparing students for professional success (Prince, 2004).

Benninga (2008) and Holden (2012) highlight the versatility of Excel as a tool for connecting financial theory with practical application, enabling students to better understand and apply abstract concepts in real-world scenarios. Expanding on these foundations, Zhang (2014) demonstrates how features like Data Tables, Charts, Scenario Manager, Goal Seek, and Solver can transform the teaching of introductory finance courses, leading to improved learning outcomes. Finley (2014) illustrates another powerful use of Excel by solving and simulating a discrete-time specification of the Life-Cycle/Permanent-Income Model of Consumption and Saving (LCPI Model), showcasing its utility for advanced quantitative modeling. Similarly, Jablonsky (2014) applies Excel's Solver to multiple criteria decision-making (MCDM) models, further emphasizing its potential across diverse applications.

In addition to facilitating complex problem-solving, Excel serves as a bridge between theoretical understanding and hands-on practice, especially in quantitative disciplines such as finance, computer science, and engineering. Active, problem-based learning environments that incorporate Excel not only boost student engagement but also develop critical thinking skills. By giving students the opportunity to work directly with financial data and optimization tools, these approaches ensure they are equipped with transferable, in-demand skills for both academic and professional success.

Optimal capital structure has been a central topic in corporate finance since the seminal work of Miller and Modigliani (1958), which introduced the foundational propositions of capital structure irrelevance under idealized market conditions. Over time, this framework has been expanded and refined, giving rise to leading theories that seek to explain the observed variations in firms' capital structures. The Static Trade-Off Theory, proposed by Myers (1984), emphasizes the balance between the tax benefits of debt and the costs of financial distress. The Pecking Order Theory suggests that firms prioritize funding sources based on information asymmetry, preferring internal financing over debt, and debt over equity. Additionally, Jensen's (1988) Free Cash Flow Hypothesis provides an agency cost perspective, arguing that debt can act as a disciplinary mechanism to reduce managerial inefficiencies.

From a modeling perspective, the capital structure puzzle—why firms choose specific combinations of debt and equity—can be framed as an optimization problem. The goal is to maximize the amount of debt, B , within the constraints imposed by tax benefits, financial distress costs, and other factors. The equations below illustrate this theoretical approach, capturing the trade-offs that firms must navigate to optimize their capital structure decisions. From a modelling standpoint the capital structure puzzle can be expressed as maximization of the amount of debt, B , in the equations below:

$$V_L = V_U + T_c B \quad (1)$$

Subject to

$$-\left[\sum_{j=0}^J x_j \right] \leq R_D T_c B \quad (2)$$

Where:

R_D = a fixed rate, “the cost of debt capital”;

x_j = costs related to financial distress and bankruptcy;
 T_c = the marginal corporate tax rate;
 B = the amount of total corporate debt

The model outlined above represents a simplified interpretation of the Static Trade-Off Theory, which suggests that a firm adds value as long as the annual tax shield from interest outweighs the annual costs of financial distress and bankruptcy. However, this static view does not fully capture the complexities of real-world decision-making. In practice, capital structure optimization is more appropriately analyzed as a present value problem. Even if the costs of financial distress exceed the benefits of the interest tax shield in a given year, the firm may still maximize value when viewed as a going concern over the long term. By assuming cash flows in perpetuity, the model simplifies these dynamics into a framework that balances short-term trade-offs with long-term value creation.

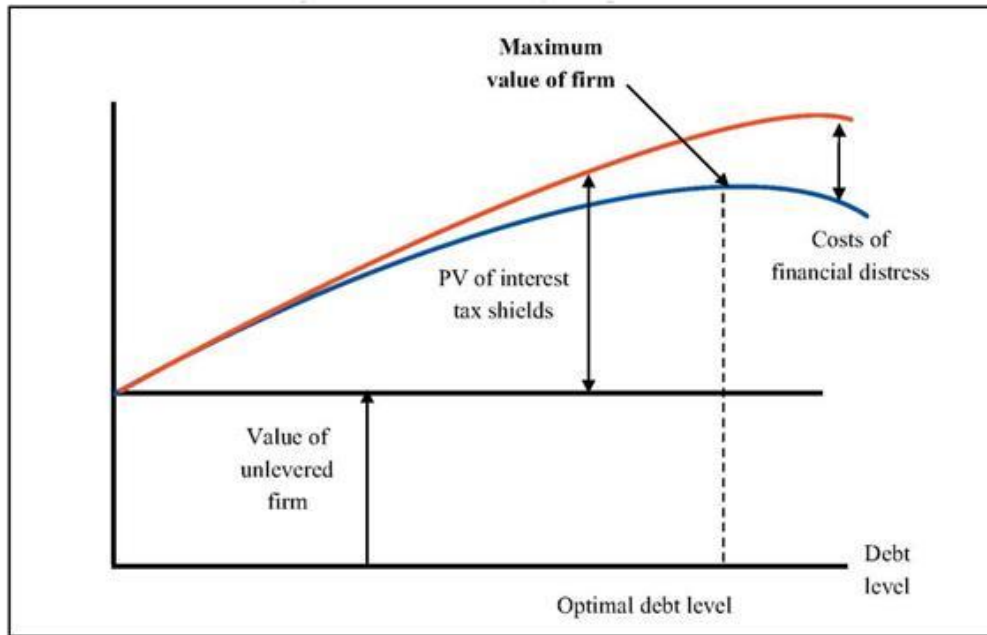
$$-\left[\sum_0^t \sum_0^j \frac{x_j}{(1 + R_D)} \right] \leq T_c B \quad (3)$$

Model Development

Practical examples that integrate theoretical concepts with quantitative analysis provide students with the tools to make informed and effective decisions, bridging the gap between classroom learning and real-world application. Leveraging spreadsheets such as Microsoft Excel and Google Sheets allows students to tackle more complex scenarios than those typically presented in introductory textbooks, while maintaining the material's accessibility and relevance. Most textbooks, however, tend to oversimplify capital structure concepts, stripping away the critical thinking challenges inherent to real-world decision-making. This simplification often overlooks the nuanced trade-offs and interdependencies present in financial management. Adding to the complexity is the fact that costs associated with financial distress—both direct, such as legal fees, and indirect, such as reputational damage—are inherently difficult to quantify, making the optimization process even more challenging for students to grasp. By employing dynamic spreadsheet models, educators can reintroduce these complexities in a manageable way, encouraging students to engage with the material at a deeper level.

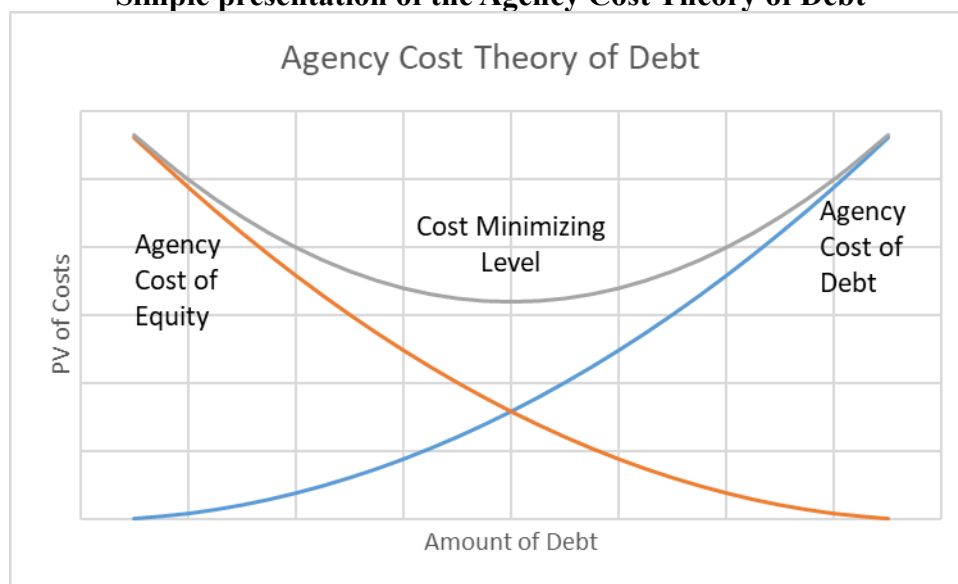
Figure 1 provides a simplified representation of the Static Trade-Off Theory, illustrating a clear maximum point for firm value where the benefits of the interest tax shield are optimally balanced against the costs of financial distress. While this graphical depiction offers a useful starting point for understanding the trade-offs in capital structure decisions, it does not fully account for the complexities of real-world scenarios. The costs of financial distress, which include both direct elements like legal fees and indirect factors such as reputational harm, are inherently difficult to measure. As a result, the precise value-maximizing amount of debt remains challenging to determine in practice. The second major framework for capital structure optimization, Agency Cost Theory, builds on these concepts by suggesting that the optimal debt level is found at the intersection of two opposing agency costs—those incurred by equity-holder and debt-holder conflicts. However, even within this framework, the issue of immeasurable costs continues to pose significant challenges for practical application.

Figure 1
Simple presentation of the Capital Structure Static Tradeoff



This paper introduces a simple Linear Programming Model (LPM) that incorporates real costs of debt and published median financial ratios from S&P rating criteria to determine the maximum amount of debt that can be sustained at a specific bond rating. By grounding the model in real-world data, it bridges theoretical concepts with practical application, offering a more tangible framework for understanding capital structure decisions. This approach aligns with foundational theories from Miller and Modigliani, adapting their principles to scenarios encountered in actual financial management.

Figure 2
Simple presentation of the Agency Cost Theory of Debt



Through this model, optimal capital structure is reframed as the selection of a debt level that minimizes the weighted average cost of capital (WACC) while adhering to creditworthiness constraints. The LPM not only highlights the trade-offs between tax benefits and financial stability but also provides a flexible tool for exploring various scenarios, such as changes in interest rates, firm-specific financial conditions, or broader economic trends. Extensions of the model could incorporate additional constraints, such as estimated costs of financial distress or agency costs, allowing students to explore the nuances of capital structure beyond the standard frameworks. Moreover, the model serves as a valuable teaching aid, enabling instructors to integrate data-driven insights into classroom discussions and equip students with skills directly applicable to corporate decision-making.

To construct a simple Linear Programming Model (LPM), it is essential to gather either existing or forecasted financial data to calculate the financial ratios required for optimization, as presented in Figure 3. This table provides a comprehensive overview of financial ratios categorized by S&P credit ratings, offering a benchmark for assessing a firm's creditworthiness. The median ratio for each category serves as a binding constraint in the model, ensuring that the proposed debt levels align with industry standards and maintain the desired credit rating.

By using these median ratios as constraints, the model not only reflects real-world financial practices but also encourages critical analysis of the interplay between a firm's financial health and its ability to sustain additional debt. Extensions of this framework could involve scenario analysis to evaluate how shifts in financial ratios—due to economic changes or internal company adjustments—affect the optimal debt level. This approach reinforces the importance of dynamic decision-making in capital structure optimization, allowing students and practitioners alike to explore the implications of varying financial strategies within a structured framework.

Figure 3
Key Industrial Financial Ratios by Rating Categories

Key Industrial Financial Ratios (Three-year medians 2000-2002)	Credit Rating					
	AAA	AA	A	BBB	BB	B
	Investment Grade			Non-investment Grade		
EBIT interest coverage (x)	23.4	13.3	6.3	3.9	2.2	1.0
EBITDA Interest coverage (x)	25.3	16.9	8.5	5.4	3.2	1.7
Funds from operations/total debt(%)	214.2	65.7	42.2	30.6	19.7	10.4
Free operating cash flow/total debt(%)	156.6	33.6	22.3	12.8	7.3	1.5
Return on capital(%)	35.0	26.6	18.1	13.1	11.5	8.0
Operating income/sales(%)	23.4	24.0	18.1	15.5	15.4	14.7
Long-term debt/capital(%)	(LI)	211.0	33.8	40.3	53.6	72.6
Total debt/capital, incl. short-term debt(%)	5.0	35.9	42.6	47.0	57.7	75.1

Standard & Poor's defined these ratios based on the book value of these items as follows:

EBIT interest coverage = EBIT/interest expense.

EBITDA Interest coverage = EBIT plus depreciation and amortization/interest expense

Long-term debt/capital = long-term debt/(long-term debt + stockholders' equity)

Total debt/capital, incl. short-term debt = (short-term debt + long-term debt)/(short-term debt + long-term debt + stockholders' equity)

Source of data: Standard & Poor's *Credi/Stats*.

Figure 4 introduces two additional columns, labeled ‘Firm Calculated’ and ‘Difference,’ to enhance the analysis of financial ratios across S&P rating categories. The ‘Firm Calculated’ column computes each ratio listed in Column A, utilizing firm-specific data alongside rating-specific yields on debt. This column provides a dynamic assessment of how the firm's financial metrics compare to industry standards. The ‘Difference’ column quantifies the margin of safety by calculating the gap between the firm’s calculated ratios and the corresponding median ratios published by S&P. This margin serves as a critical indicator of the firm’s capacity to sustain additional debt without compromising its credit rating.

To facilitate optimization, a calculated cell below the ‘Difference’ column employs the formula =MIN(E4:E10), identifying the most binding constraint among the firm’s financial ratios. This value ensures that any proposed debt level remains consistent with the firm’s weakest financial position relative to S&P benchmarks. This structured approach not only simplifies the optimization process but also highlights the importance of maintaining financial stability while pursuing value-maximizing capital structure decisions. Future extensions of this model could include sensitivity analysis, allowing users to evaluate how changes in financial inputs affect the binding constraint and, ultimately, the firm’s optimal debt level.

Figure 3
Model Set Up

	A	B	C	D	E
1		EBIT	Rating	Debt	Cost of Debt
2		200	AAA	100	0.055
3			S&P Median	Firm Calculated	Difference
4	EBIT interest coverage (x)	23.4		=B2/(D2*E2)	=D4-C4
5	EBITDA Interest coverage (x)	25.3			
6	Funds from operations/total debt (%)	214.2			
7	Free operating cash flow/total debt (%)	156.6			
8	Operating income/sales (%)	23.4			
9	Long-term debt/capital (%)	-1.1			
10	Total debt/capital, incl. short-term debt (%)	5			
11				Min	=MIN(E4:E10)

Solver Set-Up

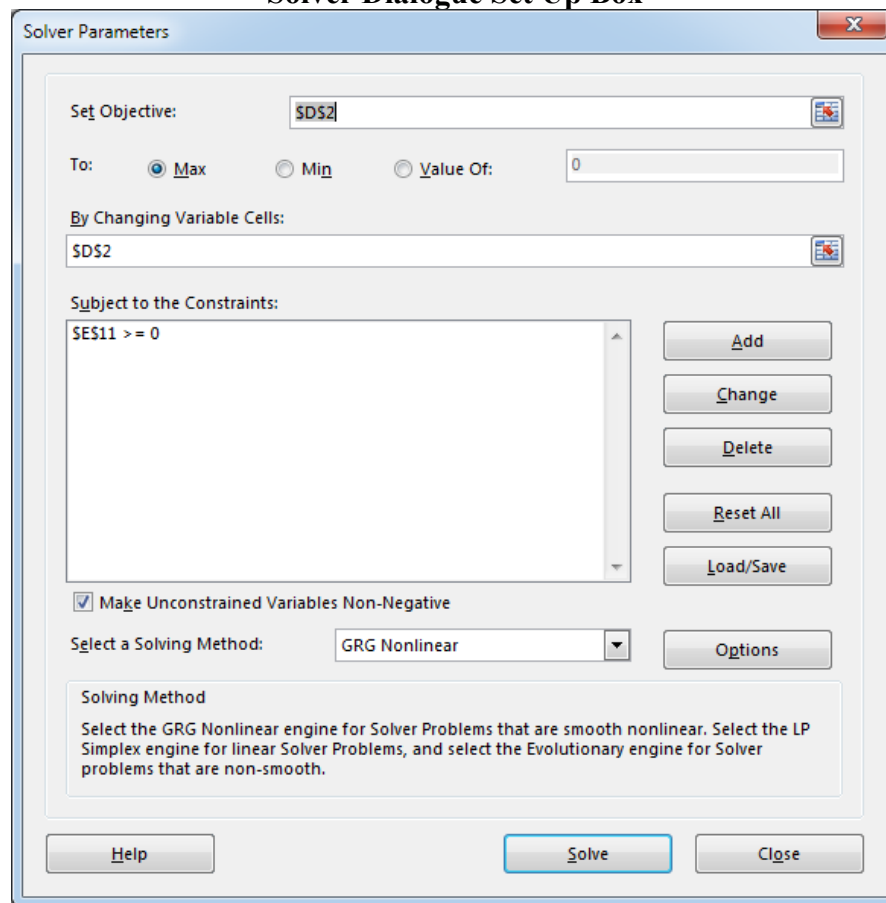
As described in Zhang (2014), the process begins by launching Excel’s ‘Solver’ tool, located within the Analysis group on the Data tab. This tool is used to define the objective and constraints, following the framework of a classic optimization problem. In this case, the primary objective is to maximize the amount of debt, in accordance with Miller and Modigliani’s Proposition I. To achieve this, both the ‘Set Objective’ and ‘By Changing Variable Cells’ fields in Solver must reference the worksheet cell dedicated to the amount of debt, identified as D2 in the figures presented.

Additional parameter constraints are critical to ensure the optimization adheres to real-world financial boundaries. These constraints will be discussed in detail in the subsequent technical explanation of Solver’s parameters. Initially, the first step involves selecting the debt cell (D2) as the target for optimization in the ‘Set Objective’ box and choosing the ‘Max’ radio button to

maximize the debt level. It is crucial that all objective and constraint cells depend on formulae tied to the relevant data inputs, ensuring the model dynamically adjusts as Solver iterates through potential solutions. By selecting the D2 cell in the 'By Changing Variable Cells' field, Solver can systematically adjust the debt level while maintaining compliance with financial constraints.

This setup ensures that Solver optimizes debt levels without allowing any of the firm's ratios to fall below the published S&P medians, preserving financial stability. Extensions to this approach could include incorporating additional constraints, such as a user-defined risk threshold or adjustments for projected financial conditions, making the model adaptable for more advanced analysis.

Figure 5
Solver Dialogue Set Up Box

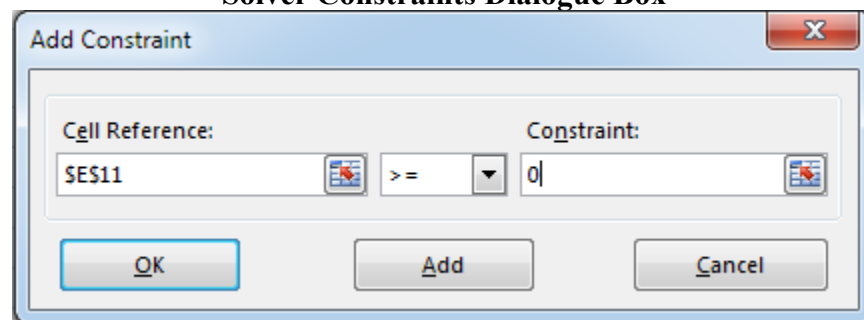


The next step involves defining the constraints, which are critical to ensuring the optimization respects the financial boundaries established by the model. These constraints are listed under the 'Subject to the Constraints:' heading in Solver. To add a constraint, click the 'Add' button, which will open a new dialogue box where the specific parameters can be defined. In the 'Add Constraint' dialogue box, the 'Cell Reference' field should point to the cell \$E\$11, which represents the minimum value from the 'Difference' column. This value serves as the most binding constraint, ensuring that none of the firm's financial ratios fall below the corresponding median ratio from the S&P rating criteria.

By selecting \$E\$11, Solver ensures that the optimization process adheres to the firm’s most vulnerable financial metric relative to the benchmark, preserving its credit rating at the target level. This constraint plays a vital role in aligning the model with real-world financial standards and reinforces the importance of maintaining financial stability while pursuing optimal debt levels.

For more advanced applications, additional constraints could be added to reflect dynamic conditions, such as projected changes in financial ratios or thresholds for specific risk levels. This flexibility allows the model to adapt to different scenarios, providing users with a powerful tool for exploring the complexities of capital structure optimization.

Figure 4
Solver Constraints Dialogue Box



Returning to the ‘Solver’ dialogue box, ensure that the “Make Unconstrained Variables Non-Negative” option is selected. This setting prevents the model from considering unrealistic negative values for debt or other financial variables. Next, choose the Simplex LP option from the ‘Select a Solving Method:’ drop-down menu. This method is well-suited for linear programming problems and ensures efficient computation of the optimal solution. Once these settings are configured, click ‘Solve’ to initiate the optimization process.

Solver will then iterate through potential solutions, adjusting the variables to meet the defined constraints and maximize the objective function. If a feasible solution exists, Solver will identify the optimal level of debt while ensuring that none of the firm’s financial ratios fall below the specified constraints. Alternatively, if no solution satisfies the constraints, a dialogue box will notify the user that a feasible solution cannot be found. This feedback is crucial, as it highlights potential inconsistencies in the model’s assumptions or input data, offering an opportunity for further refinement.

For more advanced scenarios, users can explore Solver’s sensitivity analysis options to better understand how variations in constraints or input values might affect the outcome, adding another layer of depth to the optimization process.

Figure 5
Results of Solver Optimization

	A	B	C	D	E
1		EBIT	Rating	Debt	Cost of Debt
2		<u>\$200.00</u>	<u>AAA</u>	\$ 155.40	5.5%
3			S&P Median	Firm Calculated	Difference
4	EBIT interest coverage (x)		23.40	23.40	0.00
5	EBITDA Interest coverage (x)		25.30		
6	Funds from operations/total debt (%)		214.20		
7	Free operating cash flow/total debt (%)		156.60		
8	Operating income/sales (%)		23.40		
9	Long-term debt/capital (%)		-1.10		
10	Total debt/capital, incl. short-term debt (%)		5.00		
11				Min	0.00

Teaching

Technology Enabled Active Learning (TEAL) requires that the integration of technology into the classroom produces learning outcomes that are more substantial, adaptable, and ultimately more effective than those achieved through traditional theoretical approaches. Teaching capital structure within this framework meets these criteria by leveraging technology to enhance student engagement and comprehension. The model presented not only bridges the gap between abstract financial theories and practical application but also serves as a catalyst for meaningful class discussions. By engaging with real-world scenarios and data, students are encouraged to explore the complexities of capital structure decisions in a dynamic and interactive manner.

Simulation of Complex Decision-Making: Real-World Constraints

The model integrates actual S&P median financial ratios as binding constraints, compelling students to assess the feasibility of capital structure decisions within realistic market conditions. This approach mirrors the challenges faced by financial managers, who must navigate the intricate balance between theoretical frameworks and practical limitations imposed by firm-specific factors and broader market dynamics (Holden, 2012). By incorporating critical financial metrics such as cost of debt, EBIT, and depreciation, the model creates a dynamic, data-driven environment that closely simulates professional decision-making processes.

This structure not only reinforces the practical relevance of capital structure theories but also encourages students to critically analyze how deviations from benchmark ratios might affect a firm's credit rating and overall financial health. Furthermore, it allows for scenario-based learning, where students can explore the impact of changing financial conditions, such as shifts in interest rates or market volatility, on the optimal debt level. In doing so, the model equips students with a deeper understanding of the interplay between financial theory and its application in complex, real-world contexts.

Dynamic Interaction of Variables

The model leverages Excel's Solver function to optimize debt levels while simultaneously considering the impacts on weighted average cost of capital (WACC), firm valuation, and financial ratios. This iterative process requires students to navigate the interplay between multiple variables, simulating the decision-making process in corporate finance (Zhang, 2014). Solver's optimization framework forces students to consider trade-offs and adjust inputs dynamically, reflecting the trial-and-error approach often used in real-world financial planning.

Encouragement of Critical Thinking: Evaluation of Trade-Offs

A central aspect of the model is its focus on evaluating the trade-offs between the tax advantages of debt and the potential costs associated with financial distress. By engaging with this framework, students are tasked with determining the tipping point where the marginal benefits of additional debt, such as enhanced tax shields, are outweighed by the risks of financial instability or default. This analytical process aligns their decision-making with foundational theories like Modigliani and Miller's propositions (1958) and the Static Trade-Off Theory (Myers, 1984), providing a robust theoretical foundation for their assessments.

Beyond the quantitative mechanics, the model challenges students to consider qualitative factors, such as market conditions, industry risk profiles, and a firm's strategic priorities, offering a more comprehensive perspective on capital structure optimization. This encourages students to move beyond formulaic calculations, fostering critical thinking and enabling them to approach capital structure decisions with a deeper, more nuanced understanding of the interplay between risk and value creation.

Scenario Analysis and Sensitivity Testing

The model is highly adaptable, allowing for extensions such as scenario analysis that enable students to investigate how variations in macroeconomic conditions or firm-specific assumptions—such as tax rates, interest rates, or market volatility—impact the optimal capital structure. By simulating these changes, students gain valuable insights into the dynamic nature of financial decision-making and the external factors influencing a firm's financial health. This hands-on approach not only fosters critical thinking but also trains students to evaluate the sensitivity of their results to varying inputs, enhancing their ability to identify key drivers of financial outcomes and assess the robustness of their conclusions (Benninga, 2008).

Additionally, these extensions provide opportunities for students to engage in stress-testing exercises, where they examine the resilience of a firm's capital structure under adverse economic scenarios. This process deepens their understanding of risk management and highlights the importance of flexibility in financial strategy. Through this iterative learning process, students develop analytical skills that are directly applicable to real-world challenges in financial analysis and corporate decision-making.

Platform for Cost-Benefit Analysis: Optimization Framework

The model's primary objective is to determine the optimal debt level that minimizes the weighted average cost of capital (WACC) while safeguarding the firm's financial stability. This

optimization framework seamlessly combines theoretical principles with practical quantitative analysis, requiring students to carefully balance the benefits of tax shields against the potential costs of financial distress. By leveraging Excel's Solver, students not only engage with the mechanics of optimization but also gain a deeper understanding of how theoretical models, such as those proposed by Modigliani and Miller (1958), translate into actionable financial strategies.

Through this process, students develop a nuanced appreciation for the trade-offs involved in capital structure decisions, including how changes in debt levels affect a firm's cost of equity, credit rating, and overall valuation. The use of Solver adds an experiential dimension to their learning, providing hands-on exposure to tools commonly used in professional financial analysis. Extensions of this framework could include sensitivity analysis, allowing students to explore how shifts in variables such as interest rates or tax policy influence the optimal capital structure, further enhancing their ability to apply these concepts in dynamic, real-world contexts.

Analysis of Financial Ratios

Incorporating financial ratios as constraints enables students to quantify the margin of safety between their firm's calculated ratios and the median ratios published by S&P. This approach provides a clear, data-driven framework for evaluating the feasibility of proposed debt levels and their alignment with industry benchmarks. By analyzing these margins of safety, students gain insights into the immediate benefits of increased debt capacity, such as enhanced tax shields, while also considering the potential long-term risks, including credit rating downgrades and heightened financial distress (Holden, 2012).

This analysis encourages students to adopt a holistic perspective on capital structure decisions, weighing the trade-offs between short-term financial flexibility and the sustainability of the firm's financial health over time. Furthermore, the use of ratio constraints introduces an element of real-world complexity, mirroring the decision-making processes financial managers undertake when navigating the delicate balance between growth opportunities and risk management. Extensions of this methodology could include sensitivity analysis to explore how changes in market conditions or firm-specific metrics impact these margins, providing students with a more comprehensive understanding of financial stability and strategic planning.

Integration with Broader Financial Concepts:

The model's adaptability allows for seamless integration with a variety of advanced financial concepts, including leveraging and unlevering beta, share buybacks, and estimating financial distress costs. These extensions encourage students to view capital structure decisions holistically, recognizing the interconnected nature of financial strategies. For example, instructors can introduce the FRICTO acronym to guide discussions on how factors such as flexibility, risk, income, control, timing, and other considerations influence the optimal debt level identified through the optimization exercise. If maintaining financial flexibility or preserving a specific credit rating is a priority, the model provides a framework for quantifying and analyzing these objectives in relation to the firm's debt capacity.

Extensions of the model also enable dynamic exploration of how changes in median ratios across S&P ratings influence optimal debt levels, leading to greater tax shields, potentially higher stock prices, and lower weighted average costs of capital. By adjusting the model to incorporate additional constraints, such as the estimated costs of financial distress, students can better

understand the trade-offs between risk and reward in real-world scenarios. These enhancements not only deepen students' analytical skills but also provide a practical foundation for addressing complex financial challenges in professional settings.

Evidence from Implementation: Student Engagement and Understanding

Over the course of three semesters, encompassing nine sections of an intermediate finance course, students engaged with the Deluxe Corporation Case from Bruner et al. This module was strategically integrated into the curriculum following in-depth study of long-term capital management and a comprehensive module on ratio analysis. The sequencing was designed to ensure that students had a foundational understanding of financial concepts before tackling the case. To assess their baseline knowledge, students were first presented with a straightforward ex-ante prompt: "Name as many ratios as you can, up to 10, that should be used in assessing creditworthiness and provide their corresponding formulas." This exercise served as an initial diagnostic tool to gauge their familiarity with relevant financial metrics and their application to credit analysis. On average, students were able to correctly name and recall the formulas for 4.63 ratios ex-ante.

The activity set the stage for the interactive case-based learning approach that followed, enabling a clear comparison of pre- and post-treatment comprehension and practical application skills. This design allowed for measurable insights into the pedagogical effectiveness of the module in fostering critical thinking and analytical rigor. The same question was posed to students after completing the module and engaging with the pedagogical approach described herein. Following this "treatment," students demonstrated a marked improvement in their responses, not only identifying a greater number of relevant financial ratios but also providing more accurate formulas and explanations of their significance in assessing creditworthiness. Ex-post students were able to recall on average 6.74 ratios and formulas, for an increase on average of 2.12, with 84.8% of students showing some level of improvement. We acknowledge that as active learning assignment should demonstrate increases in recall and application and that the gains presented may not be directly attributable to the specific pedagogical method detailed in this paper.

This post-treatment exercise served as both a summative assessment and a means of measuring the effectiveness of the case-based, interactive learning approach. Students consistently showed deeper insight into key metrics, such as debt-to-equity, interest coverage, and cash flow ratios, and could articulate how these ratios inform financial decision-making. The improvement in their responses reflected not only their enhanced comprehension but also their ability to apply theoretical knowledge to practical, real-world scenarios. The comparative results between the pre-treatment and post-treatment assessments suggest that this approach fosters significant gains in analytical rigor, critical thinking, and the practical application of financial concepts. This progression highlights the pedagogical value of active, case-based learning as a tool for cultivating a more nuanced understanding of capital structure and credit analysis.

Classroom discussions provided valuable qualitative feedback, with many students describing the model as intuitive, practical, and more engaging than standard methods. They often highlighted its ability to simplify complex financial concepts into a structured and accessible framework, making it easier to apply theoretical knowledge to real-world scenarios. The model's balance between simplicity and depth was particularly appreciated, as it offered a hands-on approach that reinforced critical thinking and problem-solving skills, ultimately boosting their confidence in conducting detailed analyses.

Figure 8
Results of Ex-Ante/Ex-Post Assessment

Difference in (Ex-Post-Ex-Ante) Correct Responses									
Cohort Size	Cohort 1	Cohort 2	Cohort 3	Cohort 4	Cohort 5	Cohort 6	Cohort 7	Cohort 8	Cohort 9
1	2	5	1	4	0	1	2	3	0
2	5	3	1	3	3	1	4	3	5
3	0	1	3	2	3	2	1	2	1
4	2	1	0	3	0	1	5	3	2
5	2	4	4	2	1	1	2	5	2
6	0	2	1	1	5	2	3	2	2
7	1	5	2	0	1	1	5	2	5
8	5	5	4	3	5	1	1	2	0
9	4	0	4	3	1	2	3	1	1
10	2	0	2	0	3	4	4	2	1
11		5	0	2	1	0	0	2	5
12		0	0	1	2	3	1	0	4
13		2	3	3	2	5	4	4	1
14		0	1	1	2	3	2	1	2
15		0	0	5	5	4	1	2	1
16		3	1	4	1	1	1		1
17				4	4	0	2		1
18				1	0	1			0
19				1		1			
20				2		3			
21				2					
22									
Average	2.30	2.25	1.69	2.24	2.17	1.85	2.41	2.27	1.89
Total	2.12								

However, we also recognize that the model was not equally accessible to all students. Those with limited prior experience in Excel or optimization techniques reported initial difficulties, particularly when navigating advanced spreadsheet functions or understanding the underlying mechanics of optimization. This learning curve sometimes led to frustration, requiring additional instructional time and one-on-one support to help these students build the necessary skills. These challenges emphasize the importance of providing supplemental resources, such as step-by-step tutorials, pre-session workshops, or simplified introductory tasks, to ensure all students can engage effectively with the methodology regardless of their starting point. By addressing these disparities, we aim to make the model more inclusive while preserving its practical and intuitive design.

Conclusion

This paper presents a spreadsheet-based model that leverages Microsoft Excel’s Solver function to optimize capital structure decisions under multiple constraints. By integrating theoretical frameworks with practical quantitative tools, the model provides a dynamic and interactive approach to teaching capital structure. Its flexibility makes it suitable for a range of finance courses, from introductory to advanced financial modeling classes at both undergraduate and graduate levels.

The model’s ability to bridge theory and practice not only deepens students’ understanding of core financial principles but also equips them with the technical skills required for real-world

decision-making. The hands-on approach fosters critical thinking and engagement, encouraging students to analyze trade-offs, evaluate constraints, and simulate scenarios that mirror professional challenges. Ultimately, this model represents a practical and versatile tool for finance education, bridging the gap between abstract concepts and actionable insights, and preparing students to navigate the complexities of financial decision-making in their professional careers.

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A Modern Approach to Teaching Options Pricing Using Monte Carlo Simulation with Python

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This paper proposes a modern pedagogical approach to teaching option pricing by integrating Monte Carlo simulation with Python programming. Traditional instruction based on the Black-Scholes model often relies on advanced mathematics, which can hinder student comprehension and engagement. Furthermore, many real-world financial derivatives, such as path-dependent or exotic options, lack closed-form solutions, making simulation-based methods both relevant and essential in contemporary finance. To address these challenges, we design a curriculum that utilizes Python program for interactive coding, visual simulations, and structured exercises. The course culminates in a group project where students modify option payoff functions and implement custom pricing logic using Monte Carlo methods. Grounded in constructivist and experiential learning theories, this approach enhances conceptual understanding, promotes active learning, and develops practical computational skills. The framework offers a scalable and accessible solution for modernizing financial education in quantitative subjects.

Keywords: Option Pricing, Monte Carlo Simulation, Python Programming, Financial Education, Quantitative Finance Pedagogy, Interactive Teaching

Introduction

The Black-Scholes-Merton (BSM) option pricing model, developed by Robert C. Merton, Fischer Black, and Myron Scholes, stands as one of the most influential contributions to modern financial economics. Its significance was recognized with the awarding of the Nobel Memorial Prize in Economic Sciences in 1997. The BSM framework has become a cornerstone in both academic curricula and financial industry practices, enabling investors to price derivatives, manage risk, and construct hedging strategies with mathematical rigor. The model's practical relevance extends across various markets—from index and currency options traded on futures exchanges to equity-linked warrants issued by brokerage firms—where accurate pricing and sensitivity measures (such as implied volatility and the Greeks) are essential.

This article proposes a modernized, pedagogically driven framework for teaching option pricing using Python and Monte Carlo simulation. With the rise of computational finance and the growing importance of reproducible education, integrating programming tools into finance instruction has become imperative. By guiding students through the logic and implementation of Monte Carlo simulations for option pricing in Python, this instructional approach fosters both conceptual understanding and technical proficiency.

Interestingly, Nigel Goldenfeld, a theoretical physicist at the University of Illinois Urbana-Champaign, has remarked that the Black-Scholes equation is likely the most widely used mathematical formula in the modern world—surpassing even Newton's laws of motion and Schrödinger's equation in terms of daily application. This observation underscores not only the ubiquity of the BSM model in global finance, but also the importance of equipping students with

tools to understand and apply it in practice. However, in practice, not all derivative securities possess payoff structures or boundary conditions as analytically tractable as those of European call and put options. For many complex derivatives—particularly path-dependent or multi-asset options—closed-form solutions such as the Black–Scholes–Merton formula do not exist. In such cases, numerical methods become indispensable. Among these, Monte Carlo simulation stands out as a versatile tool for valuing derivatives whose payoffs depend on the trajectory of the underlying asset, or on multiple sources of market uncertainty. Although computationally intensive, Monte Carlo methods have become increasingly accessible and efficient due to advancements in hardware and the availability of high-level programming environments such as Python.

We argue that a robust understanding of option pricing and risk dynamics is essential in finance education. Inadequate knowledge of these concepts can lead to catastrophic consequences, as evidenced by real-world market events. A notable example is the February 6, 2018 options volatility incident on the Taiwan Futures Exchange (TAIFEX). Triggered by a sharp decline in the U.S. stock market on February 5, this event caused extreme fluctuations in Taiwan index futures the following day. Deep out-of-the-money options—both calls and puts—unexpectedly hit their price limits due to sudden shifts in implied volatility. Many retail investors, who had heavily sold options to earn premium income, faced massive losses, particularly because they underestimated the leverage effect and margin risk inherent in options trading. The ensuing wave of forced liquidations ("margin calls") and price distortions across strike prices highlighted a breakdown in the conventional pricing assumptions. This event—one of the few globally recognized instances where option pricing models seemingly “failed”—underscored the necessity for more comprehensive financial education. It is imperative that students in business and finance programs not only learn the mechanics of option pricing models, but also understand their limitations, assumptions, and real-world implications under market stress.

Option pricing, as a core subject within financial engineering, synthesizes insights from financial economics, advanced mathematics, and statistical modeling. This interdisciplinary field has been propelled by the integration of sophisticated software and high-performance computing, enabling theoretical models to be deployed across diverse financial markets—including equities, fixed income, foreign exchange, and commodities. Financial engineering serves not only as a tool for innovation in financial products, but also as a framework for valuation, arbitrage strategy development, and risk management.

Modern financial computation courses demand that students not only grasp the theoretical foundations of option pricing but also acquire practical competencies to implement and test pricing models. Traditionally, however, such courses have relied heavily on mathematical derivations and symbolic manipulation—approaches that can intimidate and disengage those whose prior exposure to calculus, differential equations, and stochastic processes is limited. The conventional pedagogy for option pricing centers on rigorous proofs, most notably the continuous-time Black–Scholes–Merton framework, which involves stochastic calculus, partial differential equations and risk-neutral valuation arguments. For undergraduates in business schools, such methods often present formidable barriers to understanding and stifle intellectual curiosity (Rich, 2005).

Rich (2005) study of finance teaching revealed that heavy emphasis on mathematical proofs can obscure practical relevance and discourage student engagement. In a parallel vein, Gaviria et al. (2024) have shown that simulation-mediated learning—by shifting focus from abstract manipulation to experiential experimentation—significantly enhances comprehension and motivation in accounting courses. These findings suggest that a solely mathematical exposition of option pricing may fail to foster intuitive understanding or sustained interest. In response,

educators have increasingly adopted case-based and simulation-driven pedagogies in the finance curriculum. Case studies introduce real-world complexity, requiring students to analyze data, formulate assumptions and defend strategic decisions—activities that mirror professional practice and foster critical thinking as well as communication skills (Rich, 2005). Perhaps the most potent simulation technique is the Monte Carlo method, which allows learners to approximate complex option payoffs by generating numerous simulated price paths under stochastic dynamics.

Among simulation techniques, the Monte Carlo method stands out as especially potent. It enables learners to approximate complex option payoffs by generating thousands of price paths under stochastic dynamics, thus visualizing the probabilistic nature of financial markets. Rather than passively absorbing formulas, students actively observe how changes in volatility, maturity, or interest rates affect payoff distributions. Munshi (2014) argues that simulation can replace—or at least substantially supplement—algebraic derivations, providing intuitive insights inaccessible through symbolic methods alone. By embedding these exercises within case narratives, instructors can create a cohesive learning experience that emphasizes both the “why” and the “how” of option pricing.

The pedagogical adoption of Monte Carlo simulation in finance education, particularly for teaching option pricing, has gained momentum since the early 2000s. Wilmott, Howison, and Dewynne (1995) emphasized the flexibility of Monte Carlo methods in valuing complex derivative instruments, motivating its inclusion in computational finance curricula. More specifically, Hull (2012) integrated Monte Carlo examples into his widely-used derivatives textbook, illustrating how simulation can be used to price European, Asian, and path-dependent options. Similarly, Clewlow and Strickland (1998) presented practical frameworks for teaching Monte Carlo techniques in financial engineering programs, highlighting the method’s intuitive appeal in demonstrating stochastic processes and risk-neutral pricing. These educational efforts align with the broader trend toward experiential learning in quantitative finance, where students engage directly with randomness, convergence, and the law of large numbers through computational experimentation.

In the context of modern financial education, educators may choose among several computational platforms, each presenting distinct merits and limitations. Take Excel, MATLAB and Python. Excel enjoys ubiquity and a familiar interface, making it an accessible entry point for many learners. Duan and Stretcher (2023) demonstrate how a multi-sheet workbook can guide students through constructing Monte Carlo simulators for option pricing, leveraging cell formulas and built-in charting to visualize payoff distributions. Tysiak (2018) similarly shows that Excel-based simulations can introduce risk-management concepts with minimal coding overhead. Varma and Virmani (2022) summarize the debate, noting that while several studies (e.g., Barreto, 2015; Zhang, 2014) advocate for Excel’s pedagogical utility, others highlight its shortcomings (e.g., McCullough & Heiser, 2008; Yalta, 2008). These critiques emphasize Excel’s lack of numerical robustness and its difficulty in supporting reproducible workflows. A notable example is the work of Arnold and Henry (2005), who present an Excel-based implementation of Monte Carlo simulation for valuing European options. While this contribution is closely related to our work, its pedagogical design reflects the technological constraints and instructional paradigms of its time. The authors employ a cell-based simulation framework, which, although pedagogically effective in small-scale settings, lacks scalability and algorithmic transparency when compared to contemporary programming environments. As financial education increasingly emphasizes data-driven experimentation, reproducibility, and coding literacy, the pedagogical limitations of Excel become more salient. Chung (2024) further notes that Excel templates are inherently limited in

scalability and are ill-suited for constructing and adjusting mean-variance portfolios with varying numbers of assets. These structural constraints impede efficient experimentation and algorithmic thinking in pedagogical settings. Although Excel VBA offers some degree of programmability, its limited popularity and lack of robust open-source support further constrain its educational utility. Moreover, Excel's performance degrades significantly when executing Monte Carlo simulations with large numbers of iterations, and its reliance on manual formula management increases the likelihood of computational errors.

MATLAB offers optimized matrix operations, a comprehensive financial toolbox, and high-quality plotting capabilities. Wang (2012) provides a wide range of MATLAB-based Monte Carlo examples across various derivative structures, emphasizing the language's numerical precision and extensive built-in functions. Similarly, Kienitz and Wetterau (2012) have contributed numerous ready-to-use scripts on MATLAB Central for pricing under complex asset dynamics. Despite its computational strengths, MATLAB's commercial licensing costs may limit access for students and institutions, and its proprietary nature poses integration challenges with modern, web-based learning environments.

In contrast, recent pedagogical literature has increasingly advocated for the adoption of general-purpose programming languages—most notably Python—in finance education. As a free and open-source platform, Python offers an expansive ecosystem of libraries tailored for computational finance: NumPy for numerical operations, Pandas for data wrangling, Matplotlib and Plotly for visualization, and SciPy for optimization and statistical analysis. Wang (2012) notes that Python's scriptability enhances both automation and reproducibility in financial modeling. Priyatna et al. (2023) demonstrate how Python can be used to build web-based Monte Carlo simulators with interactive dashboards, facilitating student engagement and interactivity. Chung (2024) highlights that Python not only handles large data sets efficiently but also provides a wealth of open-source packages for accessing real-time financial data via APIs. This allows instructors to link theoretical models with real-world applications. Moreover, the JupyterLab Notebook environment enhances learning by combining executable code with markdown text, enabling students to produce well-documented, reproducible investment analysis workflows. Such a structure promotes both technical skill development and reflective learning (Chung, 2024).

Although novices may initially struggle with installation, debugging and programming concepts, these challenges can be ameliorated through preconfigured environments. Platforms such as Jupyter notebooks, Google Colab, Docker containers or cloud-based platforms—allowing instructors to concentrate on conceptual understanding rather than technical minutiae. The given table 1 succinctly compare the major platforms discussed and highlights Python's suitability for contemporary finance curriculum.

With the availability of preconfigured Jupyter notebooks, Docker containers, and cloud-based platforms such as Google Colab, the traditional technical barriers to using Python in the classroom have largely been eliminated. These environments allow educators to focus on conceptual instruction and simulation logic, rather than software configuration or debugging. Python's open-source nature, integration with real-time data via APIs, and compatibility with interactive dashboards further enhance its suitability for simulation-based teaching.

Table 1
Comparison of Computational Platforms in Financial Education

Platform	Advantages	Disadvantages	Key References
Excel	<ul style="list-style-type: none"> Ubiquitous and familiar interface for beginners Easy visualization through built-in charts Suitable for low-code instructional tasks 	<ul style="list-style-type: none"> Poor scalability for large simulations Prone to formulaic errors in manual setups Criticized for statistical inaccuracy and lack of reproducibility Limited automation and community support (VBA) 	Duan & Stretcher (2023); Tysiak (2018); Barreto (2015); Zhang (2014); McCullough & Heiser (2008); Yalta (2008); Chung (2024); Varma & Virmani (2022); Arnold and Henry (2005)
MATLAB	<ul style="list-style-type: none"> High numerical precision and performance Extensive financial toolbox Large repository of pre-built scripts (e.g., MATLAB Central) Optimized for matrix operations 	<ul style="list-style-type: none"> Commercial license cost may hinder access Proprietary nature limits integration with open-source workflows 	Wang (2012); Kienitz & Wetterau (2012)
Python	<ul style="list-style-type: none"> Free, open-source, and widely supported Rich ecosystem for finance: NumPy, Pandas, Matplotlib, SciPy Supports real-time data integration (via APIs) Reproducibility via JupyterLab environment Facilitates case-based, simulation-driven pedagogy 	<ul style="list-style-type: none"> Steeper learning curve for beginners Initial setup (e.g., environment configuration) may be challenging, though mitigated by tools like Google Colab and JupyterHub 	Chung (2024, 2025); Priyatna et al. (2023); Wang (2012)

Accordingly, this article advocates for Python as the principal tool for teaching Monte Carlo simulation in option pricing. Leveraging the pedagogical strengths of case studies and experiential learning, Python’s opensource nature and scriptable flexibility will enable students to interactively explore the stochastic dynamics of stock prices, evaluating option payoffs, and option values, cultivating both theoretical acumen and practical coding proficiency. In the chapters that follow, we outline a comprehensive instructional approach that combines annotated Jupyter notebooks for guided exploration of Monte Carlo option pricing models with a collaborative group project that fosters applied learning, critical thinking, and peer-based engagement.

Monte Carlo Simulation and Its Application to Option Pricing

This section reviews key concepts in Monte Carlo simulation and explores its application in pricing financial derivatives. As a computational tool grounded in probability theory and statistical sampling, Monte Carlo methods offer a flexible framework for solving problems where analytical solutions are intractable. While students may initially perceive the topic as abstract or mathematically intensive, instructors can build intuition by introducing real-world analogies and simple simulations. Starting with foundational examples—such as geometric sampling and natural phenomena forecasting—can help students develop an appreciation for how randomness,

convergence, and estimation underpin Monte Carlo logic. These preliminary cases serve as a stepping stone toward understanding how such methods can be scaled up to tackle the complexities of option pricing in financial markets.

Basic Foundation and Real-World Application of Monte Carlo Simulation

Basic Foundation

Monte Carlo simulation is a fundamental computational technique widely employed in econometrics and financial engineering, especially for solving expectation-based problems that arise naturally in the valuation of financial derivatives, default risk estimation, and option pricing. These problems often involve computing the expected value of a nonlinear function of one or more stochastic variables:

$$E[h(X)] = \int h(x) f_X(x) dx \quad (1)$$

where X denotes a random variable representing an underlying asset price or risk factor, $f_X(x)$ is the known probability density function of X , and $h(x)$ is a payoff or response function. This integral form arises in various applications such as pricing European-style options, calculating expected shortfall, or determining ruin probabilities. The method derives its name from the Monte Carlo region in Monaco, famously associated with games of chance. This allusion reflects the central role of randomness in the technique. The concept was formalized by Stanislaw Ulam and Nicholas Metropolis in the mid-20th century, during their work on nuclear physics, when they recognized the power of repeated random sampling in solving probabilistic problems that defied closed-form solutions.

In low-dimensional cases, standard numerical integration techniques—such as Simpson’s rule or Gaussian quadrature—can be applied to evaluate this integral with high accuracy (see Stoer & Bulirsch, 1980; Miranda & Fackler, 2002). However, when the dimensionality of the problem increases, such as in multi-asset derivatives or exotic options with path-dependent features (e.g., Asian option), the computational burden of numerical integration grows exponentially. This phenomenon, known as the curse of dimensionality, severely reduces the efficiency and tractability of traditional quadrature methods.

Moreover, in many realistic settings, the underlying distribution of the risk factors may not be known, or the payoff function may lack analytical tractability. In such contexts, Monte Carlo simulation offers a flexible and robust alternative. By drawing a large number of random samples from the joint distribution of the risk factors, and computing the average of the simulated payoffs, the method approximates the expectation through sample means. As the number of simulations increases, the estimate converges to the true value due to the law of large numbers—regardless of the dimensionality or shape of the function.

In summary, Monte Carlo simulation is not only a conceptually intuitive approach, but also a practical necessity in modern financial computation. It excels in scenarios where analytical integration is infeasible, numerical integration is computationally prohibitive, or model specifications are complex and path-dependent.

Typhoon Path Forecasting

Monte Carlo simulation (MCS) has found widespread application across disciplines involving uncertainty and complex systems. A compelling real-world example can be observed in meteorological forecasting, particularly in the prediction of typhoon trajectories. Weather agencies collect real-time atmospheric data—such as sea surface temperatures, pressure fields, and wind shear—and use numerical models to simulate hundreds or even thousands of possible future typhoon paths. Each simulated trajectory is generated by perturbing initial conditions and model parameters within plausible bounds, reflecting the inherent uncertainty of atmospheric systems.

The aggregation of these simulated paths produces a probabilistic forecast represented visually through a “cone of uncertainty,” where the central track indicates the most likely trajectory, and the surrounding shaded area captures the confidence interval derived from the simulations. This approach enables emergency management and the public to assess potential risk regions rather than relying on a single deterministic forecast.

This forecasting methodology closely parallels the application of Monte Carlo simulation in financial engineering, particularly in option pricing. Just as a typhoon’s path is influenced by stochastic variables, the future price of an underlying asset is subject to random fluctuations driven by market volatility and economic shocks. In both cases, Monte Carlo methods serve to generate a distribution of future outcomes, from which expected values and risk measures can be inferred. This analogy illustrates the flexibility and robustness of Monte Carlo simulation as a tool for quantifying uncertainty and informing decision-making under risk.

Figure 1
Typhoon Path Forecasting



Monte Carlo Estimation of π : A Geometric Sampling Example

Monte Carlo simulation is not limited to finance or weather forecasting; it also serves as an effective pedagogical device for demonstrating probabilistic estimation through random sampling. A classical example is the estimation of the mathematical constant π using geometric probability. By simulating a large number of random dart throws within a unit square that circumscribes a quarter circle, students can visually and computationally approximate π as a ratio of areas. To support this intuition-building activity, an interactive Jupyter Notebook is provided below to demonstrate the implementation in Python.

Jupyter Notebook: MCS for π

In this notebook, we will explore how we can use the Monte Carlo method to estimate the value of π (pi). Monte Carlo simulation is a technique that relies on random sampling to obtain numerical results. Here, we'll use it to estimate the value of pi by simulating the throwing of random darts at a square enclosing a circle.

Let's get started by understanding the concept behind this approach and then implementing it step-by-step using Python.

Concept Overview

- Imagine a square of side length 2, centered at the origin, enclosing a circle of radius 1.
- The circle is inscribed within the square, meaning the entire circle fits perfectly inside the square.
- We will randomly throw 'darts' at this square.
- By counting how many darts land inside the circle versus the total number of darts thrown, we can estimate the ratio between the area of the circle and the square.

The ratio of points inside the circle to the total number of points is approximately equal to the ratio of the area of the circle to the area of the square. Using this, we can derive the value of π .

Mathematical Formula

- Consider a square with a side length of 2, centered at the origin, enclosing a circle of radius $r = 1$.
- The area of the circle is defined as $A_{\text{circle}} = \pi r^2$. Since $r = 1$, it follows that $A_{\text{circle}} = \pi$.
- The area of the square is $A_{\text{square}} = 2 \times 2 = 4$.
- Consequently, the ratio of the area of the circle to the area of the square is $\frac{\pi}{4}$.

If we throw N points randomly (uniformly distributed within the square). According to the law of large numbers, the ratio of the number of points falling inside the circle (N_{inside}) to the total number of points (N_{total}) approximates the ratio of their areas:

$$\frac{N_{\text{inside}}}{N_{\text{total}}} \approx \frac{A_{\text{circle}}}{A_{\text{square}}} = \frac{\pi}{4}$$

Rearranging this equation provides an estimator for π :

$$\pi \approx 4 \times \frac{N_{\text{inside}}}{N_{\text{total}}}$$

Implementation

Below, we'll implement this step-by-step in Python.

[1]:

```
# Import Necessary Libraries
import random
import matplotlib.pyplot as plt
```

Step 1: Define Function to Estimate π

We will define a function that simulates the throwing of darts.

[2]:

```
def estimate_pi(num_points):
    points_inside_circle = 0

    for _ in range(num_points):
        # Generate random (x, y) points between -1 and 1
        x = random.uniform(-1, 1)
        y = random.uniform(-1, 1)

        # Check if the point is inside the circle
        if x**2 + y**2 <= 1:
            points_inside_circle += 1

    # Use the ratio to estimate pi
    pi_estimate = 4 * points_inside_circle / num_points
    return pi_estimate
```

Step 2: Running the Simulation

Now, let's run the simulation with a large number of points to get a good approximation.

[3]:

```
num_points = 10000
pi_estimate = estimate_pi(num_points)
print(f"Estimated value of pi after {num_points} points:
      {pi_estimate}")
```

Step 3: Visualizing the Dart Throws

Visualization can help understand the distribution of points and why the simulation works.

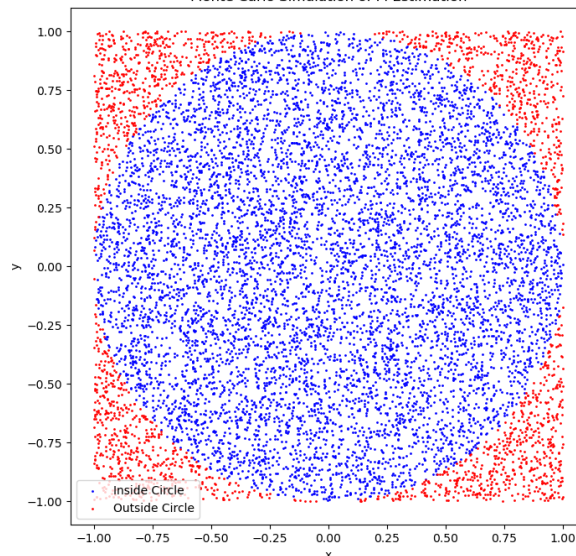
[4]:

```
x_inside , y_inside = [], [] x_outside,
y_outside=[],[]

for _ in range(num_points):
    x=random.uniform(-1,1)
    y=random.uniform(-1,1)
    if x**2 + y**2 <= 1:
        x_inside.append(x)
        y_inside.append(y)
    else:
        x_outside.append(x)
        y_outside.append(y)

plt.figure(figsize=(8, 8))
plt.scatter(x_inside,y_inside,color='blue',s=1,label='Inside Circle')
plt.scatter(x_outside,y_outside,color='red',s=1,label='Outside Circle')
plt.gca().set_aspect('equal')
plt.xlabel('x')
plt.ylabel('y')
plt.title( 'Monte Carlo Simulation of Pi Estimation' )
plt.legend()
plt.show()
```

Figure 2
Monte Carlo Simulation of π Estimation
Monte Carlo Simulation of Pi Estimation



Summary and Conclusion

- We used random sampling to estimate the value of π .
- The accuracy of the estimated value of π increases with the number of points used in the simulation.
- Monte Carlo methods are powerful tools for estimating quantities that are difficult to compute analytically, especially in higher dimensions or for complex systems.

Feel free to experiment with different numbers of points and observe how the accuracy of the estimate changes. The larger the number of points, the closer the estimate will be to the true value of π .

Monte Carlo Simulation for option pricing

The foundational work of Black and Scholes (1973) employed geometric Brownian motion (GBM) under no-arbitrage assumptions to derive a partial differential equation (PDE) for pricing European-style options. Mathematically analogous to the heat diffusion equation in physics, this PDE led to the celebrated closed-form solution known as the Black-Scholes formula. While elegant and efficient, this approach relies on analytical tractability and specific assumptions that limit its applicability to a narrow class of options.

In contrast, Boyle (1977) introduced a groundbreaking alternative by applying Monte Carlo simulation to estimate option prices. Although initially underappreciated due to its computational demands—particularly in an era when high-performance computing was scarce—the method has since gained widespread relevance. The emergence of exotic derivatives, complex path-dependent contracts, and nonlinear stochastic models has rendered analytical solutions increasingly elusive. In these settings, the flexibility and generality of Monte Carlo simulation have become indispensable.

This section provides a step-by-step instructional walkthrough designed to help learners implement Monte Carlo simulation for pricing a European call option. The exercise is built in Python within a Jupyter (JupyterLab) Notebook and is divided into six pedagogical steps. The user-friendliness and pedagogical utility of the JupyterLab Notebook environment have been clearly articulated by Chung (2024), who emphasizes its role in supporting interactive, reproducible, and transparent financial modeling. Importantly, the Python programs presented in this module are not limited to execution within Jupyter-based environments. As noted by Chung (2025), the same code cells are fully compatible with freely available online Python compilers such as Google Colab, as well as open-source distributions like Anaconda. This platform flexibility enhances accessibility and allows students to engage with the content regardless of their local computing setup. Each step isolates a key component of the pricing process—starting from parameter setup to simulation, payoff computation, and result visualization. This progressive structure encourages not only technical mastery, but also conceptual clarity regarding the dynamics of asset evolution and option valuation under uncertainty.

Jupyter Notebook: MCS for Option Pricing

Objective

This notebook demonstrates how to use Monte Carlo simulation to price a European call option. By simulating a large number of potential future stock price paths, we estimate the option's value.

Monte Carlo methods are particularly useful when analytical solutions are unavailable or impractical.

Learning Outcomes

1. Understand the Monte Carlo simulation approach for financial derivatives.
2. Learn to simulate stock price paths using Geometric Brownian Motion.
3. Calculate the option payoff and present value.
4. Visualize the results to analyze price distributions.

[1]:

```
# Import Necessary Libraries
import math
import numpy as np
import matplotlib.pyplot as plt
from time import time
```

Step 1: Setting Up Parameters

Before starting the simulation, we define the required parameters:

- S_0 : Initial stock price (\$100)
- K : Strike price (\$105)
- T : Time to maturity (1 year)
- r : Risk-free interest rate (5%)
- y : Dividend yield (2%)
- σ : Volatility of the underlying asset (20%)
- M : Number of time steps (50)
- Δt : Time step length (T/M)
- I : Number of simulation paths (50,000)

[2]:

```
# Define Parameters
S0 = 100.0 # Initial stock price
K = 105.0 # Strike price
T = 1.0 # Time to maturity ( in years)
r = 0.05 # Risk- free interest rate
y = 0.02 # Dividend yield
sigma = 0.2 # Volatility
M = 50 # Number of time steps
dt = T / M # Time step length
I = 50000 # Number of simulation paths
```

In this initial step, students define the financial and numerical parameters required for the simulation. These include the initial stock price S_0 , strike price K , time to maturity T , risk-free rate r , dividend yield y , volatility σ , number of time steps M , and number of simulated price paths I . By explicitly assigning values, students begin to connect each variable with its real-world financial interpretation and understand its role in the option pricing model.

Step 2: Generating Stock Price Paths

We simulate stock price paths using the Geometric Brownian Motion model:

$$S_{t+1} = S_t \cdot \exp\left(\left(r - y - \frac{1}{2}\sigma^2\right)\Delta t + \sigma\sqrt{\Delta t}Z\right)$$

Where:

- Z is a random variable from the standard normal distribution.
- Δt : Time step length.

[3]:

```
# Start the timer to measure simulation performance
t0 = time()

# Set seed for reproducibility
np.random.seed(20000)

# Simulate Stock Prices
S = S0 * np.exp(np.cumsum(((r-y) - 0.5 * sigma ** 2) * dt
                        + sigma * math.sqrt(dt) * np.random.
                          standard_normal((M, I)),
                        axis=0))

# Stop the timer
t1 = time()
print(f"Stock Price Simulation Completed in {t1 - t0:.2f} seconds")
```

Here, the stock price paths are simulated using the Geometric Brownian Motion (GBM) process, a widely used stochastic model in finance. The asset price evolution over time under the risk-neutral measure. Students implement this simulation in Python by generating standard normal random variables Z and iteratively updating asset prices, reinforcing their understanding of stochastic dynamics.

Step 3: Calculate Option Payoff and Present Value

In this step, the final option payoff is computed based on the simulated terminal asset prices. At maturity T , the payoff for a European call option is given by:

$$\text{Payoff} = \max(S_T - K, 0)$$

The present value of the option is then:

$$C_0 = e^{-rT} \cdot \text{Average Payoff} = e^{-rT} \frac{1}{I} \sum_{i=1}^I \max(S_T^i - K, 0)$$

This exercise bridges the simulation with valuation theory and reinforces the concept of expected discounted payoff under risk-neutral valuation.

[4]:

```
# Calculate the payoff at maturity
payoffs = np.maximum(S[-1] - K, 0)

# Discount back to present value
C0 = np.exp(-r * T) * np.mean(payoffs)

# Print the result
print(f"European Call Option Value: {C0:.3f}")
```

European Call Option Value: 7.044

Step 4: Visualize Simulated Stock Price Paths

We will now visualize the simulated stock price paths to understand the range of possible outcomes. To better understand the results of the simulation, we visualize:

1. A subset of 10 simulated stock price paths for clarity.
2. All simulated stock price paths to see the complete distribution.

Preparing Data for Visualization

In our Monte Carlo simulation, the stock price paths start at the first time step, meaning the initial stock price S_0 is not explicitly included in the simulation results. To ensure the visualization accurately reflects the full trajectory of stock prices, we add the initial stock price as the first row of the dataset.

This is achieved using the following code:

[5]:

```
# Add initial stock price for better visualization
S_with_initial = np.vstack((np.full((1, I), S0), S))
```

Explanation

1. `np.full((1, I), S0)`

- Creates a 2D array with 1 row and I columns, where every value is S_0 (the initial stock price).
- This represents the starting stock price for all simulation paths.

2. `np.vstack:`

- Vertically stacks the initial stock price row (`np.full(...)`) with the simulated stock price paths (S).
- The result is a new array, `S_with_initial`, where:
 - The first row contains S_0 .
 - Subsequent rows contain the simulated stock prices.

Why is this important?

Without this step, the visualization would show the simulated paths starting at the first time step, omitting the starting price S_0 . Adding S_0 ensures the plots reflect the entire stock price evolution from the initial value to maturity.

[6]:

```
# Plot a subset of the simulated paths
plt.figure(figsize=(10, 6))
plt.plot(S_with_initial[:, :10]) # Plot only the first 10 paths
    for clarity
plt.grid(True)
plt.xlabel('Time Steps')
plt.ylabel('Stock Price')
plt.title('Simulated Stock Price Paths')
plt.show()
```

[7]:

```
# Plot all simulated stock price paths
plt.figure(figsize=(12, 7))
plt.plot(S_with_initial, linewidth=0.5) # Simple line plot for all
    paths
plt.grid(True)
plt.xlabel('Time Steps')
plt.ylabel('Stock Price')
plt.title('Simulated Stock Price Paths (All Paths)')
plt.show()
```

Figure 3
Simulated Stock Price Paths

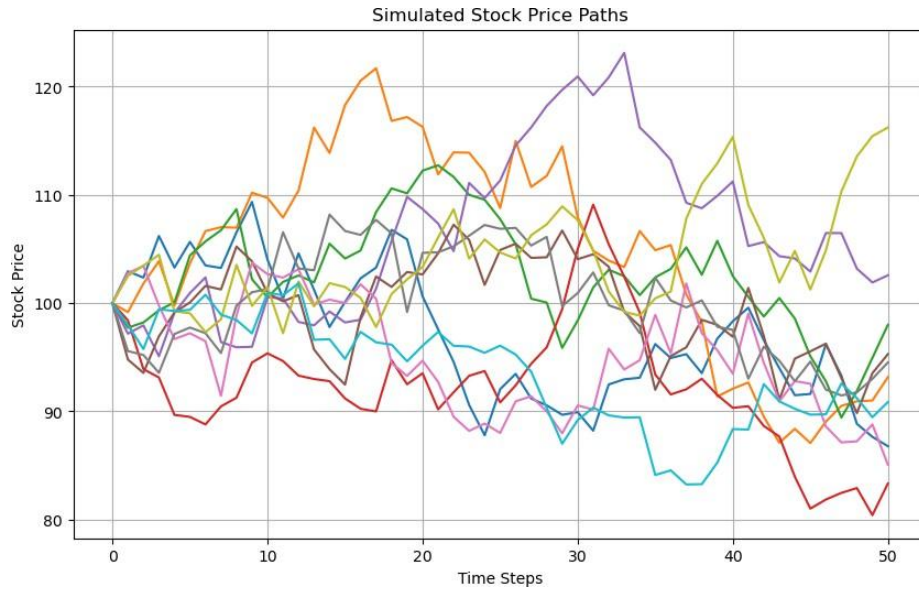
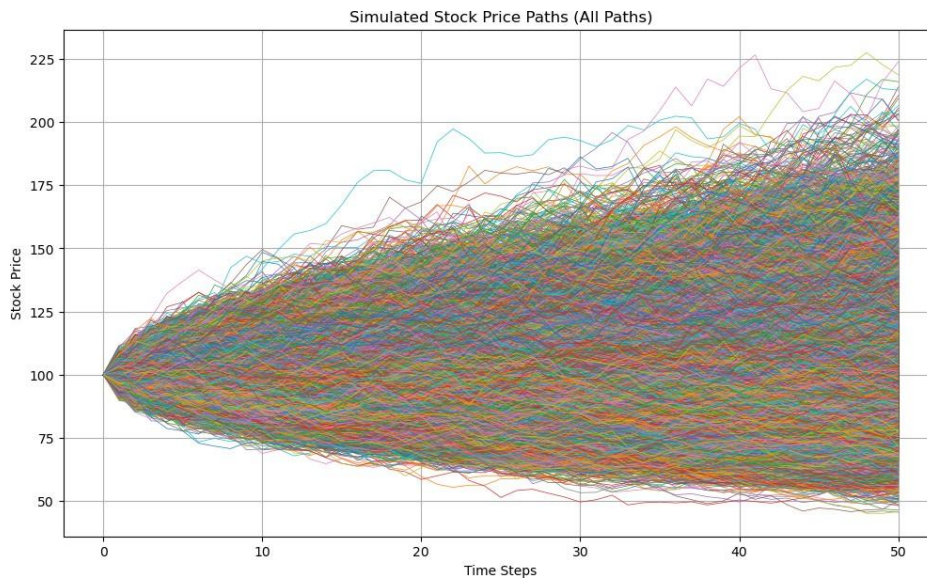


Figure 4
Simulated Stock Price Paths (All Paths)



To develop intuitive understanding, students plot the simulated price paths. By visualizing both a small subset (e.g., 10 paths) and the full set of trajectories, learners gain insight into the stochastic variability of asset prices and the dispersion induced by volatility and time.

Step 5: Plot Histogram of Stock Prices at Maturity

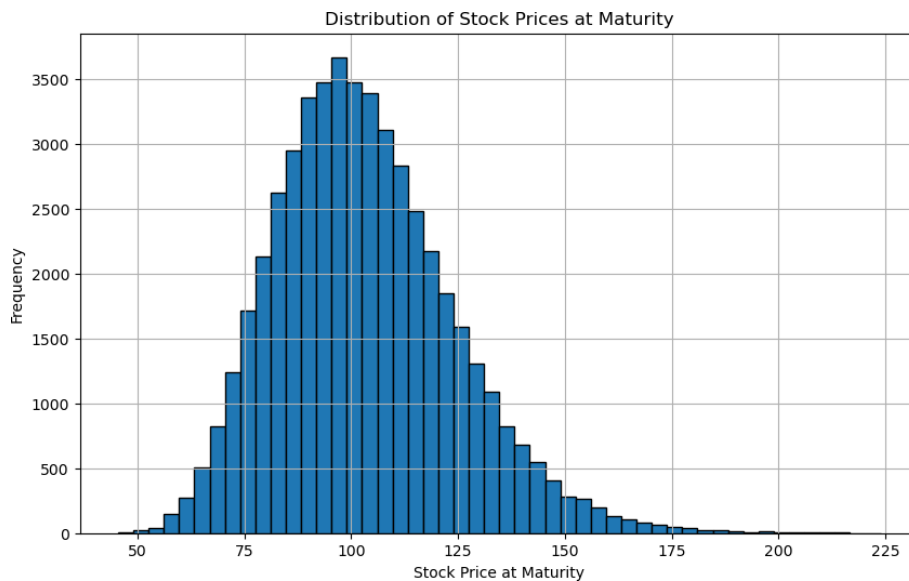
This histogram illustrates the distribution of stock prices at the maturity time T .

A histogram of S_T values (stock prices at maturity) reveals the empirical distribution emerging from the GBM process. Students are encouraged to observe skewness, variance, and concentration of the distribution, thereby deepening their understanding of simulated uncertainty.

[8]:

```
# Plot histogram of stock prices at maturity
plt.figure(figsize=(10, 6))
plt.hist(S[-1], bins=50, edgecolor='black')
plt.grid(True)
plt.xlabel('Stock Price at Maturity')
plt.ylabel('Frequency')
plt.title('Distribution of Stock Prices at Maturity')
plt.show()
```

Figure 5
Distribution of Stock Prices at Maturity



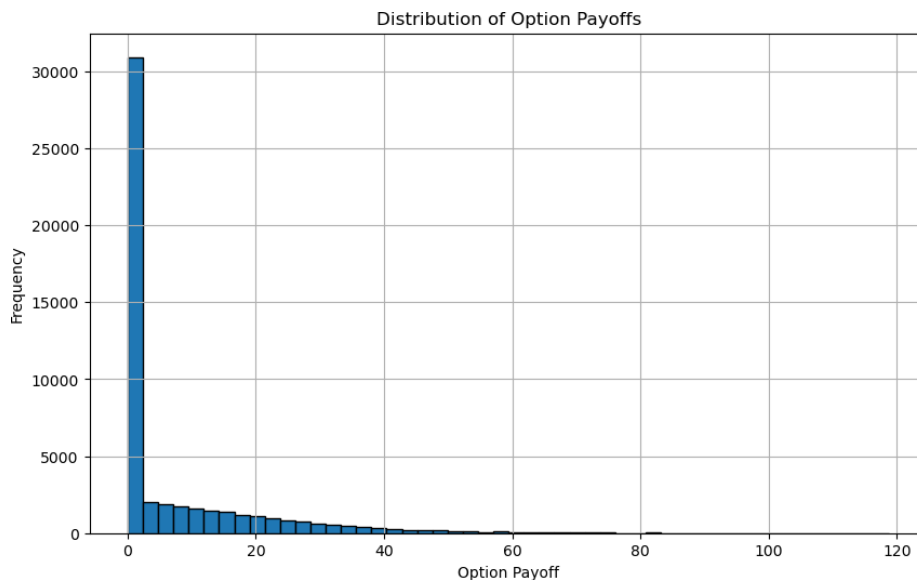
Step 6: Plot Histogram of Option Payoffs

The final step presents the distribution of the option's payoff. By plotting the histogram of $\max(S_T - K, 0)$, students visualize the payoff structure and reflect on how deep out-of-the-money paths lead to zero payoff while in-the-money paths contribute positively. This reinforces the asymmetric nature of option payouts and the probabilistic reasoning behind option pricing.

[9]:

```
# Plot histogram of option payoffs at maturity
plt.figure(figsize=(10, 6))
plt.hist(payoffs, bins=50, edgecolor='black')
plt.grid(True)
plt.xlabel('Option Payoff')
plt.ylabel('Frequency')
plt.title('Distribution of Option Payoffs')
plt.show()
```

Figure 6
Distribution of Option Payoffs



Insights and Observations

1. **Stock Price Paths:** The simulated paths represent possible future trajectories of the stock price, driven by randomness in the market.
2. **Option Payoffs:** Most of the payoffs cluster near zero, reflecting scenarios where the option is out-of-the-money.
3. **Monte Carlo Efficiency:** The accuracy of the estimated option value improves with the number of paths (I) and time steps (M).

Monte Carlo simulation is a flexible and robust method for pricing options, particularly when analytical solutions are unavailable. However, careful consideration is needed to balance computational cost and accuracy.

Advanced Topic 1: Confidence Interval Estimation in Monte Carlo Pricing

In practical implementations of Monte Carlo simulations, a single simulation run may not yield a stable estimate of the option price due to the randomness inherent in sampling. To quantify the estimation variability and improve accuracy, it is common to repeat the simulation multiple times and compute statistical properties of the output distribution.

To enhance reusability and support different types of options, we first define a modular pricing function `mc_price_once()` that estimates the value of a single European call or put option using Monte Carlo simulation. This function serves as a core building block for repeated simulations.

[10]:

```
def mc_price_once(S0,r,y,sigma,T,M,I,K,option_type='call'):
    """
    Monte Carlo pricing for European call/put options.

    Parameters:
    - S0: Initial stock price
    - r: Risk-free interest rate
    - y: Dividend yield
    - sigma: Volatility
    - T: Time to maturity
    - M: Number of time steps
    - I: Number of simulation paths
    - K: Strike price
    - option_type: 'call' or 'put'

    Returns:
    - Discounted expected payoff (option price)
    """
    dt = T / M
    Z = np.random.standard_normal((M,I)) # standard normal
        innovations
    ST_paths = S0 * np.exp(np.cumsum(((r-y) - 0.5 * sigma**2) * dt
        + sigma * math.sqrt(dt) * Z, axis=0))

    ST = ST_paths[-1] # terminal stock price

    option_type = option_type.lower()
    if option_type == 'call':
        payoff = np.maximum(ST - K, 0.0)
    elif option_type == 'put':
        payoff = np.maximum(K - ST, 0.0)
    else:
        raise ValueError("option_type must be 'call' or 'put'")

    return math.exp(-r * T) * np.mean(payoff)
```

Instructional Explanation

This function implements the basic logic of Monte Carlo simulation for European-style options:

- It simulates I stock price paths using Geometric Brownian Motion over M time steps.
- The terminal asset price S_T is extracted from each path.
- The option's payoff is computed based on the contract type:
 - For a call: $\max(S_T - K, 0)$
 - For a put: $\max(K - S_T, 0)$
- The average payoff is then discounted back to present value using the exponential discount factor e^{-rT} .

The following function performs the repeated pricing operation:

[11]:

```
def mc_price(S0, r, y, sigma, T, M, I, K,
             option_type='call', N_reps=20):

    prices = [mc_price_once(S0, r, y, sigma, T, M, I, K,
                           option_type) for _ in range(N_reps)]
    prices = np.array(prices)

    mean_price = prices.mean()
    std_price = prices.std(ddof=1)      # sample std

    # 95% Confidence Interval: Approximate using  $\pm 2 \times$  standard
    # deviation
    ci_low = mean_price - 2 * std_price
    ci_high = mean_price + 2 * std_price

    print(f"{option_type.upper()} N={N_reps} "
          f"Option values={mean_price:.4f} CI (95%)=[{ci_low:.4f},
          {ci_high:.4f}]")
    return mean_price, (ci_low, ci_high)
```

We then use this function to evaluate both call and put options:

[12]:

```
mc_price(S0, r, y, sigma, T, M, I, K, option_type='call', N_reps
=20)
mc_price(S0, r, y, sigma, T, M, I, K, option_type='put', N_reps
=20)
```

Instructional Explanation

This advanced exercise introduces students to the concept of simulation variance and its impact on pricing precision. The `mc_price_once()` function performs a standard Monte Carlo estimation for a single run, while `mc_price()` repeats this estimation N times to generate a distribution of outcomes.

By analyzing the sample mean and standard deviation across repeated simulations, students learn to:

- Understand the stochastic variability in Monte Carlo estimates,
- Construct an approximate 95% confidence interval using $\pm 2 \times$ standard deviation,
- Compare price stability between call and put options under the same parameters.

This exercise also reinforces the concept of convergence: as N increases, the confidence interval narrows, reflecting improved precision due to the law of large numbers. It offers a natural segue into discussions of simulation efficiency, variance reduction techniques, and sample size planning in financial modeling.

Advanced Topic 2: Simulation of Continuous-Time Price Dynamics — Exact Discretization vs. Euler–Maruyama Method (EM)

The Monte Carlo engine implemented in Steps 1–2 prices a derivative by approximating a risk-neutral expectation with simulated paths. Importantly, Monte Carlo simulation addresses *how to approximate an expectation* given simulated terminal payoffs, but it does not by itself determine *how to generate a path* from a continuous-time model. To simulate a continuous-time stochastic differential equation (SDE) on the grid used in this notebook, one must specify a discrete-time transition rule for moving from t_n to t_{n+1} . This advanced topic clarifies a practical modeling choice that naturally arises once students move beyond GBM: whenever a model admits an *exact* (closed-form) one-step transition, it is typically preferred; otherwise, one relies on a numerical discretization such as the Euler–Maruyama (EM) method (Maruyama, 1955; Kloeden and Platen, 1992). The learning objective is therefore twofold: (i) to explain why Step 2 uses an exact GBM update rather than a generic Euler-type update, and (ii) to prepare students for richer specifications (e.g., stochastic volatility or interest-rate models) where exact transitions are unavailable and EM becomes indispensable.

Simulation grid and Brownian increments. As in Steps 1–2, we work on an equally spaced grid with M steps over $[0, T]$, so that $\Delta t = T/M$, and we simulate I independent paths indexed by $i = 1, \dots, I$. For each step we use

$$\Delta W_n = W_{t_{n+1}} - W_{t_n} \sim N(\mathbf{0}, \Delta t), \quad \Delta W_n = \sqrt{\Delta t} \mathbf{Z}_{n+1}^{(i)}, \quad \mathbf{Z}_{n+1}^{(i)} \sim N(\mathbf{0}, \mathbf{1}) \text{ i.i.d.}$$

GBM under the risk-neutral measure: exact discretization (Step 2). In Step 2, the stock price follows Geometric Brownian Motion (GBM) under the risk-neutral measure with continuous dividend yield y :

$$dS_t = (r - y)S_t dt + \sigma S_t dW_t, \quad (2)$$

where (r, y, σ) are exactly the parameters defined in Step 1. Applying Itô's lemma to $\log S_t$ yields

$$d \log S_t = \left((r - y) - \frac{1}{2} \sigma^2 \right) dt + \sigma dW_t.$$

Integrating over $[t_n, t_{n+1}]$ and using $\Delta W_n = \sqrt{\Delta t} Z_{n+1}$ gives the exact one-step transition:

$$S_{t_{n+1}} = S_{t_n} \exp \left(\left((r - y) - \frac{1}{2} \sigma^2 \right) \Delta t + \sigma \sqrt{\Delta t} Z_{n+1} \right), \quad Z_{n+1} \sim N(0, 1). \quad (3)$$

This discretization is exact in the sense that it reproduces the correct lognormal conditional distribution of $S_{t_{n+1}}$ given S_{t_n} for any step size Δt , and it preserves positivity ($S_{t_n} > 0$ almost surely). Hence, when an exact transition is available, it is typically preferred because it avoids unnecessary discretization bias in the simulated terminal distribution S_T .

From exact discretization to Euler–Maruyama method (EM): when exact transitions are unavailable. To move beyond settings with an exact discrete-time transition, let X_t denote a continuous-time state variable evolving according to the Itô diffusion

$$dX_t = u_t(X_t) dt + \sigma_t(X_t) dW_t, \quad (4)$$

where $u_t(\cdot)$ is the drift and $\sigma_t(\cdot)$ is the diffusion coefficient. If a closed-form transition for $X_{t+\Delta t} | X_t$ is not available, we approximate (4) on the simulation grid using the Euler–Maruyama method (EM):

$$X_{t_{n+1}}^{(i)} = X_{t_n}^{(i)} + u_{t_n}(X_{t_n}^{(i)}) \Delta t + \sigma_{t_n}(X_{t_n}^{(i)}) \sqrt{\Delta t} Z_{n+1}^{(i)}, \quad Z_{n+1}^{(i)} \sim_{\text{iid}} N(0, 1). \quad (5)$$

Unlike (3), EM is an approximation whose accuracy depends on Δt (hence M): smaller time steps typically reduce discretization error but increase computation.

OU as a benchmark: exact transition exists, EM illustrates discretization error.

As a transparent mean-reversion benchmark, consider the Ornstein–Uhlenbeck (OU) process

$$dX_t = -\theta X_t dt + \sigma_X dW_t, \quad \theta > 0, \sigma_X \geq 0. \quad (6)$$

OU admits an exact transition:

$$dX_{t_{n+1}} = e^{-\theta \Delta t} X_{t_n} + \sigma_X \sqrt{\frac{1 - e^{-2\theta \Delta t}}{2\theta}} Z_{n+1}, \quad Z_{n+1} \sim N(0, 1) \quad (7)$$

and thus does not require EM for simulation. We include OU here because it provides a controlled environment in which students can compare an exact scheme (7) to the EM approximation

$$X_{t_{n+1}}^{(i)} = X_{t_n}^{(i)} - \theta X_{t_n}^{(i)} \Delta t + \sigma_X \sqrt{\Delta t} Z_{n+1}^{(i)}, \quad (8)$$

thereby making discretization error and the role of Δt concrete and measurable. This comparison is meant to highlight two practical lessons. First, Euler–Maruyama is best viewed as a generic discretization device rather than a model-specific necessity: it is indispensable precisely in settings

where no closed-form transition is available, but it can be stress-tested most cleanly when an exact benchmark exists. Second, the exercise makes the consequences of time discretization operational. A finite step size does not merely introduce an abstract approximation error; it can systematically alter economically salient features of the simulated data—such as persistence, long-run dispersion, and the accuracy of moment-based targets—thereby affecting both inference and downstream Monte Carlo outputs. By varying the step size, students can directly observe the trade-off between computational cost and numerical accuracy and develop disciplined guidelines for selecting a discretization grid in more complex diffusion models.

Why this matters for option-pricing Monte Carlo. In option pricing, the Monte Carlo estimator depends on the simulated terminal distribution (e.g., S_T in $\max(S_T - K, 0)$).

When an exact transition is available (GBM in (3), OU in (7)), using it avoids unnecessary discretization bias. In contrast, Euler–Maruyama becomes indispensable for richer specifications without a convenient closed-form transition, such as the Cox–Ingersoll–Ross (CIR) square-root diffusion and the Constant Elasticity of Variance (CEV) model, as well as multifactor nonlinear systems (e.g., stochastic volatility models). This perspective clarifies the role of Step 2’s exact GBM simulation and prepares students to extend the notebook to advanced continuous-time specifications.

3. Collaborative Project: Designing and Valuing Custom Option Payoffs

To deepen students’ understanding of Monte Carlo simulation and option valuation, this section introduces a group-based experiential learning project. Building on the foundational knowledge and coding practice established in Section 2, students are now tasked with modifying the core option pricing function to evaluate non-standard payoff structures. This transition from replication to creation is designed to foster critical thinking, model experimentation, and collaborative problem-solving.

The project centers around the following core function, which students have previously encountered:

[1]:

```
def mc_price_once(S0, r, y, sigma, T, M, I, K, option_type='call'):
    ...
    if option_type == 'call':
        payoff = np.maximum(ST - K, 0.0)
    elif option_type == 'put':
        payoff = np.maximum(K - ST, 0.0)
```

In this assignment, students will modify the payoff component to create their own option structure—for example, capped payoffs, range-bound conditions, exotic hybrids, or even time-averaged variants. They are encouraged to justify the financial rationale of their design, simulate its pricing using Monte Carlo methods, and analyze the implications of their model results.

Educational Rationale

This project is grounded in constructivist learning theory (Vygotsky, 1978; Piaget, 1970), which emphasizes that learners construct knowledge most effectively through active engagement and contextual problem-solving. Rather than simply applying a known formula, students must conceptualize and encode a payoff function that reflects real-world risk scenarios—an exercise that bridges mathematical theory with financial application.

It also embodies Biggs (1999) principle of constructive alignment, aligning learning outcomes (e.g., simulation design, pricing interpretation) with the assessment tasks (code accuracy, financial reasoning, and presentation). Furthermore, the collaborative nature of the project reflects Kolb's experiential learning cycle (1984), allowing students to move through stages of abstract modeling, coding implementation, empirical observation, and reflective interpretation. Importantly, this simulation-based group project is grounded in the principles of active learning, which emphasize learner engagement through meaningful activities and immediate application. Prince (2004) provides a comprehensive review of the literature, concluding that active learning—particularly in the forms of collaborative problem solving and student-led inquiry—consistently improves student understanding and retention across technical disciplines. This is further supported by Freeman et al. (2014), whose meta-analysis found that active learning significantly enhances student performance and reduces failure rates in STEM education. In this spirit, the proposed group project is designed not only to teach option pricing, but also to promote deep learning through problem-solving, collaboration, and ownership of the modeling process.

Project Objectives and Implementation Structure

By the end of the project, students should be able to:

- Formulate and mathematically define a novel option payoff.
- Justify the structure in the context of financial markets or investor behavior.
- Implement the payoff logic in Python using a Monte Carlo simulation engine.
- Generate and interpret option prices, including confidence intervals.
- Communicate results in a clear, structured report or notebook.

Each group (3–4 students) will be guided through the following milestones:

Table 2
Weekly Project Deliverables

Week	Deliverable
Week 1	Proposal submission with payoff logic and financial motivation
Week 2	Code draft review and checkpoint meeting with instructor
Week 3	Complete simulation results, confidence intervals, visualizations
Week 4	Final notebook/report + 10-minute group presentation

Acceptable Deliverables:

- A well-annotated Jupyter Notebook (.ipynb), or structured PDF report.
- Code must be functional and reproducible.
- Visualizations of price paths, payoff distributions, or scenario analysis.

Suggested Payoff Variations

To inspire creativity and ensure feasibility, the following ideas can be provided:

Table 3
Suggested Payoffs

Option Type	Description
Capped Call	$\min(\max(S_T - K, 0), C)$
Digital Call	Pays fixed amount if $S_T > K$; zero otherwise
Asian Option	Payoff based on average price over time
Range Option	Positive payoff only if $S_T \in [L, U]$
Knock-Out Option	Pays nothing if S_t ever crosses a barrier
Hybrid Exotic	Combination of Asian + barrier or capped + digital structures

Evaluation Rubric

To ensure consistency, transparency, and alignment with the intended learning outcomes, student performance in the group project is assessed using a structured evaluation rubric. The rubric emphasizes not only technical correctness and analytical depth but also the clarity of financial reasoning, reproducibility of code, and quality of communication. This multidimensional approach reflects the competencies required in real-world financial modeling—where technical implementation must be paired with rigorous justification and effective presentation.

As shown in Table 4, the evaluation criteria are distributed across five core dimensions: correctness of code, financial justification, analytical insight, report quality, and teamwork. This design encourages students to demonstrate both domain knowledge and transferable skills, such as collaboration and communication. Instructors may also incorporate peer evaluation mechanisms to assess individual contributions within teams.

By designing and evaluating their own derivative instruments, students move from passive application to creative construction of pricing models. This process reinforces the stochastic intuition behind Monte Carlo simulation, cultivates Python programming proficiency, and encourages financial innovation. Furthermore, by engaging in team-based inquiry and peer feedback, students develop soft skills that mirror real-world financial engineering practice.

Table 4
Evaluation Criteria for Student Group Projects on Option Pricing

Criterion	Weight	Description
Correctness of Code	30%	Accurate implementation of the payoff logic and pricing engine
Financial Justification	20%	Clear economic motivation and relevance of option structure
Result Analysis	20%	Depth of simulation analysis, insight from confidence intervals
Report Quality	20%	Clarity, reproducibility, documentation, visuals
Teamwork & Presentation	10%	Peer collaboration, oral presentation, Q&A readiness

Conclusion

In 1997, Robert C. Merton and Myron Scholes were awarded the Nobel Prize in Economic Sciences in recognition of their groundbreaking contribution to financial theory—the Black-Scholes option pricing formula. Their work laid the mathematical foundation for modern financial engineering, offering a closed-form solution to value European-style options under assumptions of no arbitrage and continuous trading. Despite its elegant formulation and analytical tractability, the Black-Scholes model is often perceived by students as abstract and mathematically intimidating, particularly when taught through conventional lecture-based instruction that emphasizes stochastic calculus and partial differential equations.

This pedagogical challenge presents a dilemma: emphasizing mathematical rigor may alienate learners without strong technical backgrounds, while oversimplification risks undermining conceptual depth. This pedagogical challenge presents a dilemma: emphasizing mathematical rigor may alienate learners without strong technical backgrounds, while oversimplification risks undermining conceptual depth. Compounding this challenge is the practical reality that many modern derivative products—such as Asian options, barrier options, and other path-dependent contracts—lack closed-form solutions altogether. As such, reliance on numerical procedures, especially Monte Carlo simulation (MCS), is not just a pedagogical choice but a practical necessity.

To bridge this gap between theory and practice, this article advocates for a modernized, Python-based approach to teaching option pricing. By embedding Monte Carlo simulations in an interactive Jupyter Notebook environment, instructors can demystify abstract concepts through executable code, visual feedback, and incremental exploration. Students not only engage more deeply with the probabilistic structure of financial models but also acquire transferable skills in computational finance and data-driven reasoning.

Grounded in simulation-based learning and constructivist pedagogy, the instructional framework presented in this study promotes both conceptual clarity and practical proficiency. The integration of hands-on implementation and group-based experimentation enables learners to internalize complex ideas by actively constructing knowledge through modeling, iteration, and reflection.

Ultimately, incorporating Monte Carlo simulation into the curriculum serves a dual imperative: to modernize the delivery of financial education and to equip students with tools suited to the

pricing of increasingly complex financial products. In doing so, it transforms option pricing pedagogy from a purely theoretical exercise into an applied, exploratory process that mirrors real-world analytical challenges.

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Understanding Your Student Loans: A Personalized Case Study

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This paper outlines an active learning Excel based personalized case study for an introductory finance course utilizing the student's own student loan data. The purpose of this assignment is twofold: to create student "buy in" by demonstrating the relevance of the course material, and to practice basic of time value of money & amortization calculations. This project was run at two separate US colleges between 2011 and 2024. Student feedback was largely positive and indicated increased engagement and understanding of course material.

Keywords: Finance Pedagogy, Time Value of Money, Financial Literacy, Excel, Student Engagement

Introduction and Literature Review

As any professor of an introductory finance course can attest, student engagement is a challenge. In my experience, aside from the one or two majors in a typical class of 35 students, the vast majority are just there to fulfill a requirement. The goal therefore becomes, how can I quickly and effectively create student "Buy-in"? One of the primary keys to obtaining student buy-in is making the material relevant to the students (Burke, 2006). In 2012, 71% of all students graduating from four-year colleges had student loan debt, averaging between \$25,550 and \$32,300 for public and private colleges respectively (ICAS fact sheet, 2014) so clearly, loans are relevant. Additionally, the use of personal loans meshes well with the movement towards a focus on personal (rather than managerial finance) as the foundation of introductory finance courses as advocated by Vihtelic (1996). The effectiveness of the of board personalized financial planning exercises has been documented by Butcher (2016) and Gunmison et al (2015); the advantage of this project is that it focuses solely on student loans so it can serve as a separate standalone project rather than a course long assignment.

One of this issues often raised in the TVM instruction literature is the risk that students focusing on the mechanics of the calculations will lose an application for the underlying concepts on which the calculations are based (Delaney, Rich & Rose, 2016). For this reason, the project includes periodic analysis questions which clearly link the calculations to the relevant course content namely, annuity and amortization calculations. The assignment is designed for Excel because most calculations done "on the job" are done using spreadsheets (as opposed to financial calculator) (Bloski, 2012) and because employers expect job candidates to have strong Excel skills (Formby et al., 2017).

The Assignment

Understanding Your Student Loans

The purpose of this project is to familiarize you with your student loan debt. This exercise will walk you through gathering your current student loan information, calculating your loan debt and

determining exactly how much you will pay in total for your education. This personalized active learning case study will review basic time value of money calculations and amortization tables in Excel.

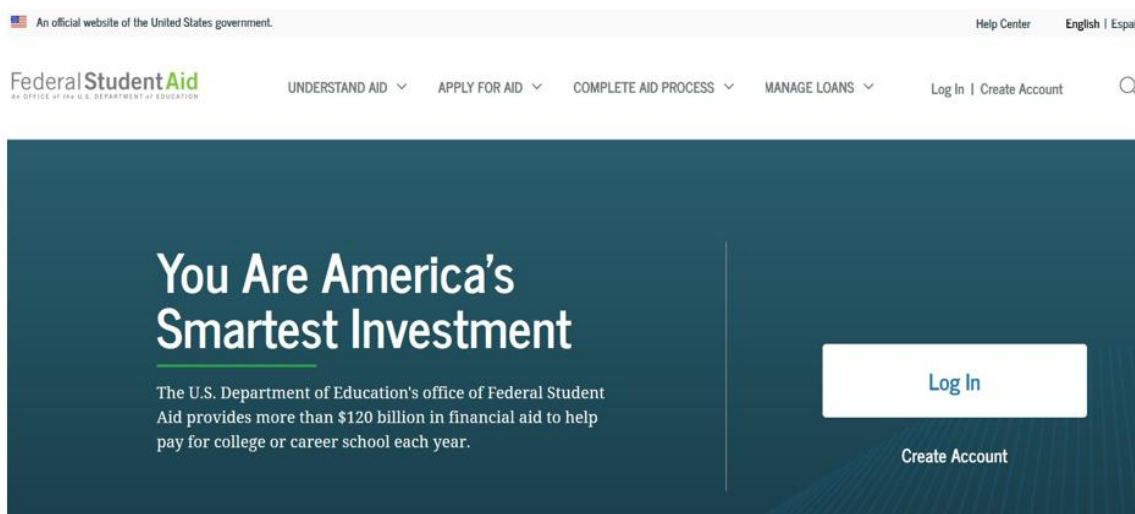
Please **print or screenshot** and **highlight** all relevant information as instructed.

While assignments submitted through Canvas are graded anonymously, the files I will be asking you to upload in step 1 show your name and financial information. To protect your privacy, you may black out your name in step 1 and change interest rates and loan amounts in step 2. You may also request for your assignment data to be deleted after you receive feedback. *If you do not have student loans, or are uncomfortable randomizing and blacking out sensitive data, you may request may complete the project using sample data.*

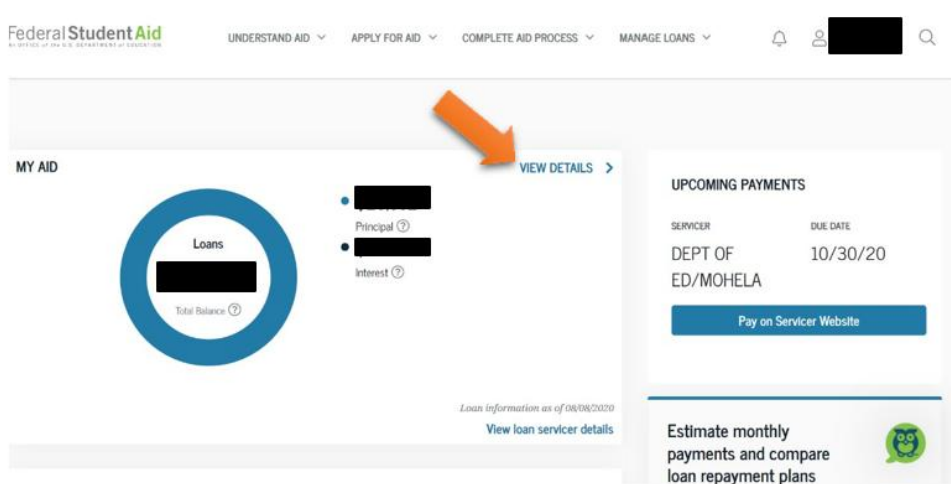
Step 1: Gather the data

You will need a full list of your loans along with their interest rates, loan origination fees, and principal and interest balances. The steps to gather this data are listed below.

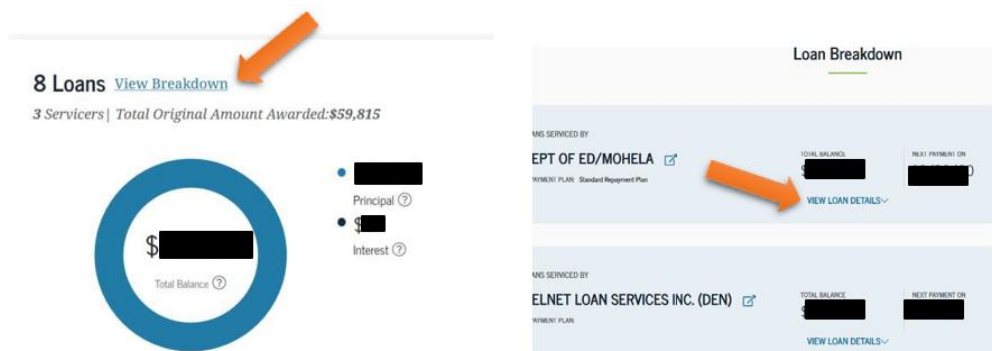
For government loans you obtained by filling out the FASA form go to: <https://studentaid.gov/>



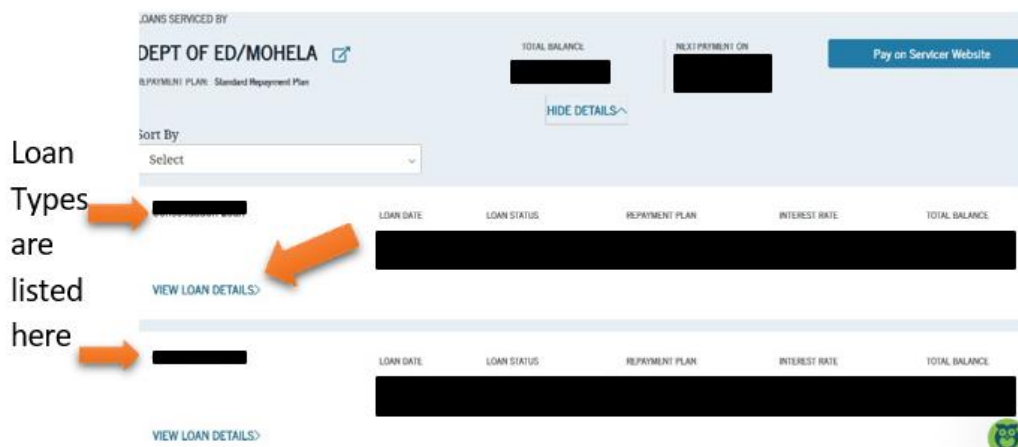
- Select “Log In”
 - Enter your username and password and select LOG IN if you already have an *FSA ID*. If you do not have an *FSA ID*, select the “Create An *FSA ID*” tab. This will require you to enter your Social Security number.
 - This will bring you to this page. **Screenshot this page**, then click “View Details”



- Next you will see a loan summary pie chart. This pie chart summarizes the total interest and principal for all of your current student loans. Click “View Breakdown” to see the loans that you have taken out so far. **Screenshot these pages**



- Now you will examine each loan individually by clicking “View Loan Details” under each loan. **Screenshot this page.** Your screen should look like this:



For **PRIVATE** loans you need to look at your Student Account Statement. Examples of private loans include loans from: Discover, CITI, WellsFargo, Chase, and Sallie Mae.

This sample statement shows both **public** and **private** loans as well as **grants and Scholarships**

DATE	STATEMENT ACTIVITY	CHARGE	CREDIT
03/17/2020	Spring 2020 - Snackbar Purchases		
05/06/2020	Spring 2020 - COVID19 Room Adjustment		
05/06/2020	Spring 2020 - COVID19 Meal Plan Adjustment		
08/20/2019	Fall 2019 - On-Line Credit Card Payment		
08/26/2019	Fall 2019 - SALLIE MAE BANK		
09/04/2019	Fall 2019 - Presidential Scholarship		
09/04/2019	Fall 2019 - Trustee Grant		
09/04/2019	Fall 2019 - Direct Unsubsidized Stafford Loan		
09/04/2019	Fall 2019 - Direct Subsidized Stafford Loan		
10/17/2019	Fall 2019 - Trustee Grant		
10/17/2019	Fall 2019 - Pennsylvania State Grant		
10/30/2019	Fall 2019 - On-Line Credit Card Payment		
11/07/2019	Fall 2019 - On-Line Credit Card Payment		
01/14/2020	Fall 2019 - On-line Credit Card Payment/NQ		
01/27/2020	Spring 2020 - SALLIE MAE BANK		
02/06/2020	Spring 2020 - Presidential Scholarship		
02/06/2020	Spring 2020 - Trustee Grant		
02/06/2020	Spring 2020 - Pennsylvania State Grant		
02/06/2020	Spring 2020 - Direct Subsidized Stafford Loan		
02/06/2020	Spring 2020 - Direct Unsubsidized Stafford Loan		

UNLESS YOU ARE A GRADUATING SENIOR, YOU WILL NEED TO ESTIMATE YOUR FUTURE LOAN AMOUNTS AND INTEREST RATES:

Your financial aid package and loan amounts may change from year to year for a variety of reasons. For example, if you rely on grants and scholarships which require you to maintain a certain GPA and you fail to meet that standard, you may need to take out additional loans to compensate for the loss of that aid. Conversely, strong academic performance in one semester may make you eligible for additional scholarships the next semester, thus reducing your loans. Your family’s expected financial contribution also plays a key role. Significant changes in family income, such as a raise or bonuses, can increase (decrease) your family's expected financial contribution, thus decreasing (increasing) need-based aid. If your family is unable to cover these added costs, you may need to take out additional loans. Your projected future loans are a “best guess” based on loan eligibility limits and your assessment of your family’s financial situation.

The maximums for the government's Stafford program can be found at:

<https://studentaid.gov/understand-aid/types/loans/subsidized-unsubsidized>

Scroll to the middle of the page. You are looking for this chart:

Year	Dependent Students (except students whose parents are unable to obtain PLUS Loans)	Independent Students (and dependent undergraduate students whose parents are unable to obtain PLUS Loans)
First-Year Undergraduate Annual Loan Limit	\$5,500-No more than \$3,500 of this amount may be in subsidized loans.	\$9,500-No more than \$3,500 of this amount may be in subsidized loans.
Second-Year Undergraduate Annual Loan Limit	\$6,500-No more than \$4,500 of this amount may be in subsidized loans.	\$10,500-No more than \$4,500 of this amount may be in subsidized loans.
Third Year and Beyond Undergraduate Annual Loan Limit	\$7,500 per year-No more than \$5,500 of this amount may be in subsidized loans.	\$12,500-No more than \$5,500 of this amount may be in subsidized loans.

Look at your previous and current loans. Are you receiving the maximum allowable amount each year? If so, and you do not anticipate that your family's expected contribution will increase dramatically, you should estimate that you will continue to take the maximum amount for each year. For example, a student who took out \$3,500 in subsidized loans and \$2,000 unsubsidized loans as a Freshman then \$4,500 in subsidized loans and \$2,000 unsubsidized loans as a Sophomore can reasonably expect to take \$5,500 in subsidized loans and \$2,000 unsubsidized loans as a Junior and Senior.

Step 2: Understand your current debt levels

1. How much did I borrow?
 - Add up the principal balances of your loans
2. How much do you owe today?
 - This is your loan balance which is the principal plus all accrued interest
3. What type of loans did/ will you take out?
 - Are your loans Public (from FASFA) or Private? What is the difference?
 - Are your loans subsidized or unsubsidized? What is the difference?
4. What are your interest rates?
 - If you have both Private and public loans, how do the interest rates compare? How would you explain these differences based on your understanding of risk?
5. When do you need to start repaying these loans?
6. What risks could prevent you from making your scheduled payments (job loss, illness, etc.)
 - What do I do if I can't make my scheduled payments?

Step 3: Calculate your payments

This section will walk you through calculating your total outstanding loan balances as well as the standard repayment scenarios.

1. Calculate the minimum monthly payment you will need make to repay each of your loans in 10 years (this is the standard repayment schedule)
 - PMT(rate, nper, pv) *** make sure to make rate and nper monthly and enter the PV as negative*****
 - Ex: Calculate the monthly payment of a 10 year \$5,000 loan at 6%:*
 $=PMT(6\%/12, 10*12, -5000)$
 - Do this calculation for each current and predicted future loan separately then add the payments together to find your total monthly payment.
- a. How much will you end up paying in total for your education if you stick to this payment plan?
 - FV(rate, nper, pmt) *** Make the PMT negative!!!*****
 - Ex: How much will you end up repaying for a 10 year \$36,000 at 6% if you make monthly payments of \$42.94?*
 $=FV(6\%/12, 10*12, -\$42.94)$
 - Do this calculation for each current and predicted future loan separately then add the payments together to find your total monthly payment
2. Calculate the minimum monthly payment you will need make to repay your loans in 25³ years (the maximum possible extension for government loans)
 - b. How much will you end up paying in total for your education if you stick to this payment plan?
3. Do you prefer the 10 or 25 years repayment plan? Why?

Step 4: Analyze repayment scenarios

This section involves amortization tables which show the allocation of payments across interest and principal.

For simplicity, these instructions ask you to consolidate all of your loans into one amortization schedule which will introduce some rounding errors. You can avoid these rounding errors by creating amortization tables for each loan separately.

4. Calculate the weighted average interest rate to consolidate all of your loans into a single amortization table.
 - Ex: You have 3 loans for \$10,000, \$5,000 and \$12,000. Their interest rates are 4%, 3.5% and 6% respectively. Calculate the weighted average interest rate.*
 - Step 1: Calculate the total outstanding loans: =SUM(10000, 5000, 12000)=27,000*
 - Step 2: Calculate the ratio of each loan to the total outstanding loans*
 - Loan 1: $10000/27000= 37\%$*
 - Loan 2: $5000/27000=18.5\%$*
 - Loan 3: $12000/27000=44.5\%$*
 - Step 3: Use the ratios in step 2 and the interest rates to calculate the weighted average interest rate*

$$13\%(4\%)+18.5\%(3.5\%)+44.5\%(6\%)=4.8\%$$

³ A 25-year repayment plan may not be possible for some private loans. Please read the terms of your loan to see if a repayment timeline was agreed to when you took out the loan.

5. Use the weighted average interest rates to create amortization tables⁴ showing how your loans will be repaid in the 10 year time horizons based on the payments you calculated above.

Ex: Set up an amortization table for a 4-year \$1,000 with a 10% interest rate.

Year	Balance	Interest Due	Payment	Amortization
1	1,000	.1(1000)= 100	315.47	315.47-100= 215.47
2	1000-215.47= 784.53	.1(784.53)= 78.45	315.47	315.37-78.45= 237.02
3	784.53- 237.53=547.51	.1(547.51)= 54.75	315.47	315.47-54.75= 260.72
4	547.51- 260.72=286.79	.1(286.79)= 28.68	315.47	315.47- 28.68=286.79

*** This example is annual but you will make monthly payments on your loans. Don't forget to divide your weighted average interest rate by 12 to reflect this change. This way your interest rate and payments (calculate above) will both be on a monthly basis.

6. Use the weighted average interest rates to create amortization tables⁵ showing how your loans will be repaid in the 25 year time horizons based on the payments you calculated above.

7. Use these tables to show how long it will take you to repay your loans if you increase your monthly payments by 15%. **Note, you are doing this twice: once for the 10 year plan and once for the 25 year plan**

Ex: Suppose you make monthly payments of \$399.67. An increase of 15% would make your new loan payment: $\$399.67 \times (1.15) = 459.6205$

a. **EXPLAIN THE RELATIONSHIP YOU SEE**

8. You receive \$10,000 five years after graduation which you use to pay down your loans

EX: Reduce the loan balance by \$10,000 in month 1 of year 5.

a. **BASED ON THESE CALCULATIONS IS IT BETTER TO INCREASE YOUR PAYMENTS CONSISTENTLY OR PAY OFF A LARGE LUMP SUM OR AT A LATER DATE? WHY?**

9. Additional questions to consider:

- How do your expected career earnings influence your repayment choices (e.g., 10-year vs. 25-year plan)?
- What is the trade-off between aggressively repaying student loans and simultaneously saving for retirement or other long-term goals?
- How does your personal repayment plan align with your long-term financial values (e.g., risk aversion, security, flexibility)?

⁴ Your amortization tables may not end at exactly 120 or 300 months due to rounding errors

⁵ Your amortization tables may not end at exactly 120 or 300 months due to rounding errors

Project implementation

This project was run during 15 “regular⁶” semesters across two separate US colleges between 2011 and 2024. It was incorporated into the first finance course at each institution known as Foundations of Financial Management and Financial Management respectively. Both classes used Brigham and Houston’s Foundations of Financial Management as the primary text and the assignment was completed in tandem with chapter 5 “time value of money”. The project was originally scaffolded across 2 submissions on the schools LMS (Canvas). Submission 1 corresponded to steps 1 & 2 where students asked students to access and upload their data as screenshots and enter the data into Excel in preparation for analysis. This submission corresponded with the beginning of the chapter. Students expressed frustration with accessing and interpreting the data which often delayed the submission of this step. Some needed to contact their parents for access, others were unable to use the campus financial aid portal.

Some students who expressed concerns about data privacy were unsure how to properly obscure sensitive information or alter numerical values in their screenshots. Additionally, students often assumed that the initial summary screen contained all the data that they needed, so they would skip the loan breakdown step. This led to confusion in the analysis because they did not know which interest rates applied to which loans in their subsequent analysis. To better support the students, this initial assignment was spun off to a separate submission. Once students received feedback that their initial loan balance and interest rate were correct for each of the loans they examined, they could proceed to new the second submission asked students to up students, from step 1 in Excel using a provided template (available upon request) and answer the questions in analytical questions step 2. The third submission corresponded with step 3 and was always due after we had covered annuity calculations in class. The final submission, step 4, corresponded with the discussion of amortization in class.

Scaffolding the assignment into sequential steps: first understanding current debt levels, then calculating payments, and finally analyzing repayment scenarios provided students with a structured pathway that reduces cognitive overload and builds confidence in progressively mastering financial literacy skills. This approach aligns with the principles of Universal Design for Learning (UDL), which emphasize offering multiple means of representation, engagement, and expression to support diverse learners. By first grounding students in the foundational knowledge of their debt, then guiding them through applied calculations, and ultimately encouraging them to evaluate repayment options, the assignment accommodates varied levels of prior knowledge while ensuring equitable access to higher-order analytical tasks. In doing so, the scaffolded design not only enhances accessibility but also promotes deeper conceptual understanding and the transfer of skills to real-world financial decision-making.

Student Feedback

Students were asked to evaluate the assignment by answering the following questions based on a 5-point Likert scale where (1) represented Strongly Disagree and (5) represented Strongly Agree:

- This assignment was relevant to me
- This assignment improved my understanding of annuity calculations

⁶ The assignment was also included in two interim (3 week) sessions but these are not included in the analysis because the project was completed during class

- This assignment improved my understanding of amortization
- I found this assignment engaging
- I would like to see more assignments like this

These evaluations were completed in class the day the assignments were due (but before grades were received). Based on enrollment the total potential sample size was 526 students; however, a total of 45 students across the 15 semesters were absent on the due date and thus did not participate in these evaluations. Additionally, roughly two or three students per semester did not have student loans, these students (42 in total) completed alternate projects; hence, their evaluations were excluded from the analysis. The ending sample size is 439. The following table shows the percentage respondents who rated the assignment as either a 4 or 5 in each of the categories:

Number of Responses	439
This assignment was relevant to me	91%
This assignment improved my understanding of annuity calculations	78%
This assignment improved my understanding of amortization	86%
I found this assignment engaging	81%
I would like to see more assignments like this	84%

As this table clearly shows, overall student response to the project was largely positive. Follow up questions revealed that the most common reason for the low rating on question 5, “I would like to see more assignments like this,” was that students felt that the assignment was “too challenging”, or “too much work.”

Several students also choose to comment on this assignment in their end of course evaluations. Here are a sample of the most positive, negative and random statements:

- “The student loan project was long and detailed. It made me want to cry, but at least now I know what I owe. Also, it made me think differently about the calculations we did in class.”
- “I liked this better than the retirement problems and car loan examples in the text because it was more ‘real’ to me. Because we used my loans I paid more attention and actually cared to learn the Excel, before it was just a new kind of problem.”
- “I didn’t realize how much I would be repaying on my loans.”
- “I hated the student loan project! It was long and there were way to(o) many interpretations! Why couldn’t you just grade the calculations?”

Qualifying note and data limitations.

Since I was the sole professor teaching the introduction to finance course, there was no “control group” of students who did not complete this assignment. Future research is needed to truly examine the effectiveness of the project on overall student learning outcomes.

Conclusion and Applications

The purpose of this assignment is twofold: to create student “buy in” by demonstrating the relevance of the course material, and to practice basic of time value of money & amortization

calculations. The personalized nature of the project dovetails well into the active learning methodology because students have a desire to understand their future loan repayments. It is my hope that other students and professors will find this assignment useful.

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