

# Digital Finance Coursework

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**Module name:** Digital Finance

**Module code:** COMP0164

**Academic year:** 2023-24

**Term 1, 2 or 3:** Term 1

**Nature of assessment:** Group

## **Section Content**

- A. Core Information
- B. Coursework Brief and Requirements
- C. Assessment of This Coursework
- D. Group Instructions

## Section A: Core Information

Feature	Description
This assessment is marked out of	100 marks
% weighting of this assessment within the total module mark	70%
Academic misconduct (including plagiarism)	Academic Misconduct is any action or attempted action that may result in a student obtaining an unfair academic advantage. Refer to Academic Manual Section 9: Student Academic Misconduct Procedure - 9.2 Definitions.
Submission date & time	16:00 (UK time) on 07 December 2023
Penalty for late submission	Standard UCL penalties apply. Students should refer to the <a href="#">UCL Academic Manual</a> . If you encounter problems, issues, challenges which fall under the scope of Extenuating Circumstances, please apply to the Computer Science Department.
Submitting your assignment	The assignment MUST be submitted to the module submission link located within this module's Moodle 'Submissions' tab by the specified deadline. Submissions should be as both a pdf of your work and the Jupyter Notebook of your work. For questions 1-6 you should comment your python code and show your formulas and working steps in markdown.
Anonymity of identity	Normally, all assignments are anonymous unless the nature of the assessment e.g. video, presentation, group work, is such that anonymity is not possible.

## Section B: Coursework Brief and Requirements

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This assignment will require you to apply what you have learnt in the lectures, tutorials and covered in the reading materials to answer six questions.

You should submit your answers as both a Jupyter Notebook written in python of your code and markdown, as well as an exact pdf copy.

For each question where a numerical answer is required, you should show the python code that you used to compute the answer and the relevant formulas and working steps to solve the problem. If you do not include each of these in your answers, you will only gain partial marks. The final answer for each question should be printed out below the cell it was obtained in.

**[5 marks]** are available for the structure, clarity, language, mathematical notion and overall presentation of your coursework.

## Scenario Setting

Conglomerates are companies that hold assets including other companies and involve themselves directly into the operations of their subsidiaries. Therefore, it is common for conglomerates to evaluate the business projects of their holdings to understand the returns of these projects.

Suppose that you are an executive director working for a conglomerate called Accretion and your job is to assist various operations of the subsidiaries that exist under Accretion, and then report back to the stakeholders.

### Question 1 [16 marks]

You are asked to evaluate businesses and investment ideas on behalf of Accretion as part of their portfolio reshuffling.

Boogle is one of the conglomerate's largest holdings. During the latest earnings report, Boogle's CFO announced an investment of \$150 million for a new business expansion project. The project is planned to be financed with an \$100 million public offering of a 10-year debt and the remainder with an equity offering. You have collected the information necessary to evaluate this project in Exhibits 1 and 2.

#### Exhibit 1: Relevant Information for Analysis

Equity risk premium	4.93%
Risk-free rate of interest	4.3%
Market value of Boogle's debt	\$1.0 billion
Market value of Boogle's equity	\$2.6 billion
Boogle's equity beta	1.3
Boogle's before-tax cost of debt	9.4%
Corporate tax rate	37.5%
Corporate tax rate	37.5%

#### Exhibit 2: Estimated Project Financials

	Year 1	Year 2	Year 3
Revenue	96.7	111.2	115.44
Operating Costs	32	36	38
Depreciation	16	16	16

a.) Calculate the weighted average cost of capital of Boogle prior to its new project investment. **[3 marks]**

- b.) Find Boogle's asset beta prior to the new project. **[2 marks]**
- c.) Assuming the new project has the same asset beta as the Boogle company in b.), find the the project equity beta. **[2 marks]**
- d.) The formula for project after-tax free cash flow at time  $t$  is

$$FCF = (\text{Revenue} - \text{Operating Costs} - \text{Depreciation}) \times (1 - \text{Tax Rate}) + \text{Depreciation}$$

Define a Python function to calculate the project FCFs and demonstrate that the after-tax free cash flow generated for the next three years are \$46.4 million, \$53 million, and \$54.4 million respectively. **[2 marks]**

- e.) Find the project NPV and IRR with the next three years after-tax free cash flow given in d.). **[2 marks]**

You also aim to add dividend-paying stock to the conglomerate's portfolio of holdings. You begin by reviewing the following candidates:

### **Candidate 1:**

Atat Steel is in the steel manufacturing sector with a required rate of return of 7.35%. You estimate that if the economy is booming, the company's current annual dividend of \$0.7 per share will grow 11.5% a year for the next four years and then stabilize at a 3.5% growth rate a year indefinitely. However, if the economy falls into a recession, then Atat Steel will not likely experience the elevated 11.5% short-run growth and instead will grow by 3.5% indefinitely.

### **Candidate 2:**

GT&T company is a mature company with a stable capital structure. The company had an EPS of \$2 in 2023. The earnings in the next year without the additional planned investments are expected to remain at \$2. The earnings retention ratio is 0.60. The company is expected to earn an ROE of 15% on its investments, and the required rate of return is 12%. Assume that all dividends are paid at the end of the year.

- f.) Use the discount dividend method and find the current value of Atat Steel stock under both economic conditions. **[3 marks]**
- g.) Calculate GT&T's sustainable growth rate, find the value of the company's stock at the beginning of 2024 and determine the company's present value of growth opportunities. **[2 marks]**

## Question 2 [15 marks]

One of the businesses owned by Accretion, Nautilus is a machine tool manufacturer and system integrator, specialising in precision hydraulics for large-scale industrial applications.

Nautilus currently has several ground-breaking patents, on the stabilisation of structural columns for large-scale industrial developments in difficult soil conditions. This is planned to revolutionise the industry and be a massive boom for the future of Nautilus. The bond market has not reacted to this reveal of information for a whole year. With a new windfall from a successful year, Nautilus plans to repurchase some bonds it has already issued onto the market, thus you're tasked to evaluate these issued bonds.

### Exhibit 3: Current Par Yield and Spot Rates

Maturity	Par Rate (Annual Coupon)	Spot Rate (Annual Coupon)
1 year	2.50%	2.50%
2 years	2.99%	3.00%
3 years	3.48%	3.50%
4 years	3.95%	4.00%
5 years	4.37%	?

### Exhibit 4: Information for Selected Bonds

Bond Name	Maturity	Coupon	Type of Bond
Bond A (Face value \$1,000)	3 years	6.40% annual	Option-free
Bond B	3 years	4.30% annual	Callable at par on start of year 1 and year 2
Bond C	3 years	4.30% annual	Puttable at par on start of year 1 and year 2

**Exhibit 5: Binomial Interest Rate Tree, based on an estimated interest rate volatility of 10%, where 'u' represents an up move and 'd' represents a down move.**

Year 0	Year 1	Year 2
2.2500% (r)	3.5930% (ru node)	4.6470% (ruu node)
	2.9417% (rd node)	3.8046% (rud node)
		3.1150% (rdd node)

a.) Based on Exhibit 3, find the five-year spot rate. **[2 marks]**

b.) Assuming the law of one price, use Exhibit 3 to calculate the forward rate of a one-year loan starting

in three years. **[1 mark]**

c.) Given spot rates for one-, two-, and three-year zero bonds, how many forward rates can be calculated? Please list the forward rates that can be calculated and briefly explain your answer. **[3 marks]**

d.) Find the yield to maturity for Bond A. You can use the IRR function from NumPy Financial. **[3 marks]**

e.) Based on Exhibit 5, assume an equal probability of interest rate going up and down at each node. Calculate the value of Bond B and Bond C with the binomial tree model. **[3 marks]**

f.) All else being equal, explain the effect of a fall in interest rates on Bond B and Bond C. **[2 marks]**

g.) All else being equal, which bond is most likely to increase in value if interest rate volatility is 15% rather than 10%? Briefly explain your answer. (Hint: consider the value of options) **[1 mark]**

### Question 3 [19 marks]

Uiop, manages the money generated in the conglomerate. As part of your role to be in the know of the many operational parts of Accretion, you've been rotated to the strategic options desk within Uiop, and you've been asked to refresh your knowledge on derivatives and their pricing, by answering these questions.

Consider a stock that is trading at \$100 today. The stock does not generate income/pay dividends. The stock is traded in a well-functioning market with no transaction costs and no restrictions on short sales. Both borrowing and lending can be done in unlimited amounts at the 2% risk-free rate.

- a.) What is the difference between forward contracts and futures contracts (Answers should be no longer than 200 words) **[4 marks]**
- b.) Consider a futures contract on the stock with a maturity of one year. Suppose that the futures price is currently at \$110. Are the futures fairly priced? Describe an arbitrage strategy that would allow you to make a riskless profit. **[2 marks]**
- c.) Same as question b) but suppose that the futures price is currently at \$95. Describe your arbitrage strategy. **[2 marks]**

Suppose that you hold a long position on a European call option that has an underlying asset price of \$57.03, strike price of \$55, risk-free rate of 0.22%, 32% volatility, and time-to-expiration of 0.25. The underlying asset does not have any investment yield.

- d.) Value this call option. **[1 mark]**
- e.) Based on the Black-Scholes-Merton model, describe a portfolio that replicates the call option's payoff. **[1 mark]**
- f.) Define a function to price the option with the binomial tree method. The function should take the number of steps (n) as one of the inputs. You should NOT use list comprehension in the function. **[3 marks]**
- g.) By setting n = 10, 50 and 100, compare and comment on the results under the two methods. **[2 marks]**

When buying two calls with the exercises price of  $x_1$  and  $x_3$  and selling two calls with the exercise price of  $x_2$ , where

$$x_2 = \frac{x_1 + x_3}{2},$$

with the same maturity for the same stock, we call it a butterfly. Consider the following call options for the stock that trades at \$57.03:

Option Name	Strike Price	Call Premium (Price)
Call Option 1	50	10



Option Name	Strike Price	Call Premium (Price)
Call Option 2	55	7
Call Option 3	60	5

h.) Create a graphical representation of the butterfly strategy's payoff. **[2 marks]**

i.) Why might an investor enter into such a strategy? **[2 marks]**

## Question 4 [13 marks]

Suppose that you want to build a portfolio with the stocks (with tickers of) AAPL, GOOG, AMZN and META. You plan to retrieve the relevant Yahoo Finance data with the yfinance Python module from the 1st of Jan. 2017 to 1st of Nov. 2023 (inclusive).

- a.) Calculate the daily returns of these stocks. You should use the adjusted daily closing price. **[1 mark]**
- b) Based on a.), find the covariance matrix of these stocks. **[1 mark]**
- c.) Suppose that the four stocks are equally weighted, find the annualised portfolio expected returns and portfolio variance. **[2 marks]**
- d.) Find the efficient portfolio with the maximum Sharpe ratio. What is the corresponding Sharpe ratio? **[2 marks]**
- e.) Plot the efficient frontier (Without the use of the Plotly library in Python). **[3 mark]**
- f.) Based on the concept of diversification, comment on the current portfolio. How can this portfolio be improved? (Answers should be no longer than 200 words) **[4 marks]**

## Question 5 [14 marks]

A high-profile client Pam, whom you've built a great business relationship with over the years has asked you to quickly double-check some figures for life insurance he has received. You decide to apply the [2015 VBT Unismoke ANB/ALB](#), the Valuation Basic Table (VBT) to using the Age Nearest Birthday (ANB) method, with a valuation interest rate of 5.2% you submit your calculated figures to aid Pam's decision.

Today is 11 November 2023, and the type of life insurance Pam was viewing was permanent life insurance. Pam was born on 25 March 1980, with the health condition standard for her cohort of the same age and gender (Female).

- a.) Calculate Pam's annual unconditional survival rates  ${}_np_x$  from now to age 54. **[4 marks]**
- b.) Calculate Pam's life expectancy in years (to one decimal place). **[3 marks]**
- c.) Calculate the probability that Pam dies exactly between 6 and 9 years from now (to five decimal places). **[3 marks]**
- d.) Calculate the minimum annual premium rate (premium as a fraction of death benefit) that your company should charge for Pam's cohort (to five decimal places). **[4 marks]**

## Question 6 [8 marks]

The conglomerate you are working for, Accretion, decided to digitalize the financial analysis in order to optimize their operations. Since you have expertise in a multitude of financial instruments, you have been tasked to perform the innovation.

Firstly, you are asked to design a tool for computing the zero spot rates using the bootstrap method, and then verify its validity by applying it to Exhibit 6 below.

### Exhibit 6: Spot Rate Table

Principal	Maturity (Years)	Coupon (per Year)	Price	Coupon Frequency	Zero Rate (Continuous)
100	0.5	0	99.8	0.5 (SA)	0.4%
100	1	4	101.2	1 (A)	2.729%
100	1.5	5	102.4	0.5 (SA)	3.353%

- SA: Semi-annual coupon
- A: Annual coupon

a.) Design a function that take in the required parameters for the bootstrap method in form of a Pandas DataFrame and returns the same DataFrame but with a new column called "Zero Rates". Then, check that your function gives the correct spot rates in the table above. **[4 mark]**

It is often that in real world investors encounter friction costs such as fees, commissions and other types of expenses. Currently, NPV is used to measure the value of an investment opportunity:

$$NPV = C_0 + PV.$$

Your task is to design a tool for evaluating net value of a bond, which takes into consideration accrued interest, commission fees on entrance and exit (assume there is commission for settling the return of the principal), and administrative fees, which are monthly fees associated with the exchange that keeps track of asset ownership.

- b.) Define a python function for calculating the net value of a bond subject to accrued interest, entry and exit fees and administrative fees (assume the administrative fees are paid out at the same frequency as the coupons). The accrued interest MUST be computed from the coupon value. **[3 marks]**
- c.) Using the values from Exhibit 7 compute the net value of the investment. Is this a good investment considering all the expenses? **[1 mark]**

### Exhibit 7: Information for an Investment

Parameter	Value
Principal	\$100
Coupon	\$4 (Yearly)
Price	\$101.5
Interest Rate	2%
Maturity	3 years
Administrative Fee	\$1 (Yearly)
Entry Fee	\$5
Exit Fee	\$5
Days from Last Coupon	200

## Section C: Assessment of This Coursework

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Within each section of this coursework, you may be assessed on the following aspects, as applicable and appropriate to this particular assessment, and should thus consider these aspects when fulfilling the requirements of each section:

- The accuracy of any calculations;
- The strengths and quality of your overall analysis and evaluation;
- Appropriate use of relevant theoretical models, concepts and frameworks;
- The rationale and evidence that you provide in support of your arguments;
- The credibility and viability of the evidenced conclusions/recommendations/plans of action you put forward;
- Structure and coherence of your considerations and reports;
- Appropriate and relevant use of, as and where relevant and appropriate, real world examples, academic materials and referenced sources. Any references should use either the Harvard OR Vancouver referencing system (see [References, Citations and Avoiding Plagiarism](#));
- Academic judgement regarding the blend of scope, thrust and communication of ideas, contentions, evidence, knowledge, arguments, conclusions;
- Each part has requirements with allocated marks, maximum word count limits/page limits and where applicable, templates that are required to be used.

You are advised to refer to the [UCL Assessment Criteria Guidelines](#).

## Section D: Group Instructions

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You should create your own groups in Moodle (minimum 2; maximum 4). Each group member should contribute to the coursework equally. Only one person from each group needs to submit the various parts of the assignment.