Financial Engineering

Module Introduction and Overview

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1 Introduction to the Module

Welcome to this module on *Financial Engineering*. The module provides an introduction to the analysis of derivatives in financial markets. You will learn the main features of the most commonly used financial derivatives, and you will understand how to use them for the management of risk.

These units explain and discuss the theoretical models that are used to analyse derivatives, and you will also see how derivatives are used in practice. You will study spreadsheet models of derivatives, analysing the performance and valuation of derivatives contracts and trading strategies, starting with the simplest options, and extending to more complex strategies and derivatives contracts. These spreadsheet models will help you to develop a deeper and stronger understanding of derivatives and how they work.

This module focuses on the conceptual and analytical aspects of derivatives. After studying this module, you will be able to understand the main characteristics of derivatives, the potential for using derivatives to manage risk, and you should be able to avoid some of the more serious misunderstandings and mistakes associated with using derivatives. The module is not a substitute for the professional expertise that can only be acquired by directly working in financial markets. But you will find that a solid grounding in the principles of derivatives will enable you to understand much better the practical aspects of derivatives investment and risk management.

The module is concerned with financial engineering as the application of statistical and mathematical methods to analyse and use derivatives in financial markets. The term 'financial engineering' also refers to the manipulation of the capital structure of a company to attempt to increase shareholder value. Financial engineering in relation to capital structure is studied in the CeFiMS modules *Corporate Finance* and *Introduction to Valuation*.

2 The Module Authors

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Professor Scaramozzino has taught *Risk Management* for the on-campus MSc in Finance and Financial Law in London and has contributed to several off-campus CeFiMS modules, including *Mathematics and Statistics for Economists*, *Portfolio Analysis and Derivatives*, *Quantitative Methods for Financial Management*, *Managerial Economics* and *Risk Management: Principles and Applications*.

Jonathan Simms is a tutor for CeFiMS, and has taught at Manchester Business School, University of Manchester, University of Durham and University of London. Dr Simms has contributed to development of various CeFiMS modules including *Risk Management: Principles and Applications*, *Econometric Principles and Data Analysis*, *Econometric Analysis and Applications*, *Financial Econometrics*, *Introduction to Valuation*, *Advanced Topics in Valuation*, *Public Financial Management: Reporting and Audit*, *Banking Strategy*, *Corporate and Investment Banking*, and *Introduction to Law and to Finance*.

3 Study Resources

This study guide is your main learning resource for the module, and it directs you through the eight study units. In the units you will be asked to work through and use spreadsheet models, and to answer questions and solve exercises relating to the module materials. The review questions and exercises are an essential part of the module, and it is important that you take your time to answer them. Answers to the review questions are provided within the units, and solutions to the exercises are provided at the end of each unit.

Each unit also has recommended reading from two key texts.

Key texts

The first reference for this module is a textbook by John Hull:

Hull JC (2018) *Options, Futures, and Other Derivatives*. 9th Edition. Harlow, UK: Pearson Education.

This is a classic textbook on derivatives. It is written by an authority in the field, and covers both theoretical and practical aspects in the use of derivatives. It discusses all the most commonly used derivative instruments, and contains a large number of examples and exercises. This textbook also explains a number of significant events and analyses relevant case studies in financial markets.

The textbook itself is very thorough. In this module you will not study the book by Hull in its entirety, but will instead concentrate on a selected number of key chapters. If you have a professional interest in derivatives and financial engineering, however, you will find it extremely useful to study all the remaining chapters as well.

The second reference is a textbook by Simon Benninga:

Benninga S (2014) *Financial Modeling*. 4th Edition. Cambridge MA: The MIT Press.

This textbook explains and demonstrates how to implement financial models in Excel. It includes very useful worked examples and applications. The practical 'how to' approach favoured by Benninga works well with the more theoretical approach you will find in your Hull textbook, and the Excel workbooks will develop and reinforce your understanding of the theoretical material.

The Benninga textbook applies financial modelling in Excel for a range of topics also including corporate finance, valuation, and portfolio models. In this module you will focus on the sections of the book relating to options, bonds, and Monte Carlo simulations.

Software

The textbook by Hull comes with an access code for the proprietary software DerivaGem. This software enables you to compute the prices of a large number of derivatives and to draw the relevant graphs. You should familiarise yourself with DerivaGem, and you will make extensive use of it as you study the textbook and the module units.

Please now install the DerivaGem software on your PC. You may wish to refer to the appendix on DerivaGem Software on pages 862–66 of the textbook by Hull for a general description of the software, although for the moment all you will need are the general instructions on page 862.

The publication by Benninga comes with Excel workbooks that implement the models covered in the *Financial Modeling* textbook. These Excel workbooks demonstrate the theoretical models that you will study in the units and in the Hull textbook.

Each unit includes one or two application sections that will guide you through the structure and operation of the relevant spreadsheet models and Excel workbooks. The Excel workbooks studied in the module will be available in your module study area on the VLE.

The application sections build very gently and steadily as you progress through the module, starting with the construction of profit patterns for simple options, through to more complex option strategies, simulating asset price paths, option valuation, dynamic hedging, trading volatility, computing default-adjusted expected bond returns, constructing binomial trees, and using simulation and Monte Carlo techniques to value more complex, exotic options.

As you work through the units you will also strengthen your understanding of the related spreadsheet techniques, including data tables and sensitivity analysis, array operations, macros and VBA routines (Visual Basic for Applications). Appropriate guidance and assistance is provided in the units.

4 Module Overview

Unit 1 Derivatives Contracts

1.1 Introduction
1.2 Forward Contracts
1.3 Futures Contracts
1.4 Options
1.5 Types of Traders
1.6 A 'Health Warning'
1.7 Application: Data tables
1.8 Conclusion
1.9 Solutions to Exercises

Unit 2 Properties of Stock Options

2.1 Introduction
2.2 Options
2.3 Stock Options
2.4 Warrants, Employee Stock Options and Convertibles
2.5 Basics of Pricing Stock Options
2.6 Trading Strategies Involving Options
2.7 Application: Profit Patterns for Options and Option Strategies
2.8 Conclusion
2.9 Solutions to Exercises

Unit 3 The Behaviour of the Stock Price and the Black–Scholes–Merton Model

3.1 Introduction
3.2 The Wiener Process
3.3 The Behaviour of Stock Prices
3.4 Itô's Lemma
3.5 The Lognormal Property of Stock Prices
3.6 The Black–Scholes–Merton Equation and the Black–Scholes–Merton Formula
3.7 Application 1: Simulating a Lognormal Process
3.8 Application 2: Black–Scholes–Merton Option Pricing
3.9 Conclusion
3.10 Solutions to Exercises

Unit 4 Greek Letters and Trading Strategies

4.1 Introduction
4.2 Naked and Covered Positions
4.3 Delta Δ Hedging
4.4 Theta Θ
4.5 Gamma Γ
4.6 Vega ν
4.7 Rho ρ
4.8 Hedging and Portfolio Insurance
4.9 Application 1: Delta Hedging a Call
4.10 Application 2: VBA Code for Option Pricing and the Greeks
4.11 Conclusion

This module presents some of the main types of derivatives, how they are used, and how to analyse them.

Unit 1 introduces the basic derivatives contracts – *i.e.* forwards, futures and options. The application section introduces data tables, a tool widely used for sensitivity analysis, and constructs the profit pattern for a simple call option.

Unit 2 discusses in more detail the properties of stock options, which are among the most commonly traded derivative contracts. The unit develops a deeper understanding of how options work and how they can be used to manage risk. In the application section you will construct the profit patterns for a number of trading strategies involving call and put options.

Unit 3 examines some of the stochastic processes that are widely applied in finance. To value an option we need to model how the price of the underlying asset varies over time. So we need to understand the stochastic process that we believe drives the asset price. In the application sections you will use a spreadsheet model to simulate stock price paths based on one particular stochastic process, the lognormal distribution, and price options using the Black–Scholes–Merton option pricing formulas.

Unit 4 discusses how you can measure the sensitivity of a derivative portfolio to its risk factors, and explains how you can effectively reduce the risk of your position. You will analyse a delta hedging strategy in Excel. You will also study how to formulate user-defined spreadsheet functions to calculate option prices and the option 'Greeks'.

Unit 5 is concerned with volatility. The unit considers how to compute the volatility of asset returns implied by the market prices of options. It examines the relationship between implied volatility and the strike price of options, known as a 'volatility smile'. The unit explains how options can be characterised by their option delta, and priced in terms of their volatility. The unit also examines options strategies for trading volatility, for hedging and speculation.

Unit 6 examines the concept of credit risk and introduces credit derivatives. It considers how risk is rated, and discusses a number of investment vehicles for transferring credit risk, including 'single-name' derivatives like credit default swaps, and 'multi-name' derivatives like asset-backed securities and collateralised debt obligations. The unit assesses the methods for computing correlation of possible default between securities. You will also consider a spreadsheet model of default-adjusted expected bond returns, incorporating credit rating, probability of default, migration of credit rating, and partial recovery.

Unit 7 introduces some of the more advanced numerical procedures that are necessary to analyse complex options. The unit also considers alternatives to the Black–Scholes–Merton model. The application sections construct binomial trees in Excel, and demonstrate how Monte Carlo methods can be used

to value an option. This approach involves simulating the price path of the underlying asset.

Unit 8 examines options that have more complex, non-standard features, known as exotic options. The value of some of these more complex options depends not only on the price of the underlying asset at the maturity of the option, but also on the price of the asset during the life of the option. You will see how to value this type of option using the Monte Carlo approach.

5 Learning Outcomes

When you have completed your study of this module, you will be able to:

- analyse advanced derivative trading strategies for hedging and speculation
- understand the Black–Scholes–Merton model and its applications
- calculate delta and other measures of sensitivity
- discuss volatility, and strategies for trading volatility
- assess the role of credit derivatives in risk management
- apply advanced numerical techniques for valuing complex options
- construct and use spreadsheet models to analyse derivatives.