Irish Math. Soc. Bulletin
Number 97, Summer 2026, 154–155
ISSN 0791-5578

Cónall Kelly: Computation and Simulation for Finance: An Introduction with Python, Springer, 2024. ISBN:978-3-031-60574-1, EUR 53.49, 330+xvi pp.

REVIEWED BY NIALL MADDEN

The book introduces mathematical modelling in finance, and is aimed at undergraduate and beginning graduate students. The origins of the book are in undergraduate and postgraduate courses delivered by the author in UCC and the African Institute for Mathematical Sciences (AIMS). This shows throughout: there is a natural flow in the narrative where theoretical concepts are followed by specific examples from finance, which are then investigated computationally. Thus this book serves as an introduction to asset pricing, to stochastic methods, and to associated numerical methods.

Previous experience of coding in Python, though of course useful, is not assumed: the opening chapter provides a summary of Python fundamentals and the NumPy package, as well as the web-based Jupyter environment. Other elements of Python are introduced as needed, such as random number generation (§1.3.1), root-finding with SciPy's `fsolve` (§2.3.2), and Pandas DataFrame objects (Chap. 6). However, in general there is very little reliance on Python packages, and readers are encouraged to develop their own functions and reuse these later as needed. When that occurs, there are helpful tables summarising which earlier presented functions are being reused, and in which sections they were first developed.

Some basic understanding of probability is required: for example, it is assumed that the reader is familiar with the terminology of σ-algebras. However, these opening sections deftly weave such formalities with concrete discussion of financial assets to help develop intuition. Consequently, stochastic differential equations and Itô calculus are introduced early, and in a natural way. An understanding of fundamental linear algebra, calculus, and differential equations is also expected.

The book is organised into three sections: *Modelling Assets and Markets*, *Computational Pricing Methods in the Black-Scholes Framework*, and *Simulation Methods Beyond the Black-Scholes Framework*.

The first of these provides the necessary understanding to, for example, derive the Black-Scholes-Merton PDE via the Feynman-Kac theorem linking partial differential equations and stochastic processes. Related problems, such as option price sensitivities (the Greeks), are also presented. That section nicely encapsulates the general approach of this book: the concepts are introduced and then explored through a practical investigation of dynamic hedging in Python. The reader who carefully reproduces the computations (and completes the related exercises) is bound to develop a good understanding of this topic.

The second section, on numerical methods, deals with binomial methods, Monte Carlo methods, and then finite difference methods. The first of these is introduced first for European options, and then those with early exercise facilities. The Monte Carlo Method chapter includes study of exotic options, and the topic of variance reduction.

Received on 09-06-2026; revised 09-06-2026.
DOI: 10.33232/BIMS.0097.154.155.

I dwell a little more on the lengthy chapter on finite difference schemes for the Black-Scholes-Merton PDE, since these methods are closer to my own interests. This chapter includes some relatively standard material on transforming it to the heat equation, and derivation of the standard explicit central finite difference scheme from Taylor series. Less standard, I think, for books on mathematical finance (with the possible honourable exception of Higham [1]) is the careful numerical analysis of the method, covering the stability and consistency of the scheme.

This is followed by a presentation of the unconditionally stable Implicit Euler and Crank-Nicolson schemes. Since implementing implicit schemes requires the solution of a linear system, a detailed presentation of a Python program for the Implicit Euler scheme is given. (This leads to one of my very few quibbles with this book, and it is a very minor one. The author is correct to mention that there is a large body of research on the topic of inverting large sparse matrices. However, much of that is concerned with avoiding explicitly inverting large sparse matrices at all costs. In this example, SciPy's `solve_banded` could be used with minimal changes to the code).

The third and final section of the book concerns more advanced topics, many quite modern and based on recent publications. Its three chapters are on modelling multivariate data, stochastic models for interest rates and, of most interest to this reviewer, numerical approximation of stochastic differential equations. Here the presentation manages to be both succinct yet complete. I particularly appreciated the discussion of the theory and computation of the weak and strong orders of convergence of the Euler-Maruyama scheme. I originally picked up this volume in the hope it would help me compute these for a problem in computational fluids; I was not disappointed.

Overall, this book is a very welcome addition to the literature. There are well-established texts introducing undergraduate students to the mathematics of option pricing and related topics (e.g., [1, 2, 3]). However, the present volume distinguishes itself by complementing a rigorous treatment of both stochastics and numerical analysis with practical computing.

The preface of this book suggests that a one-semester course could be based on Part 1, and a selection of topics from Part 2. For more advanced students, Parts 2 and 3 could each be the basis for a one-semester course. Each chapter concludes with a section on "further reading", and a set of exercises. This again reflects how the book would be a very suitable basis for a course on computational financial mathematics. The preface also promises an "up-to-date treatment" of numerical techniques for computational finance. It certainly delivers that and, in particular, summarises some of the most recent advances, making it a suitable reference for anyone with research interests in stochastic differential equations.

References

[1] D.J. Higham: *An Introduction to Financial Option Valuation: Mathematics, Stochastics and Computation*, Cambridge University Press, 2004.
[2] J.C. Hull: *Options, Futures, and Other Derivatives*, 6th edition, Pearson Prentice Hall, 2006.
[3] Wilmott, S. Howison, J. Dewynne: *The Mathematics of Financial Derivatives: A Student Introduction*, Cambridge University Press, 1995.

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