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This book addresses problems in financial mathematics of pricing and hedging derivative securities in an environment of uncertain and changing market volatility. These problems are important to investors ranging from large trading institutions to pension funds. The authors present mathematical and statistical tools that exploit the "bursty" nature of market volatility. The mathematics is introduced through examples and illustrated with simulations, and the approach described is validated and tested on market data. The material is suitable for a one-semester course for graduate students who have been exposed to methods of stochastic modeling and arbitrage pricing theory in finance. It is easily accessible to derivatives practitioners in the inancial engineering industry.

Introduction 1 The Black-Scholes Theory of Derivative Pricing 1.1 Market Model 1.2 Derivative Contracts 1.3 Replicating Strategies 1.4 Risk-Neutral Pricing 1.5 Risk-Neutral Expectations and Partial Differential Equations 1.6 Complete Market 2 Introduction to Stochastic Volatility Models 2.1 Implied Volatility and the Smile Curve 2.2 Implied Deterministic Volatility 2.3 Stochastic Volatility Models 2.4 Derivative Pricing 2.5 Pricing with Equivalent Martingale Measures 2.6 Implied Volatility as a Function of Moneyness 2.7 Market Price of Volatility Risk and Data 2.8 Special Case: Uncorrelated Volatility 2.9 Summary and Conclusions 3 Scales in Mean-Reverting Stochastic Volatility 3.1 Scaling in Simple Models 3.2 Models of Clustering 3.3 Convergence to Black-Scholes under Fast Mean-Reverting Volatility 3.4 Scales in the Returns Process 4 Tools for Estimating the Rate of Mean Reversion 4.1 Model and Data 4.2 Variogram Analysis 4.3 Spectral Analysis 5 Asymptotics for Pricing European Derivatives 5.1 Preliminaries 5.2 The Formal Expansion 5.3 Implied Volatilities and Calibration 5.4 Accuracy of the Approximation 5.5 Region of Validity 6 Implementation and Stability 6.1 Step-by-Step Procedure 6.2 Comments about the Method 6.3 Dividends 6.4 The Second Correction 7 Hedging Strategies 8 Application to Exotic Derivatives 9 Application to American Derivatives 10 Generalizations 11 Applications to Interest-Rate Models Index

The Black-Scholes model rests upon a number of assumptions that are to some extent." counterfactual." Among these are continuity of the stock. price process it does not jump the ability to hedge continuously without transaction costs inde-pendent Gaussian returns. and constant volatility. We shall focus here on relaxing the last assumption by allowing volatility to vary randomly for the following rea-son a well. known discrepancy between Black-Scholes-predicted European op-tion prices and market-traded options prices the smile curve can be accounted for by stochastic volatility models. That iS. this modification of the Black-Scholes theory has a posteriori success in one area where the classical model fails. In fact. modeling volatility as a stochastic process iS motivated a priori by em-pirical studies of stock. price returns in which estimated volatility iS observed to exhibit " random" characteristics. Additionally the effects of transaction costs show up. under many models as uncertainty in the volatility fat-tailed returns distributions can be simulated by stochastic volatility and market 'jump" phe-nomena are often best modeled as volatility jump processes. Stochastic volatility modeling therefore iS not just a simple fix to one particular Biacl Scholes as-sumption but rather a powerful modification that describes a much more complex market. We cite literature that explores possible causes of stochastic volatility in the notes at the end Of this chapter. In Chapter 1 we introduced the notation and tools for pricing and hedging deriv-ative securities ander a constant volatility lognormal model 1.2 . This iS the sim-plest example of pricing in a complete market. However pricing in a market with stochastic volatility is an incomplete markets problem. a distinction that as we shall explain has far-reaching consequences-particularly for the hedging prob-lem and the problem of parameter estimation. It iS the latter inverse problem that iS the biggest mathematical and practical challenge introduced by such models and also perhaps the one that benefits most from the asymptotic methods of Chapter 5.

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