

W. Härdle • T. Kleinow • G. Stahl

Applied Quantitative Finance

Theory and Computational Tools



Springer

Contents

| | |
|---|------------|
| Preface | xv |
| Contributors | xix |
| Frequently Used Notation | xxi |
| | |
| I Value at Risk | 1 |
| 1 Approximating Value at Risk in Conditional Gaussian Models | 3 |
| <i>Stefan R. Jaschke and Yuze Jiang</i> | |
| 1.1 Introduction | 3 |
| 1.1.1 The Practical Need | 3 |
| 1.1.2 Statistical Modeling for VaR | 4 |
| 1.1.3 VaR Approximations | 6 |
| 1.1.4 Pros and Cons of Delta-Gamma Approximations | 7 |
| 1.2 General Properties of Delta-Gamma-Normal Models | 8 |
| 1.3 Cornish-Fisher Approximations | 12 |
| 1.3.1 Derivation | 12 |
| 1.3.2 Properties | 15 |
| 1.4 Fourier Inversion | 16 |

| | | |
|--|--|-----------|
| 1.4.1 | Error Analysis | 16 |
| 1.4.2 | Tail Behavior | 20 |
| 1.4.3 | Inversion of the cdf minus the Gaussian Approximation | 21 |
| 1.5 | Variance Reduction Techniques in Monte-Carlo Simulation | 24 |
| 1.5.1 | Monte-Carlo Sampling Method | 24 |
| 1.5.2 | Partial Monte-Carlo with Importance Sampling | 28 |
| 1.5.3 | XploRe Examples | 30 |
| 2 | Applications of Copulas for the Calculation of Value-at-Risk | 35 |
| <i>Jörn Rank and Thomas Siegl</i> | | |
| 2.1 | Copulas | 36 |
| 2.1.1 | Definition | 36 |
| 2.1.2 | Sklar's Theorem | 37 |
| 2.1.3 | Examples of Copulas | 37 |
| 2.1.4 | Further Important Properties of Copulas | 39 |
| 2.2 | Computing Value-at-Risk with Copulas | 40 |
| 2.2.1 | Selecting the Marginal Distributions | 40 |
| 2.2.2 | Selecting a Copula | 41 |
| 2.2.3 | Estimating the Copula Parameters | 41 |
| 2.2.4 | Generating Scenarios - Monte Carlo Value-at-Risk | 43 |
| 2.3 | Examples | 45 |
| 2.4 | Results | 47 |
| 3 | Quantification of Spread Risk by Means of Historical Simulation | 51 |
| <i>Christoph Frisch and Germar Knöchlein</i> | | |
| 3.1 | Introduction | 51 |
| 3.2 | Risk Categories – a Definition of Terms | 51 |

| | | |
|--|--|-----------|
| 3.3 | Descriptive Statistics of Yield Spread Time Series | 53 |
| 3.3.1 | Data Analysis with XploRe | 54 |
| 3.3.2 | Discussion of Results | 58 |
| 3.4 | Historical Simulation and Value at Risk | 63 |
| 3.4.1 | Risk Factor: Full Yield | 64 |
| 3.4.2 | Risk Factor: Benchmark | 67 |
| 3.4.3 | Risk Factor: Spread over Benchmark Yield | 68 |
| 3.4.4 | Conservative Approach | 69 |
| 3.4.5 | Simultaneous Simulation | 69 |
| 3.5 | Mark-to-Model Backtesting | 70 |
| 3.6 | VaR Estimation and Backtesting with XploRe | 70 |
| 3.7 | P-P Plots | 73 |
| 3.8 | Q-Q Plots | 74 |
| 3.9 | Discussion of Simulation Results | 75 |
| 3.9.1 | Risk Factor: Full Yield | 77 |
| 3.9.2 | Risk Factor: Benchmark | 78 |
| 3.9.3 | Risk Factor: Spread over Benchmark Yield | 78 |
| 3.9.4 | Conservative Approach | 79 |
| 3.9.5 | Simultaneous Simulation | 80 |
| 3.10 | XploRe for Internal Risk Models | 81 |
| II | Credit Risk | 85 |
| 4 | Rating Migrations | 87 |
| <i>Steffi Höse, Stefan Huschens and Robert Wania</i> | | |
| 4.1 | Rating Transition Probabilities | 88 |
| 4.1.1 | From Credit Events to Migration Counts | 88 |

| | | |
|---|--|------------|
| 4.1.2 | Estimating Rating Transition Probabilities | 89 |
| 4.1.3 | Dependent Migrations | 90 |
| 4.1.4 | Computation and Quantlets | 93 |
| 4.2 | Analyzing the Time-Stability of Transition Probabilities | 94 |
| 4.2.1 | Aggregation over Periods | 94 |
| 4.2.2 | Are the Transition Probabilities Stationary? | 95 |
| 4.2.3 | Computation and Quantlets | 97 |
| 4.2.4 | Examples with Graphical Presentation | 98 |
| 4.3 | Multi-Period Transitions | 101 |
| 4.3.1 | Time Homogeneous Markov Chain | 101 |
| 4.3.2 | Bootstrapping Markov Chains | 102 |
| 4.3.3 | Computation and Quantlets | 104 |
| 4.3.4 | Rating Transitions of German Bank Borrowers | 106 |
| 4.3.5 | Portfolio Migration | 106 |
| 5 | Sensitivity analysis of credit portfolio models | 111 |
| <i>Rüdiger Kiesel and Torsten Kleinow</i> | | |
| 5.1 | Introduction | 111 |
| 5.2 | Construction of portfolio credit risk models | 113 |
| 5.3 | Dependence modelling | 114 |
| 5.3.1 | Factor modelling | 115 |
| 5.3.2 | Copula modelling | 117 |
| 5.4 | Simulations | 119 |
| 5.4.1 | Random sample generation | 119 |
| 5.4.2 | Portfolio results | 120 |

| | |
|---|------------|
| III Implied Volatility | 125 |
| 6 The Analysis of Implied Volatilities | 127 |
| <i>Matthias R. Fengler, Wolfgang Härdle and Peter Schmidt</i> | |
| 6.1 Introduction | 128 |
| 6.2 The Implied Volatility Surface | 129 |
| 6.2.1 Calculating the Implied Volatility | 129 |
| 6.2.2 Surface smoothing | 131 |
| 6.3 Dynamic Analysis | 134 |
| 6.3.1 Data description | 134 |
| 6.3.2 PCA of ATM Implied Volatilities | 136 |
| 6.3.3 Common PCA of the Implied Volatility Surface | 137 |
| 7 How Precise Are Price Distributions Predicted by IBT? | 145 |
| <i>Wolfgang Härdle and Jun Zheng</i> | |
| 7.1 Implied Binomial Trees | 146 |
| 7.1.1 The Derman and Kani (D & K) algorithm | 147 |
| 7.1.2 Compensation | 151 |
| 7.1.3 Barle and Cakici (B & C) algorithm | 153 |
| 7.2 A Simulation and a Comparison of the SPDs | 154 |
| 7.2.1 Simulation using Derman and Kani algorithm | 154 |
| 7.2.2 Simulation using Barle and Cakici algorithm | 156 |
| 7.2.3 Comparison with Monte-Carlo Simulation | 158 |
| 7.3 Example – Analysis of DAX data | 162 |
| 8 Estimating State-Price Densities with Nonparametric Regression | 171 |
| <i>Kim Huynh, Pierre Kervella and Jun Zheng</i> | |
| 8.1 Introduction | 171 |

| | | |
|--|--|------------|
| 8.2 | Extracting the SPD using Call-Options | 173 |
| 8.2.1 | Black-Scholes SPD | 175 |
| 8.3 | Semiparametric estimation of the SPD | 176 |
| 8.3.1 | Estimating the call pricing function | 176 |
| 8.3.2 | Further dimension reduction | 177 |
| 8.3.3 | Local Polynomial Estimation | 181 |
| 8.4 | An Example: Application to DAX data | 183 |
| 8.4.1 | Data | 183 |
| 8.4.2 | SPD, delta and gamma | 185 |
| 8.4.3 | Bootstrap confidence bands | 187 |
| 8.4.4 | Comparison to Implied Binomial Trees | 190 |
| 9 | Trading on Deviations of Implied and Historical Densities | 197 |
| <i>Oliver Jim Blaskowitz and Peter Schmidt</i> | | |
| 9.1 | Introduction | 197 |
| 9.2 | Estimation of the Option Implied SPD | 198 |
| 9.2.1 | Application to DAX Data | 198 |
| 9.3 | Estimation of the Historical SPD | 200 |
| 9.3.1 | The Estimation Method | 201 |
| 9.3.2 | Application to DAX Data | 202 |
| 9.4 | Comparison of Implied and Historical SPD | 205 |
| 9.5 | Skewness Trades | 207 |
| 9.5.1 | Performance | 210 |
| 9.6 | Kurtosis Trades | 212 |
| 9.6.1 | Performance | 214 |
| 9.7 | A Word of Caution | 216 |

| | |
|---|------------|
| IV Econometrics | 219 |
| 10 Multivariate Volatility Models | 221 |
| <i>Matthias R. Fengler and Helmut Herwartz</i> | |
| 10.1 Introduction | 221 |
| 10.1.1 Model specifications | 222 |
| 10.1.2 Estimation of the BEKK-model | 224 |
| 10.2 An empirical illustration | 225 |
| 10.2.1 Data description | 225 |
| 10.2.2 Estimating bivariate GARCH | 226 |
| 10.2.3 Estimating the (co)variance processes | 229 |
| 10.3 Forecasting exchange rate densities | 232 |
| 11 Statistical Process Control | 237 |
| <i>Sven Knoth</i> | |
| 11.1 Control Charts | 238 |
| 11.2 Chart characteristics | 243 |
| 11.2.1 Average Run Length and Critical Values | 247 |
| 11.2.2 Average Delay | 248 |
| 11.2.3 Probability Mass and Cumulative Distribution Function | 248 |
| 11.3 Comparison with existing methods | 251 |
| 11.3.1 Two-sided EWMA and Lucas/Saccucci | 251 |
| 11.3.2 Two-sided CUSUM and Crosier | 251 |
| 11.4 Real data example – monitoring CAPM | 253 |
| 12 An Empirical Likelihood Goodness-of-Fit Test for Diffusions | 259 |
| <i>Song Xi Chen, Wolfgang Härdle and Torsten Kleinow</i> | |
| 12.1 Introduction | 259 |

| | |
|--|----------------|
| 12.2 Discrete Time Approximation of a Diffusion | 260 |
| 12.3 Hypothesis Testing | 261 |
| 12.4 Kernel Estimator | 263 |
| 12.5 The Empirical Likelihood concept | 264 |
| 12.5.1 Introduction into Empirical Likelihood | 264 |
| 12.5.2 Empirical Likelihood for Time Series Data | 265 |
| 12.6 Goodness-of-Fit Statistic | 268 |
| 12.7 Goodness-of-Fit test | 272 |
| 12.8 Application | 274 |
| 12.9 Simulation Study and Illustration | 276 |
| 12.10 Appendix | 279 |
| 13 A simple state space model of house prices | 283 |
| <i>Rainer Schulz and Axel Werwatz</i> | |
| 13.1 Introduction | 283 |
| 13.2 A Statistical Model of House Prices | 284 |
| 13.2.1 The Price Function | 284 |
| 13.2.2 State Space Form | 285 |
| 13.3 Estimation with Kalman Filter Techniques | 286 |
| 13.3.1 Kalman Filtering given all parameters | 286 |
| 13.3.2 Filtering and state smoothing | 287 |
| 13.3.3 Maximum likelihood estimation of the parameters . . . | 288 |
| 13.3.4 Diagnostic checking | 289 |
| 13.4 The Data | 289 |
| 13.5 Estimating and filtering in XploRe | 293 |
| 13.5.1 Overview | 293 |
| 13.5.2 Setting the system matrices | 293 |

| | |
|---|------------|
| 13.5.3 Kalman filter and maximized log likelihood | 295 |
| 13.5.4 Diagnostic checking with standardized residuals | 298 |
| 13.5.5 Calculating the Kalman smoother | 300 |
| 13.6 Appendix | 302 |
| 13.6.1 Procedure equivalence | 302 |
| 13.6.2 Smoothed constant state variables | 304 |
| 14 Long Memory Effects Trading Strategy | 309 |
| <i>Oliver Jim Blaskowitz and Peter Schmidt</i> | |
| 14.1 Introduction | 309 |
| 14.2 Hurst and Rescaled Range Analysis | 310 |
| 14.3 Stationary Long Memory Processes | 312 |
| 14.3.1 Fractional Brownian Motion and Noise | 313 |
| 14.4 Data Analysis | 315 |
| 14.5 Trading the Negative Persistence | 318 |
| 15 Locally time homogeneous time series modeling | 323 |
| <i>Danilo Mercurio</i> | |
| 15.1 Intervals of homogeneity | 323 |
| 15.1.1 The adaptive estimator | 326 |
| 15.1.2 A small simulation study | 327 |
| 15.2 Estimating the coefficients of an exchange rate basket | 329 |
| 15.2.1 The Thai Baht basket | 331 |
| 15.2.2 Estimation results | 335 |
| 15.3 Estimating the volatility of financial time series | 338 |
| 15.3.1 The standard approach | 339 |
| 15.3.2 The locally time homogeneous approach | 340 |

| | |
|---|------------|
| 15.3.3 Modeling volatility via power transformation | 340 |
| 15.3.4 Adaptive estimation under local time-homogeneity | 341 |
| 15.4 Technical appendix | 344 |
| 16 Simulation based Option Pricing | 349 |
| <i>Jens Lüssem and Jürgen Schumacher</i> | |
| 16.1 Simulation techniques for option pricing | 349 |
| 16.1.1 Introduction to simulation techniques | 349 |
| 16.1.2 Pricing path independent European options on one underlying | 350 |
| 16.1.3 Pricing path dependent European options on one underlying | 354 |
| 16.1.4 Pricing options on multiple underlyings | 355 |
| 16.2 Quasi Monte Carlo (QMC) techniques for option pricing | 356 |
| 16.2.1 Introduction to Quasi Monte Carlo techniques | 356 |
| 16.2.2 Error bounds | 356 |
| 16.2.3 Construction of the Halton sequence | 357 |
| 16.2.4 Experimental results | 359 |
| 16.3 Pricing options with simulation techniques - a guideline | 361 |
| 16.3.1 Construction of the payoff function | 362 |
| 16.3.2 Integration of the payoff function in the simulation framework | 362 |
| 16.3.3 Restrictions for the payoff functions | 365 |
| 17 Nonparametric Estimators of GARCH Processes | 367 |
| <i>Jürgen Franke, Harriet Holzberger and Marlene Müller</i> | |
| 17.1 Deconvolution density and regression estimates | 369 |
| 17.2 Nonparametric ARMA Estimates | 370 |

| | |
|--|------------|
| 17.3 Nonparametric GARCH Estimates | 379 |
| 18 Net Based Spreadsheets in Quantitative Finance | 385 |
| <i>Gökhan Aydinalı</i> | |
| 18.1 Introduction | 385 |
| 18.2 Client/Server based Statistical Computing | 386 |
| 18.3 Why Spreadsheets? | 387 |
| 18.4 Using MD*ReX | 388 |
| 18.5 Applications | 390 |
| 18.5.1 Value at Risk Calculations with Copulas | 391 |
| 18.5.2 Implied Volatility Measures | 393 |
| Index | 398 |