

LINDA ALLEN, JACOB BOUDOUKH, and ANTHONY SAUNDERS

**UN** **ERSTANDING**  
**ET CREDIT, AND**  
**AT** **NAL RI**

**THE VALUE AT RISK APPROACH**

UNIVERSITÄT  
LIECHTENSTEIN  
Bibliothek



**Blackwell  
Publishing**

# SHORT CONTENTS

|  |       |
|--|-------|
| List of Figures                                    | xiv   |
| List of Tables                                     | xvi   |
| Preface  | xviii |
| List of Abbreviations                              | xx    |
| 1 Introduction to Value at Risk (VaR)              | 1     |
| 2 Quantifying Volatility in VaR Models             | 21    |
| 3 Putting VaR to Work                              | 82    |
| 4 Extending the VaR Approach to Non-tradable Loans | 119   |
| 5 Extending the VaR Approach to Operational Risks  | 158   |
| 6 Applying VaR to Regulatory Models                | 200   |
| 7 VaR: Outstanding Research                        | 233   |
| Notes  | 236   |
| References   | 257   |
| Index  | 270   |

# CONTENTS

|   |           |
|---|-----------|
| List of Figures   | xiv       |
| List of Tables  | xvi       |
| Preface   | xviii     |
| List of Abbreviations   | xx        |
| <b>1 Introduction to Value at Risk (VaR)</b>  | <b>1</b>  |
| 1.1 Economics underlying VaR measurement  | 2         |
| 1.1.1 What is VaR?  | 4         |
| 1.1.2 Calculating VaR   | 6         |
| 1.1.3 The assumptions behind VaR calculations   | 8         |
| 1.1.4 Inputs into VaR calculations  | 10        |
| 1.2 Diversification and VaR   | 13        |
| 1.2.1 Factors affecting portfolio diversification   | 16        |
| 1.2.2 Decomposing volatility into systematic and idiosyncratic risk                       | 17        |
| 1.2.3 Diversification: Words of caution - the case of long-term capital management (LTCM) | 18        |
| <b>2 Quantifying Volatility in VaR Models</b>   | <b>21</b> |
| 2.1 The Stochastic Behavior of Returns  | 22        |
| 2.1.1 Revisiting the assumptions  | 22        |
| 2.1.2 The distribution of interest rate changes   | 23        |
| 2.1.3 Fat tails   | 25        |
| 2.1.4 Explaining fat tails  | 26        |
| 2.1.5 Effects of volatility changes   | 29        |
| 2.1.6 Can (conditional) normality be salvaged?  | 31        |
| 2.1.7 Normality cannot be salvaged  | 34        |

|              |  |     |
|--------------|--|-----|
| 2.2          | VaR Estimation Approaches  | 35  |
| 2.2.1        | Cyclical volatility  | 36  |
| 2.2.2        | Historical standard deviation                                    | 36  |
| 2.2.3        | Implementation considerations                                    | 38  |
| 2.2.4        | Exponential smoothing - RiskMetrics™<br>volatility               | 40  |
| 2.2.4.1      | The optimal smoother lambda                                      | 43  |
| 2.2.4.2      | Adaptive volatility estimation                                   | 44  |
| 2.2.4.3      | The empirical performance of<br>RiskMetrics™                     | 45  |
| 2.2.4.4      | GARCH  | 45  |
| 2.2.5        | Nonparametric volatility forecasting                             | 48  |
| 2.2.5.1      | Historical simulation  | 48  |
| 2.2.5.2      | Multivariate density estimation                                  | 51  |
| 2.2.6        | A comparison of methods  | 54  |
| 2.2.7        | The hybrid approach  | 56  |
| 2.3          | Return Aggregation and VaR                                       | 59  |
| 2.4          | Implied Volatility as a Predictor of<br>Future Volatility        | 62  |
| 2.5          | Long Horizon Volatility and VaR                                  | 66  |
| 2.6          | Mean Reversion and Long Horizon Volatility                       | 69  |
| 2.7          | Correlation Measurement  | 71  |
| 2.8          | Summary  | 74  |
| Appendix 2.1 | Backtesting Methodology<br>and Results                           | 74  |
|              | <b>Putting VaR to Work</b>                                       | 82  |
| 3.1          | The VaR of Derivatives - Preliminaries                           | 82  |
| 3.1.1        | Linear derivatives   | 83  |
| 3.1.2        | Nonlinear derivatives  | 86  |
| 3.1.3        | Approximating the VaR of derivatives                             | 86  |
| 3.1.4        | Fixed income securities with embedded<br>optionality             | 93  |
| 3.1.5        | "Delta normal" vs. full-revaluation                              | 95  |
| 3.2          | Structured Monte Carlo, Stress Testing, and<br>Scenario Analysis | 97  |
| 3.2.1        | Motivation   | 97  |
| 3.2.2        | Structured Monte Carlo   | 98  |
| 3.2.3        | Scenario analysis  | 101 |
| 3.2.3.1      | Correlation breakdown  | 101 |
| 3.2.3.2      | Generating reasonable stress                                     | 103 |

|              |  |     |
|--------------|--|-----|
| 3.2.3.3      | Stress testing in practice               | 104 |
| 3.2.3.4      | Stress testing and historical simulation | 106 |
| 3.2.3.5      | Asset concentration                      | 107 |
| 3.3          | Worst Case Scenario (WCS)                | 110 |
| 3.3.1        | WCS vs. VaR                              | 110 |
| 3.3.2        | A comparison of VaR to WCS               | 111 |
| 3.3.3        | Extensions                               | 112 |
| 3.4          | Summary                                  | 113 |
| Appendix 3.1 | Duration                                 | 114 |

## **Extending the VaR Approach to**

|                           |   |     |
|---------------------------|---|-----|
| <b>Non-tradable Loans</b> |   | 119 |
| 4.1                       | Traditional Approaches to Credit Risk Measurement   | 120 |
| 4.1.1                     | Expert systems  | 121 |
| 4.1.2                     | Rating systems  | 122 |
| 4.1.3                     | Credit scoring models   | 124 |
| 4.2                       | Theoretical Underpinnings: Two Approaches   | 128 |
| 4.2.1                     | Options-theoretic structural models of credit risk measurement  | 128 |
| 4.2.2                     | Reduced form or intensity-based models of credit risk measurement   | 132 |
| 4.2.3                     | Proprietary VaR models of credit risk measurement   | 138 |
| 4.3                       | CreditMetrics   | 138 |
| 4.3.1                     | The distribution of an individual loan's value  | 138 |
| 4.3.2                     | The value distribution for a portfolio of loans   | 143 |
| 4.3.2.1                   | Calculating the correlation between equity returns and industry indices for each borrower in the loan portfolio | 144 |
| 4.3.2.2                   | Calculating the correlation between borrower equity returns   | 144 |
| 4.3.2.3                   | Solving for joint migration probabilities   | 145 |
| 4.3.2.4                   | Valuing each loan across the entire credit migration spectrum   | 147 |
| 4.3.2.5                   | Calculating the mean and standard deviation of the normal portfolio value distribution                          | 149 |

|              |  |            |
|--------------|--|------------|
| 4.4          | Algorithmics' Mark-to-Future   | 151        |
| 4.5          | Summary  | 153        |
| Appendix 4.1 | CreditMetrics: Calculating Credit VaR<br>Using the Actual Distribution | 155        |
| <b>5</b>     | <b>Extending the VaR Approach to<br/>Operational Risks</b>             | <b>158</b> |
| 5.1          | Top-Down Approaches to Operational Risk<br>Measurement                 | 161        |
| 5.1.1        | Top-down vs. bottom-up models  | 162        |
| 5.1.2        | Data requirements  | 163        |
| 5.1.3        | Top-down models  | 165        |
| 5.1.3.1      | Multi-factor models  | 165        |
| 5.1.3.2      | Income-based models  | 166        |
| 5.1.3.3      | Expense-based models   | 167        |
| 5.1.3.4      | Operating leverage models  | 167        |
| 5.1.3.5      | Scenario analysis  | 167        |
| 5.1.3.6      | Risk profiling models  | 168        |
| 5.2          | Bottom-Up Approaches to Operational Risk<br>Measurement                | 170        |
| 5.2.1        | Process approaches   | 170        |
| 5.2.1.1      | Causal networks or scorecards  | 170        |
| 5.2.1.2      | Connectivity models  | 173        |
| 5.2.1.3      | Reliability models   | 175        |
| 5.2.2        | Actuarial approaches   | 176        |
| 5.2.2.1      | Empirical loss distributions   | 176        |
| 5.2.2.2      | Parametric loss distributions  | 176        |
| 5.2.2.3      | Extreme value theory   | 179        |
| 5.2.3        | Proprietary operational risk models                                    | 182        |
| 5.3          | Hedging Operational Risk   | 185        |
| 5.3.1        | Insurance  | 186        |
| 5.3.2        | Self-insurance   | 188        |
| 5.3.3        | Hedging using derivatives  | 190        |
| 5.3.3.1      | Catastrophe options  | 191        |
| 5.3.3.2      | Cat bonds  | 193        |
| 5.3.4        | Limitations to operational risk hedging                                | 195        |
| 5.4          | Summary  | 196        |
| Appendix 5.1 | Copula Functions   | 196        |
| <b>6</b>     | <b>Applying VaR to Regulatory Models</b>                               | <b>200</b> |
| 6.1          | BIS Regulatory- Models of Market Risk                                  | 203        |

|          |  |            |
|----------|--|------------|
| 6.1.1    | The standardized framework for market risk             | 203        |
| 6.1.1.1  | Measuring interest rate risk                           | 203        |
| 6.1.1.2  | Measuring foreign exchange rate risk                   | 204        |
| 6.1.1.3  | Measuring equity price risk                            | 205        |
| 6.1.2    | Internal models of market risk                         | 205        |
| 6.2      | BIS Regulatory Models of Credit Risk                   | 206        |
| 6.2.1    | The Standardized Model for credit risk                 | 207        |
| 6.2.2    | The Internal Ratings-Based Models for credit risk      | 209        |
| 6.2.2.1  | The Foundation IRB Approach                            | 210        |
| 6.2.2.2  | The Advanced IRB Approach                              | 214        |
| 6.2.3    | BIS regulatory models of off-balance sheet credit risk | 215        |
| 6.2.4    | Assessment of the BIS regulatory models of credit risk | 218        |
| 6.3      | BIS Regulatory Models of Operational Risk              | 221        |
| 6.3.1    | The Basic Indicator Approach                           | 223        |
| 6.3.2    | The Standardized Approach                              | 224        |
| 6.3.3    | The Advanced Measurement Approach                      | 225        |
| 6.3.3.1  | The internal measurement approach                      | 227        |
| 6.3.3.2  | The loss distribution approach                         | 230        |
| 6.3.3.3  | The scorecard approach                                 | 230        |
| 6.4      | Summary  | 231        |
| <b>7</b> | <b>VaR: Outstanding Research</b>                       | <b>233</b> |
| 7.1      | Data Availability                                      | 233        |
| 7.2      | Model Integration                                      | 234        |
| 7.3      | Dynamic Modeling                                       | 235        |
|          | Notes  | 236        |
|          | References   | 257        |
|          | Index  | 270        |