Operational Risk

A Guide to Basel II Capital Requirements, Models, and Analysis

ANNA S. CHERNOBAI Svetlozar T. Rachev Frank J. Fabozzi



John Wiley & Sons, Inc.

Operational Risk

A Guide to Basel II Capital Requirements, Models, and Analysis

ANNA S. CHERNOBAI Svetlozar T. Rachev Frank J. Fabozzi



John Wiley & Sons, Inc.

Copyright © 2007 by Anna S. Chernobai, Svetlozar T. Rachev, and Frank J. Fabozzi. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey. Published simultaneously in Canada.

Wiley Bicentennial Logo: Richard J. Pacifico

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 646-8600, or on the Web at www.copyright.com. Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at http://www.wiley.com/go/permission.

Limit of Liability/Disclaimer of Warranty: While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor author shall be liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or other damages.

For general information on our other products and services or for technical support, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books. For more information about Wiley products, visit our Web site at www.wiley.com.

ISBN: 978-0-471-78051-9

Printed in the United States of America.

 $10 \quad 9 \quad 8 \quad 7 \quad 6 \quad 5 \quad 4 \quad 3 \quad 2 \quad 1$

ASC

To my husband, Makan, and my parents

STR

To the memory of my parents, Nadezda Racheva and Todor Rachev

FJF

To my wife, Donna, and children, Francesco, Patricia, and Karly

Contents

Preface	XV
About the Authors	XİX
CHAPTER 1	
Operational Risk Is Not Just "Other" Risks	1
Effects of Globalization and Deregulation: Increased Risk	
Exposures	2
Examples of High-Magnitude Operational Losses	4
Orange County, 1994, United States	5 5
Barings Bank, 1995, United Kingdom	5
Daiwa Bank, 1995, New York	7
Allied Irish Banks, 2002, Ireland	8
The Enron Scandal, 2001, United States	8
MasterCard International, 2005, United States	9
Terrorist Attack, September 11, 2001, New York and	
Worldwide	10
Operational Losses in The Hedge Fund Industry	10
Summary of Key Concepts	12
References	12
CHAPTER 2	
Operational Risk: Definition, Classification, and Its Place among	45
Other Risks	15
What Is Risk?	15
Definition of Operational Risk	16
Operational Risk Exposure Indicators	18
Classification of Operational Risk	19
Internal versus External Operational Losses	19
Direct versus Indirect Operational Losses	19
Expected versus Unexpected Operational Losses	22
Operational Risk Type, Event Type, and Loss Type	22
Operational Loss Severity and Frequency	23

Topology of Financial Risks	26
Capital Allocation for Operational, Market, and Credit Risks Impact of Operational Risk on the Market Value of Bank	29
Equity	30
Effects of Macroeconomic Environment on Operational Risk	31
Summary of Key Concepts	31
References	32
CHAPTER 3	
Basel II Capital Accord	35
The Basel Committee on Banking Supervision	35
The Basel Capital Accord	36
Pillar I: Minimum Capital Requirements for Operational	
Risk	37
Decomposition of Capital	37
Capital for Expected and Unexpected Losses	39
Three Approaches to Assess the Operational Risk	
Capital Charge	40
The Basic Indicator Approach	41
The Standardized Approach	42
The Advanced Measurement Approaches	44
Pillar II: Capital Adequacy and Regulatory Principles	47
Pillar III: Market Discipline and Public Disclosure	48
Overview of Loss Data Collection Exercises	49
The Role of Insurance	51
Which Operational Losses Should Be Transferred?	53
FIORI Insurance Policy by Swiss Re	54
Insurance Recoveries Data from the 2002 Loss Data Collection Exercise	54
Limitations of Insurance	54 55
Policy Limit	55
High Costs of Insurance	55
Moral Hazard	55
Alternatives to Insurance	57
Catastrophe Options	58
Catastrophe Bonds	58
Compliance with Basel II in Practice	59
JPMorgan Chase	59
HBOS	61
Implementing Basel II: Some General Concerns	61
Summary of Key Concepts	63
References	64

CHAPTER 4 Key Challenges in Modeling Operational Risk	67
Operational Risk Models	67
Models Based on Top-Down Approaches	69
Multifactor Equity Pricing Models	69
Capital Asset Pricing Model	69
Income-Based Models	70
Expense-Based Models	70
Operating Leverage Models	70
Scenario Analysis and Stress Testing Models	70
Risk Indicator Models	71
Models Based on Bottom-Up Approaches	72
Process-Based Models	72
Actuarial Models	74
Proprietary Models	75
Specifics of Operational Loss Data	75
Scarcity of Available Historical Data	76
Data Arrival Process	77
Loss Severity Process	78
Dependence between Business Units	81
Summary of Key Concepts	81
References	82
CHAPTER 5	
Frequency Distributions	85
Binomial Distribution	86
Geometric Distribution	87
Poisson Distribution	88
Negative Binomial Distribution	92
Nonhomogeneous Poisson Process (Cox Process)	92
Mixture Distributions	93
Nonhomogeneous Poisson Process with Stochastic	

Mixture Distributions	93
Nonhomogeneous Poisson Process with Stochastic	
Intensity	93
Algorithm 1	93
Algorithm 2	94
Alternative Approach: Interarrival Times Distribution	94
Empirical Analysis with Operational Loss Data	95
Studies with Real Data	95
Cruz Study of Fraud Loss Data	95
Moscadelli Study of 2002 LDCE Operational	
Loss Data	97

De Fontnouvelle, Rosengren, and Jordan Study of	
2002 LDCE Operational Loss Data	98
Lewis and Lantsman Study of Unauthorized	
Trading Data	99
Chernobai, Burneçki, Rachev, Trück, and Weron	
Study of U.S. Natural Catastrophe Insurance	
Claims Data	99
Chernobai, Menn, Rachev, and Trück Study of	
1980–2002 Public Operational Loss Data	99
Chernobai and Rachev Study of 1950-2002	
Public Operational Loss Data	101
Studies with Simulated Data	103
Laycock Study of Mishandling Losses and	
Processing Errors Data	103
Cruz Study with Internal Fraud Data	103
Summary of Key Concepts	105
Appendix: Basic Descriptive Techniques for Discrete	
Random Variables	105
Sample	106
Population	106
References	109

CHAPTER 6 Loss Distributions

111 Nonparametric Approach: Empirical Distribution Function 113 Parametric Approach: Continuous Loss Distributions 114 **Exponential Distribution** 115 Lognormal Distribution 116 Weibull Distribution 117 Gamma Distribution 119 Beta Distribution 120 Pareto Distribution 122 **Burr** Distribution 123 Extension: Mixture Loss Distributions 125 A Note on the Tail Behavior 127 Empirical Evidence with Operational Loss Data 129 Studies with Real Data 129 Müller Study of 1950-2002 Operational Loss 129 Data Cruz Study of Legal Loss Data 130 Moscadelli Study of 2002 LDCE Operational Loss Data 132

De Fontnouvelle, Rosengren, and Jordan Study of	
2002 LDCE Operational Loss Data	134
Lewis Study of Legal Liability Loss Data	135
Studies with Simulated Data	135
Reynolds and Syer Study	135
Rosenberg and Schuermann Study	136
Summary of Key Concepts	136
Appendix: Basic Descriptive Techniques for Continuous	
Random Variables	137
Sample	137
Population	140
Transformations of Random Variables	142
Parameter Estimation Methods	143
References	144

CHAPTER 7

Alpha-Stable Distributions 147 Definition of an Alpha-Stable Random Variable 148 Useful Properties of an Alpha-Stable Random Variable 150 Estimating Parameters of the Alpha-Stable Distribution 152 Sample Characteristic Function Approach 152 Numerical Approximation of the Density Function Approach 153 Useful Transformations of Alpha-Stable Random Variables 153 Symmetric Alpha-Stable Random Variable 153 154 Log-Alpha-Stable Random Variable Truncated Alpha-Stable Random Variable 154 Applications to Operational Loss Data 154 Chernobai, Menn, Rachev, and Trück Study of 1980-2002 Public Loss Data 155 Chernobai and Rachev Study of 1950-2002 Public Loss Data 157 Summary of Key Concepts 158 Appendix: Characteristic Functions 158 Definition of Characteristic Functions 159 Some Properties of Characteristic Functions 160 **Relation to Distribution Functions** 161 161 References

CHAPTER 8

Extreme Value Theory	163
Block Maxima Model	163

193

	<i>(</i>)
	64
Generalized Pareto Distribution 1	64
Choosing the High Threshold 1	67
Value-at-Risk under Peak over Threshold Model 1	68
Estimating the Shape Parameter 1	69
Hill Estimator 1	69
Pickands Estimator 1	70
Advantages and Limitations of Extreme Value Theory 1	71
Empirical Studies with Operational Loss Data 1	71
Cruz Study of Fraud Loss Data 1	72
Moscadelli Study with 2002 LDCE Data 1	72
De Fontnouvelle, Rosengren, and Jordan Study with	
2002 LDCE Data 1	75
Chavez-Demoulin and Embrechts Study of Operational	
Loss Data 1	76
Dutta and Perry Study of 2004 LDCE Operational Loss	
Data 1	77
Summary of Key Concepts 1	77
References 1	79

CHAPTER 9

Truncated Distributions	183
Reporting Bias Problem	183
Truncated Model for Operational Risk	184
Data Specification	185
Parameter Estimation	187
Constrained Maximum Likelihood Function	
Approach	187
Expectation-Maximization Algorithm Approach	187
Comparison of Naive and Conditional	
Approaches: Lognormal Example	188
Empirical Studies with Operational Loss Data	191
Lewis and Lantsman Study with Unauthorized Trading	
Data	193
Baud, Frachot, and Roncalli Study with Crédit	
Lyonnais Loss Data	193
Chernobai, Menn, Rachev, and Trück Study with	
1980–2002 Public Operational Loss Data	194
Pooling Internal and External Data: Chapelle, Crama,	
Hübner, and Peters Study	197
Summary of Key Concepts	199
References	200

CHAPTER 10	
Testing for the Goodness of Fit	201
Visual Tests for the Goodness of Fit	201
Quantile-Quantile Plots	202
Mean Excess Plots	202
Common Formal Tests for the Goodness of Fit	204
Chi-Squared Tests	205
Pearson's Chi-Squared Test	205
Likelihood Ratio Test	206
Empirical Distribution Function-Based Tests	206
Kolmogorov-Smirnov Test	207
Kuiper Test	209
Anderson-Darling Test	209
Cramér-von Mises Test	210
Empirical Study with Operational Loss Data	211
Summary of Key Concepts	217
Appendix: Hypothesis Testing	217
References	219

CHAPTER 11 Value-at-Risk

Intuitively, What Is VaR? 221 Compound Operational Loss Models and Derivation of Operational VaR 222 A Simple Actuarial Model 222 Computing the Aggregate Loss Distribution 224 224 Monte Carlo Approach 225 Direct Computation Approach Panjer's Recursive Method 225 Inversion Method 226 226 Operational VaR 228 VaR Sensitivity Analysis Backtesting VaR 229 Kupiec's Proportion of Failures Test 229 Lopez's Magnitude Loss Function Test 230 Benefits and Limitations of VaR and Alternative Risk Measures 231 Benefits of VaR 231 Pitfalls of VaR 234 **Coherent Risk Measures** 234 Conditional Value-at-Risk and Other Risk Measures 235

221

Empirical Studies with Operational Loss Data De Fontnouvelle, Rosengren, and Jordan Study of 2002	237
LDCE Data	238
Chapelle, Crama, Hübner, and Peters Study with	
European Loss Data	239
Summary of Key Concepts	240
References	241
CHAPTER 12 Robust Modeling	946
-	245
Outliers in Operational Loss Data	246
Some Dangers of Using the Classical Approach	248
Overview of Robust Statistics Methodology	248
Formal Model for Robust Statistics	249
Traditional Methods of Outlier Detection	249
Examples of Nonrobust versus Robust Estimators Outlier Detection Approach Based on Influence	251
Functions	251
Advantages of Robust Statistics	252
Outlier Rejection Approach and Stress Tests	252
Application of Robust Methods to Operational Loss Data	253
Summary of Key Concepts	255
References	256
CHAPTER 13	
Modeling Dependence	259
Three Types of Dependence in Operational Risk	260
Linear Correlation	261
Covariance and Its Properties	261
Correlation and Its Properties	262
Aggregate Loss Correlation When Only Frequencies	
Are Dependent	264
Drawbacks of Linear Correlation	265
Alternative Dependence Measure: Rank Correlation	265
Copulas	266
Definition of Copula	266
Examples of Copulas	267
Using Copulas to Aggregate Credit, Market, and Operational	_0/
Risks	272
Empirical Studies with Operational Loss Data	272
Chapelle, Crama, Hübner, and Peters Study	272
Dalla Valle, Fantazzini, and Giudici Study	272

Kuritzkes, Schuermann, and Weiner Study	277
Rosenberg and Schuermann Study	278
Summary of Key Concepts	281
References	282

Index

285

Xİİİ