

Understanding Financial Risk Management

Second Edition

This page intentionally left blank

Understanding Financial Risk Management

Second Edition

Angelo Corelli

*Associate Professor of Finance,
Center of Excellence for Research in
Finance and Accounting,
American University in Dubai, UAE*



United Kingdom – North America
Japan – India – Malaysia – China

Emerald Publishing Limited
Howard House, Wagon Lane, Bingley BD16 1WA, UK

First edition 2019

Copyright © 2019 Emerald Publishing Limited

Reprints and permissions service

Contact: permissions@emeraldinsight.com

No part of this book may be reproduced, stored in a retrieval system, transmitted in any form or by any means electronic, mechanical, photocopying, recording or otherwise without either the prior written permission of the publisher or a licence permitting restricted copying issued in the UK by The Copyright Licensing Agency and in the USA by The Copyright Clearance Center. Any opinions expressed in the chapters are those of the authors. Whilst Emerald makes every effort to ensure the quality and accuracy of its content, Emerald makes no representation implied or otherwise, as to the chapters' suitability and application and disclaims any warranties, express or implied, to their use.

British Library Cataloguing in Publication Data

A catalogue record for this book is available from the British Library

ISBN: 978-1-78973-794-3 (Print)
ISBN: 978-1-78973-791-2 (E-ISBN)
ISBN: 978-1-78973-793-6 (Epub)



Certificate Number 1985
ISO 14001

ISOQAR certified
Management System,
awarded to Emerald
for adherence to
Environmental
standard
ISO 14001:2004.



INVESTOR IN PEOPLE

To the one and only:

Margherita

This page intentionally left blank

Contents

List of Tables	xv
List of Figures	xvii
About the Author	xxi
Preface to the First Edition	xxiii
Preface to the Second Edition	xxvii

Chapter 1: Risk: An Overview	1
1.1. Introduction	2
1.1.1. Randomness and Uncertainty	2
1.1.2. Rationality and Risk Aversion	5
1.1.3. Types of Risk	10
Snapshot 1.1: Common Forms of Utility Functions	15
1.2. The Process of Risk Management	16
1.2.1. Risk in Corporations and Financial Institutions	16
1.2.2. Identification, Measurement, and Mitigation	19
1.2.3. Risk Response Strategies	22
1.3. Theory of Markets	23
1.3.1. Arbitrage	23
1.3.2. The Efficient Market Hypothesis	25
1.3.3. The Brownian Motion	29
Snapshot 1.2: Sampling of Brownian Motion Paths in Excel	33
Summary	34
References	34
Exercises	34
Appendix: Types of Market Failure	37

Chapter 2: Financial Markets and Volatility	39
2.1. Modern Portfolio Theory	40
2.1.1. The Risk/Return Trade-off	40
2.1.2. Optimal Portfolios of Risky Assets	44
2.1.3. Optimal Portfolios with Risk-free Asset	48
Snapshot 2.1: Portfolio Optimization in Excel	50
2.2. The Capital Asset Pricing Model	51
2.2.1. Model Assumptions	51
2.2.2. The Security Market Line	55
2.2.3. Beyond CAPM	59

2.3. Volatility and Correlation	62
2.3.1. Types of Volatility	63
2.3.2. Correlation versus Covariance	66
2.3.3. Maximum Likelihood Methods	69
Snapshot 2.2: The Covariance Matrix of Financial Returns	72
Summary	72
References	73
Exercises	73
Appendix: The Table of the Standard Normal Distribution	77
Chapter 3: Conditional Dependence and Time Series	79
3.1. Modeling Financial Comovements	80
3.1.1. Conditional Covariance	80
3.1.2. Conditional Correlation	81
3.2. Time Series Analysis	83
3.2.1. ARCH/GARCH Models	83
3.2.2. Autocorrelation of Financial Returns	87
3.2.3. Other Stylized Facts	91
Summary	93
References	93
Chapter 4: Statistical Analysis	95
4.1. Relevant Distributions	96
4.1.1. Pareto Distribution	96
4.1.2. Binomial Distribution	100
4.1.3. Poisson Distribution	103
Snapshot 4.1: Excel Statistical Functions	108
4.2. Probabilistic Approaches	109
4.2.1. Scenario Analysis	109
4.2.2. Decision Trees	110
4.2.3. Simulations	113
Summary	115
References	116
Exercises	116
Appendix: Itô's Lemma	120
Chapter 5: Beyond Normality and Correlation	123
5.1. Copula Functions	124
5.1.1. Basic Properties	124
5.1.2. Measures of Dependence	127
5.1.3. Application to Risk Management	130
Snapshot 5.1: Monte Carlo Simulation of Copulas	133
5.2. Extreme Value Theory	133
5.2.1. Theoretical Background	134
5.2.2. Data Application	137
5.2.3. Extreme VaR	138

5.3. Beyond VaR	140
5.3.1. Model Back Testing	140
5.3.2. Expected Shortfall	143
5.3.3. Conditional VaR	145
Summary	147
References	148
Exercises	149
Appendix: VaR for Portfolios of Derivatives	150
Chapter 6: Conditional Risk Analysis	153
6.1. Beyond VaR	154
6.1.1. Expected Shortfall	154
6.1.2. Conditional VaR	156
6.2. Multivariate Return Distributions	158
6.2.1. GARCH(p, q) Modeling	159
Summary	161
References	161
Chapter 7: High-frequency Data	163
7.1. High-frequency Trading	163
7.1.1. Data Filtering	163
7.1.2. Basic Stylized Facts	166
7.2. Intraday Risk Analysis	167
7.2.1. Heterogeneous Volatility	167
Summary	169
References	170
Chapter 8: Financial Derivatives	171
8.1. Options and Futures	172
8.1.1. Types of Traders in the Market	172
8.1.2. Option Structure and Payout	175
8.1.3. Forwards and Futures	177
Snapshot 8.1: Volatility Strategy with Strangles	182
8.2. Interest Rate Derivatives	183
8.2.1. Interest Rate Swaps	183
8.2.2. Caps and Floors	185
8.2.3. Swaptions	188
Summary	192
References	192
Exercises	193
Appendix: The Market Price of Risk	194
Chapter 9: Option Pricing and Risk Modeling	197
9.1. Option Pricing Models	198
9.1.1. Binomial Trees	198
9.1.2. BSM Model	202

9.2. Portfolio Hedging	207
9.2.1. Delta Hedging	207
9.2.2. Gamma and Vega Hedging	210
9.2.3. The Cost of Hedging	212
Summary	214
References	215
Exercises	215

Chapter 10: Market Risk **217**

10.1. Market Risk Metrics	218
10.1.1. Overview of Market Risk	218
10.1.2. Quantile Metrics and Value-at-Risk	220
10.1.3. VaR Rationale and Definition	224
Snapshot 10.1: The Choice of Parameters for VaR	227
10.2. VaR Calculation Methods	228
10.2.1. Historical Simulation Approach	228
10.2.2. Parametric Method	229
10.2.3. Monte Carlo Simulation	231
Snapshot 10.2: Euler's Theorem on Homogeneous Functions	234
Summary	234
References	235
Exercises	236
Appendix: Factor Mapping for VaR	238

Chapter 11: Inside Value at Risk **241**

11.1. VaR Features	241
11.1.1. Decomposition	242
11.1.2. Limitations	245
11.1.3. Analytic Approximations	247
11.2. VaR Testing	249
11.2.1. Model Back Testing	249
11.2.2. Stress Testing	251
Summary	253
References	253
Appendix: Factor Mapping for VaR	255

Chapter 12: Interest Rate Risk **257**

12.1. The Dynamics of Interest Rates	258
12.1.1. Bond Prices and Yields	258
12.1.2. Fixed Income Futures	263
12.1.3. Yield Shifts and Immunization	267
Snapshot 12.1: Compounding Frequencies for Interest Rates	272
12.2. Short Rate Models	272
12.2.1. The Term Structure of Interest Rates	272
12.2.2. Single-factor Models	276
12.2.3. Multi-factor Models	280

12.3. IRR Management	282
12.3.1. Sources and Identification	282
12.3.2. Measurement Techniques	284
12.3.3. Duration and Convexity Hedging	286
Summary	290
References	291
Exercises	292
Appendix: Principal Component Analysis of the Term Structure	295
Chapter 13: Credit Risk	297
13.1. Basic Concepts	298
13.1.1. Default Probabilities	298
13.1.2. Loss Given Default	302
13.1.3. Credit Ratings	305
13.2. Structural Models	308
13.2.1. The KMV-Merton Approach	308
13.2.2. First Passage Models	313
13.2.3. CreditMetrics™	315
13.3. Reduced-form Models	317
13.3.1. The Jarrow-Turnbull Model	317
13.3.2. The Duffie-Singleton Model	320
13.3.3. CreditRisk+™	321
Summary	324
References	325
Exercises	326
Appendix: Markov Process for Transition Matrices	328
Chapter 14: Liquidity Risk	331
14.1. Market Prices	332
14.1.1. Market Microstructure	332
14.1.2. Price Formation	336
14.1.3. Funding versus Market Liquidity	338
Snapshot 14.1: Liquidity Black Holes	343
14.2. Models of Liquidity	344
14.2.1. Theoretical Models	344
14.2.2. Traceable Models	348
14.2.3. The Diamond-Dybvig Model	352
14.3. Liquidity Risk and Regulation	355
14.3.1. Liquidity Coverage Ratio	355
14.3.2. Net Stable Funding Ratio	358
14.3.3. Monitoring Tools	359
Summary	362
References	363
Exercises	364
Appendix: Liquidity CAPM	366

Chapter 15: Enterprise Risk	369
15.1. The Fundamentals	370
15.1.1. Identification and Assessment	370
15.1.2. The ERM Framework	373
15.1.3. The COSO ERM	374
15.2. Building and Enhancing	377
15.2.1. Improving the Process View	377
15.2.2. Technological Capabilities	380
15.3. Practical Implementation	382
15.3.1. The Role of the Management	382
15.3.2. Implementation and Models	385
Summary	386
References	386
Chapter 16: Other Risks	387
16.1. Operational Risk	388
16.1.1. Identification and Assessment	388
16.1.2. Treatment and Control	391
16.1.3. Basel II Approach	393
16.2. Currency Risk	397
16.2.1. Types of Currency Risk	397
16.2.2. Foreign Exchange Derivatives	399
16.2.3. Risk Hedging in FX Markets	404
16.3. Volatility Risk	405
16.3.1. Implied Volatility	406
16.3.2. Callable Bonds	407
16.3.3. Variance Swaps	410
Snapshot 16.1: Gamma Swaps	413
Summary	414
References	415
Exercises	415
Appendix: Risk-adjusted Return on Capital	417
Chapter 17: Financial Crisis and Securitization	419
17.1. Crisis and Regulation	420
17.1.1. The Lack in Regulatory Framework	420
17.1.2. The Crisis in Europe	424
17.1.3. The Impact on the Financial Industry	428
17.2. Credit Derivatives	430
17.2.1. Asset Swaps	430
17.2.2. Credit Default Swaps	435
17.2.3. CDS Spreads with Counterparty Credit Risk	438
Snapshot 17.1: The Newton–Raphson Method	441

17.3. Securitization	442
17.3.1. Structure and Participants	442
17.3.2. Collateralized Debt Obligations	444
17.3.3. Advantages and Disadvantages	448
Summary	450
References	451
Exercises	452
Appendix: A Model of SPVs	453
Chapter 18: Hedging Techniques	455
18.1. Market Risk Hedging	456
18.1.1. Delta Hedging	456
18.1.2. Gamma and Vega Hedging	458
18.1.3. The Cost of Hedging	460
18.2. Credit Risk Hedging	463
18.2.1. Modeling Exposure	463
18.2.2. Credit Value Adjustment	467
18.2.3. Monte Carlo Methods	472
18.3. Advanced IRR Hedging	475
18.3.1. M-Absolute and M-Squared Models	475
18.3.2. Duration Vectors	477
18.3.3. Hedging with Fixed Income Derivatives	480
Snapshot 18.1: Convexity Adjustment for Interest Rate Derivatives	483
Summary	484
References	485
Exercises	486
Chapter 19: Advanced Topics	489
19.1. VaR Advances	490
19.1.1. Modified Delta VaR	490
19.1.2. Historical Simulation Revisited	493
19.1.3. Modified Monte-Carlo and Scenario Analysis	495
19.2. Alternative Risk Transfer	496
19.2.1. The ART Market	496
19.2.2. Primary Contracts	498
19.2.3. Insurance Derivatives	501
19.3. High-frequency Trading	504
19.3.1. Data Filtering	504
19.3.2. Basic Stylized Facts	506
19.3.3. Heterogeneous Volatility	508
Summary	510
References	511
Exercises	512
Appendix: Power Laws for Intraday Data	513

Chapter 20: The Future of Financial Risk Management	515
20.1. The Role of Corporate Governance	516
20.1.1. Management Failures	516
20.1.2. Remuneration and Incentive Systems	519
20.1.3. Post-crisis Perspectives	522
20.2. The Banking Sector	522
20.2.1. Bank Risk and Business Models	522
20.2.2. Risk Management Systems	524
20.2.3. Areas of Future Improvements	528
20.3. Challenges for Research	531
20.3.1. Interbank Risk	531
20.3.2. Energy Derivatives	532
20.3.3. Sovereign Risk Dynamics	535
20.4. Digitalization and Risk Management	537
20.4.1. The Impact of Fintech	538
20.4.2. Big Data and Risk	538
Summary	539
References	540
Exercises	540
 Index	 543

List of Tables

Table 1.1	Risk Likelihood.	21
Table 1.2	Risk Impact.	21
Table 1.3	Risk Priority.	21
EXtable 2.1		50
EXtable 2.2		50
EXtable 2.3		51
EXtable 2.4		68
EXtable 2.5		68
EXtable 2.6		74
EXtable 2.7		75
EXtable 2.8		75
EXtable 2.9		76
EXtable 2.10		76
EXtable 2.11		77
EXtable 2.12		78
EXtable 4.1		108
EXtable 4.2		108
EXtable 4.3		109
EXtable 4.4		110
EXtable 4.5		118
EXtable 4.6		119
Table 8.1	Replication of a Forward Contract by Using the Underlying Asset.	179
EXtable 8.1		193

Table 12.1	Effective Annual Rate Calculation for Different Compounding Frequencies.	259
Table 12.2	Compounding Frequencies.	259
EXTable 12.1		265
EXTable 12.2		265
EXTable 12.3		266
EXTable 12.4		292
EXTable 12.5		292
EXTable 12.6		293
EXTable 12.7		293
Table 13.1	Credit Conversion Factors for PFE Calculation.	302
EXTable 13.1		303
Table 13.2	Credit Ratings Assigned by the Major Credit Agencies.	306
Table 13.3	Credit Ratings on Sovereign Countries.	307
Table 13.4	Altman's z-Score Factors and Weights.	307
EXTable 13.2		308
Table 13.5	A Typical Example of a Credit Ratings Transition Matrix.	316
EXTable 13.3		326
EXTable 13.4		326
EXTable 13.5		327
Table 14.1	Runoff Rates for the Major Asset Categories.	357
Table 14.2	RSF Factors for the Major Category Components.	360
EXTable 14.1		364
EXTable 14.2		365
EXTable 14.3		365
Table 16.1	Operational Income Factors and Indicators for the Different Business Lines in the Bank.	394
Table 18.1	Volatility Spread Approximations.	469
Table 18.2	Add-on Percentages of the Underlying Amount for Different Types of Contract.	470
EXTable 18.1		486
EXTable 18.2		487

List of Figures

Fig. 1.1	Graph Concave Utility Function.	9
Fig. 1.2	Diversification.	11
Fig. 1.3	Risk Process.	17
Fig. 1.4	Information Subsets.	28
Fig. 2.1	Normal Distribution 1.	41
Fig. 2.2	Normal Distribution 2.	41
Fig. 2.3	Normal Distribution 3.	42
Fig. 2.4	Efficient Frontier for Portfolio of Risky Assets.	45
Fig. 2.5	CML.	49
Fig. 2.6	Leverage.	50
Fig. 2.7	SML.	58
Fig. 2.8	SML Alpha.	59
Fig. 3.1	Autocorrelation.	88
Fig. 3.2	ACF.	89
Fig. 4.1	Pareto Distribution.	98
Fig. 4.2	Binomial Distribution.	102
Fig. 4.3	Poisson Distribution.	106
Fig. 4.4	Tree Nodes.	111
Fig. 4.5	Tree Example 1.	112
Fig. 4.6	Tree Example 2.	113
Fig. 5.1	Copula Gauss Student.	126
Fig. 5.2	Copula Clayton Frank.	127
Fig. 5.3	Copula Gumbel.	127
Fig. 5.4	Frechet Weibull Distribution.	136
Fig. 5.5	Gumbel Distribution.	136

Fig. 8.1	Long Call.	176
Fig. 8.2	Short Call.	176
Fig. 8.3	Long Put.	177
Fig. 8.4	Short Put.	177
Fig. 8.5	Forward.	178
Fig. 8.6	Strangles.	182
Fig. 9.1	Binomial Tree.	198
Fig. 9.2	Price Tree.	200
Fig. 10.1	Normal Distribution VaR.	221
Fig. 10.2	VaR.	223
Fig. 12.1	Yield Shift 1.	267
Fig. 12.2	Yield Shift 2.	267
Fig. 12.3	Yield Shift 3.	268
Fig. 12.4	The Yield Curve, As Resulting from Most Common Models of the Interest Rates, and Observed Empirically, Can Take Different Forms.	273
Fig. 13.1	The KMV Modeling of Expected Default.	312
Fig. 13.2	CreditMetrics™.	315
Fig. 13.3	CreditMetrics™ Thresholds.	317
Fig. 14.1	Liquidity.	340
Fig. 16.1	Structure of Internal Controls.	392
Fig. 16.2	Loss Frequency and Severity.	394
Fig. 16.3	Callable Duration.	409
Fig. 16.4	Convexity.	410
Fig. 17.1	Asset Swap.	431
Fig. 17.2	Market Asset Swap.	432
Fig. 17.3	CDS.	435
Fig. 17.4	Securitization.	443
Fig. 17.5	Tranches.	445
Fig. 17.6	CDO.	446
Fig. 17.7	ABS CDO.	446

Fig. 19.1	Captives.	499
Fig. 19.2	Multi-risk.	500
Fig. 19.3	Cat Swap Before.	502
Fig. 19.4	Cat Swap After.	503
Fig. 19.5	Stylized Facts.	507
Fig. 20.1	Board of Directors.	517
Fig. 20.2	Remuneration.	520
Fig. 20.3	Banking.	525
Fig. 20.4	Diagram of a Crude Oil Swap.	534

This page intentionally left blank

About the Author

Angelo Corelli is Associate Professor of Finance at the American University in Dubai. His field of expertise is financial risk management with a focus on credit risk. Angelo's research topics span from quantitative risk management to term structure analysis and valuation/risk of financial derivatives. The main focus of his teaching lies on corporate finance, with a special emphasis on corporate valuation mechanisms.

This page intentionally left blank

Preface to the First Edition

A Modern Approach

Understanding Financial Risk Management offers an innovative approach to financial risk management. With a broad view of theory and the industry, it aims at being a friendly, but serious, starting point for those who encounter risk management for the first time, as well as for more advanced users.

The focus is no longer on the mere measurement, but on the whole package. Risk is also opportunity, and when managing it, one should reach the right balance between opportunity and loss. That is why we propose a new approach that starts from the basic knowledge of classic theory and methodologies and moves to the latest findings in measurement and hedging.

Many books are more exhaustive in covering some of the topics that are treated in this book, but most of them do not offer the wholesome coverage on the horizon of financial risk management as the present book does.

There is no doubt that a deeper analysis of many concepts is possible, but no book in the actual market is able to collect all risks and the managing of them in one single essay. This book is definitely an all-included piece or work that guides the reader from the beginning to the end without ever losing focus on what is more important for good risk-management knowledge.

An Innovative Pedagogy

The foundations of the book rely on three main blocks: theory, analytics, and computational. They all merge in a way that makes it easy for students to understand the exact meaning of the concepts and their representation and applicability in real world contexts. Examples are given throughout the chapters in order to clarify the most intricate aspects; where needed, there are appendices at the end of chapters that give more mathematical insights about specific topics.

Learning comes from the correct combination of the three pillar elements, none of which should be excluded. The trinity stands as the foundation of the whole project.

Preferably, students have a solid background in financial mathematics, statistics, and basic econometrics. Indeed, students facing financial topics for the first time may benefit from using the book as a medium-level introduction to some aspects of financial theory and practice.

In this sense, practitioners represent a possible share of the users of the book. In recent years, due to the global financial crisis, the demand for links between academics and private industry has increased substantially. For this reason, practitioners nowadays

like to explore the work done in academic research, and this book provides useful information for managers who want to increase their knowledge about risk management and understand what may have been the lacking in their own systems.

A Selected Audience

The book is meant for third- or fourth-year undergraduate students of business finance, quantitative finance, and financial mathematics. Most of the universities that the book would target offer the kind of training in mathematics and statistics that would be prerequisites for the successful completion of a course using *Understanding Financial Risk Management*. Potential users include students of universities, technical schools, and business schools offering courses in financial risk management.

This book offers a unique approach and represents a clear improvement on existing textbooks in the field of finance. Most textbooks on financial risk management focus on measurement or on some specific kind of risk. There is no challenge or criticism in them, and there is no drive for understanding risk management in the critical sense. That is exactly what this book will offer.

Quantitative approaches now incorporate a more critical view and contribute to a vision that does not blindly rely on numbers, but takes into account the variety of (sometimes unpredictable) situations that characterize financial markets.

Certainly, it is not an easy book, but it is a book that never abandons the reader. Even in the most complicated parts, the student is guided through the processes and given the tools he needs; nothing is cryptic.

A Reliable Partner for Instructors

Understanding Risk Management is tailored mostly for in-class lectures, and it has the best effect if combined with good quality lecture slides from the instructor. Secondly, given its overall flexibility (a result of its simple structure), it can also be used for online learning. However, the medium-high level of difficulty of the book suggests the need for a closer relation with the instructor and the possibility of in-person explanations.

The structure of *Understanding Financial Risk Management* lends itself to a typical Swedish course of approximately six ECTS. The 10 chapters, of at most 60 pages each, can fit a course design of about 14–16 lectures of 1.5 hours effective teaching. That would also fit an overall international standard of a course with two lectures per week spanned over a two-month teaching term. The overall contents in the book can fill approximately 40–60 hours of teaching.

Richness in Content

This book is the ultimate tool for understanding the many aspects of financial risk management, and it comes with a solid theoretical set.

This first edition has been edited to help educators around the world, suiting users dealing with financial risk for the first time, as well as more advanced users looking for an innovative approach.

As a textbook, the richness in content, exercises, and applications makes the book the perfect partner for the students of all areas in the world, all shaped in a book featuring:

- (a) 14 chapters,
- (b) 70 major and 126 detailed learning outcomes,
- (c) numerous tasks (questions and exercises),
- (d) snapshots and appendices wherever relevant, and
- (e) numerous selected references.

Every chapter follows the same structure, where the full text is complemented by snapshots relating to cutting-edge research and up-to-date news. At the end of each chapter, there is an exercise section with targeted tasks.

This page intentionally left blank

Preface to the Second Edition

The second edition of *Understanding Financial Risk Management* aims to improve the first edition by introducing a more structured approach to the sources of risk in the organization, and the methods used to manage it.

From identification to assessment and management, all types of financial risks a company faces daily are analyzed, together with the tools and techniques that can be used to limit their impact and manage their connected risk events.

Built on the solid pedagogical approach used in the first edition, the second edition improves it by extending the narrative to modern and innovative topics like enterprise risk.

The result is a 20-chapter textbook that takes the student into a full-immersion experience. After an introductory part where distributional issues, statistical tools, and other foundation topics are analyzed, the chapters start digging deep into all types of financial risk that are normally presented to the organization on a daily basis.

An improved coverage of major risks, together with ample narrative on how to use financial derivatives to hedge risk, offer a complete view on past, current, and future trends in financial risk management.

This page intentionally left blank

Chapter 1

Risk: An Overview

Financial markets are typically characterized by transparent pricing and specific trading regulations. The costs, fees, and market forces determine the price of traded securities, and the risk embedded in any single trade.

Risk can be defined as the possibility of negative outcome as a consequence of specific choices. In all fields of life, including business and financial activities, actions that lead to a loss can be defined as risk. Various types of risk daily affect a business; but when it comes to money, they can be mainly classified into two types: business risk and financial risk.

Financial risk in particular involves the financial structure of the corporation. It generally arises by variability of prices and returns on financial markets. Movements can involve any kind of security as stocks, currencies, derivatives, and interest rates.

Financial risk managers have the duty to perform identification, measurement, and hedging of risk, if necessary. Financial instruments can be used for the purpose but it is not always necessary to do that, since often risk entails the opportunity of a good expected return in exchange.

It is not possible to prevent all possible risks, given some of them are unpredictable and not identifiable sufficiently in advance. However, for many types of risk, the analytical, computational, and numerical tools available in the literature can offer a way of reducing uncertainty.

After studying this chapter, you will be able to answer the following questions, among others:

- (1) What is financial risk and how does it differ from other types of risk?
- (2) What are the various types of financial risk and how do they link to each other?
- (3) What are the differences among risk in banks, corporation, and insurances?
- (4) How can we define the process of risk management, and what steps does it involve?
- (5) What are the most common types of strategies and instruments involved in risk management?

The first section of the chapter is an introduction to the definition of risk, and how it arises in different types of business. The second section is about the various types of financial risk and their interconnection. The final part aims at introducing the process of risk management, as identification, measurement, and mitigation and/or transfer.

1.1. Introduction

Learning Outcomes

- (1) Distinguish between uncertainty and risk.
- (2) Learn about generic concepts in utility theory.
- (3) Acquire generic knowledge about different types of risk.

1.1.1. Randomness and Uncertainty

Financial risk management has its roots in the history of commercial and financial trades, but it is still a modern quantitative discipline. Its development began during the 1970s, on the premises of the first Basel Accord, between the G10 countries, which covered the regulation of banking risk.

Modern financial markets are constantly subject to speculative attacks and external shocks, given the uncertainty of the actual worldwide economic environment. Financial risk management is therefore in a state of confusion, and gained focus, in recent years, on the minimization of capital charges and corporate risk.

Managing risk is about making decisions under uncertainty, with decisions involving a large share of investors, and determining the outcome of investing strategies for even bigger investors, like banks.

It is now clear that old-fashioned financial risk management has contributed in generating the most severe financial crisis the world ever experienced, due to common use of static risk measurement methodologies and unrestrictive regulatory provisions. As a consequence of the lack in regulation and modeling efficiency, the policies of banks and financial institutions have fed the bubble until it burst, with the effects of the explosion spreading all over the world.

The subprime mortgage affair in US turned quite fast into a global crisis, involving all sectors of the financial and real economy. At some point, it was clear that something was wrong in how risk assessment of new assets had been managed until then.

One of the first definitions of the difference between uncertainty and risk was given by Knight, in 1921. He argued that uncertainty differs from risk for the important reason that risk can be measured precisely.

This difference also plays a crucial role in financial markets, given that, if risk were the only relevant feature of randomness, it could have been possible for financial institutions properly equipped, to price and market insurance contracts based on risky phenomena only. The role of uncertainty is to create frictions that cannot be easily accommodated.

Uncertainty then refers to the situation where an event has an unknown probability, and individuals tend to choose gambles with precise expected outcome, compared to gambles with unknown odds.

Both uncertainty and risk define a random environment and affect individuals and their choices. The behavior of individual agents is often counterintuitive, if confronted to the classic expected utility model, and research has focused on that aspect.

Based on the fact that, if uncertainty is so influential on individual behavior, an equilibrium outcome should exist, Knight claims that, as oppose as risk, uncertainty cannot be insured.

The presence of uncertainty causes departure from standard utility theory and sets an environment where insurance markets may break down, while the randomness of probabilities does not allow for precise pricing of risky claims.

Randomness drives risk and uncertainty, and the two concepts are strictly linked to each other but with some differences. Risk entails the existence of a measurable probability associated to the event.

Probabilities are calculated directly or by induction, depending on the availability of observable variables. Calculation by induction is made via analytical models or by analysis of the past information.

In few words, risk is a quantifiable variable, while uncertainty is not. This is the main distinction between risk and uncertainty. The purpose of financial analysis is to assess risk based on available information.

When a choice must be made, both uncertainty and risk apply. In financial literature, most of the work has been done on risk, given its calculability. It is anyway not appropriate to fully ignore uncertainty.

Example 1.1: Consider two portfolios traded on a market. The first portfolio, *A*, is a risk-free investment on government bonds, while the second portfolio, *B*, includes risky complex securities written on a market index. If the expected return on portfolio *A* is 2.5%, and the expected return on portfolio *B* is 9.5%, that means investors are demanding an extra 7% to move their money from a risk-free investment to a risky investment.

The concept of risk spans on different disciplines from insurance and engineering to classical economic theories like portfolio theory. Each discipline defines risk in a different way. Some of these definitions are in terms of:

- (a) Probability and consequences: This definition of risk focuses on the likelihood of an event to happen and the consequences of the event. Both aspects are involved in ranking the risk-level of an event. Consider for example a tsunami: it has a very small probability of happening, but when happening, it will carry severe consequences. Therefore, it would be ranked as a high-risk event.
- (b) Risk or threat: There is a difference between a threat and a risk. Threat is considered to be a very low probability event with extremely large negative outcomes and no possibility for analysts to assess the probability of that event to happen. Risk on the other hand is similar, but it involves events happening at a higher probability, where it is possible to assess both probability and outcome.
- (c) Positive and negative outcome: Definitions of risk may involve both positive and negative variability around the mean, or just focus on the downside

scenarios. A fair definition of risk in this sense is the product of probability of an event occurring and the assessed value of the outcome. In the following chapters, it will be clear how this is the main definition of risk underlying the financial analysis.

To be more specific, in finance risk is defined as the (positive or negative) variability of financial returns on some type of investment, around some expected (mean) return. It is then fundamental to understand how to define risk broadly, in order to include both positive and negative side of the variability.

The general rule of thumb is that there is a direct link between risk and reward. High levels of positive outcome can be obtained only getting exposed to considerably large risk. The principle is that there is no free lunch in life, and especially in finance. In fact, the link between risk and return is a foundation of classical and modern finance theory.

In the following chapters, this concept will come very clear. Just for now, it is preliminary important to consider, as an example the difference between investing on financial markets. Stocks are much more risky than bonds, and give a higher expected return.

The concept can be extended to all aspects of life. Therefore, for any business the key to success is the reliability of decision on what types of risk is worth to take, and how much of it.

Protecting the business against all the risk, in some sense, results in limiting the profit opportunities. On the other hand, being exposed to the wrong type of risk can lead to even worse scenarios.

That is why a crucial part of good business management is about making the right choices on how to face different types of risk. Good risk management is a crucial part of good corporate management.

A typical example of risk and uncertainty in finance is the classical portfolio problem. Consider an agent endowed with a wealth of amount w , to invest. The market is very simple, being composed of a risk-free asset paying a fixed rate r and a risky asset with random return x . The random return is distributed according to a cumulative density function, $F(x)$. The utility function of the investor u is assumed to be concave (this is very important for the existence of a risk measure, as it will become clearer in the next paragraphs).

The total wealth is invested by the individual, by dividing it between an amount m of the risky asset, and an amount $w - m$ in the risk-free asset. Therefore, the resulting portfolio value is given by the combination of the stochastic return on the risky asset, and the deterministic return on the risk-free asset, and can be written as

$$p = mx + (w - m)r$$

The problem of asset allocation, among the assets in the market, entails an optimization program, which maximizes the expected utility from the investment strategy as described.

The investor maximizes the portfolio value given the utility function, and the program is defined as

$$\max \int u[mx + (w - m)r]dF(x)$$

The first-order condition for the program is

$$\int u' [m(x - r) + wr](x - r)dF(x) = 0$$

If the investor is risk neutral, there is no need of compensation for the risk taken, and the resulting utility function is linear and directly proportional to the value of the risky asset, in the form

$$u(x) = \lambda x$$

where
 λ is some constant.

This makes the marginal return on the investment is given by the sum of returns on both the risk-free and the risky part of the investment.

$$r_M = \lambda r(w - m) + \lambda mE(x)$$

where
 $E(x)$ is the expected return on the risky asset, which is equivalent to

$$r_M = \lambda wr + \lambda m[E(x) - r] \quad (1.1)$$

Equation (1.1) shows that returns are always positive if $E(x) > r$ and always negative otherwise. The logical consequence is that a risk-neutral investor will always invest all the wealth in the asset with highest expected return.

Given this result, the concavity of the utility function also implies that the marginal return given by investing a bit more in the risky asset is always positive. This is a very important result, implying that also a risk-averse investor will choose to not put all the wealth on just the risk-free asset.

All types of investors will always choose to put at least a small bit of their wealth on the risky assets. In terms of insurance, this means that a risk-averse agent will never choose to buy full insurance, unless insurance prices are equal or below the fair actuarial level, where the fair actuarial price is the price corresponding to a zero net present value.

1.1.2. Rationality and Risk Aversion

The theory of rational expectations is a foundation of modern economics and finance. It includes assumptions on how the investors (agents) process the available information to form their expectations.

There are some firm points in the theory of rationality and information, which is scarce on the markets, so that it is important to keep track of the relevant knowledge. Investors form their expectations in a way that depends on the structure of the economic system, and the information history embedded in market prices.

In finance, the outcome of many situations depends on the expectations of investors. Often prices depend on the trading decision of the investors, which in turn depend on how the investors behave on the market.

People tend to rush in selling and buying assets, following the predictions they have on the market price. Financial markets tend to adjust very quickly to new information and investors must be quick in implementing their strategies.

There is a two-way flow of influences between expectations and outcomes, so that people try to make forecasts of what will occur, and base their expectations on that.

Better forecast mean better profits.

Investors adjust their expectation and the way they interpret the information is highly dependent on the past outcome of the process. They adapt the forecasting rules to previous errors, to eliminate them.

Rational expectations theory states that outcomes do not differ from people prediction, when these are based on rational processing of the universally available information. Singularly taken, the investors can make mistakes, but the various sides of the market will adjust rapidly and those mistakes will not be persistent.

The theory is based on the assumption that people behave in order to maximize their utility and this belief is the core of a theory that tries to predict future outcomes of an economic system, based on past decisions of the agents.

Rational expectations are at the basis of many theories, like the random walk theory of financial assets, the efficient market hypothesis, economic theories of consumption, public economic policies, and so on.

The efficient market hypothesis applies rational expectations to efficient markets and asset pricing. It concludes that, after adjusting for discounting and dividends, the changes in a stock price follow a random walk process.

The main bug in classical consumer choice theory is that all the results are drawn in a framework of certainty. However, as mentioned above, real world is characterized by uncertainty, so that bad things may happen, and agents must adapt to it.

Investors make choices in a context of uncertainty and the outcomes are often unpredictable. But there is a need to look forward, and make predictions somehow. In order to get a realistic model of choice, it is necessary to model uncertainty.

A standard gamble has the following expected payoff:

$$E(x) = p_+ x_+ + (1 - p_+) x_-$$

where

p_+ is the probability of a positive outcome

x_+ is the positive outcome
 x_- is the negative outcome.

If asked about entering a fair gamble with positive payoff, most people behave in such a way that they would reject a gamble even if it has an expected positive payoff, when the uncertain prospects are worth less in utility terms than certain ones, even when expected tangible payoffs are the same.

Example 1.2: Assume you are offered a fair gamble. A coin is tossed with a positive payoff (win) of €1,000 if it is head and a negative payoff (loss) of €850 if it is tails. The expected value is

$$E(x) = 0.5 \times 1,000 - 0.5 \times 850 = €75$$

A positive value suggests the gamble is worth to be accepted. However, the downside potential loss is so consistent, compared to the winning amount, that most people would reject the gamble.

In order to characterize mathematically the utility maximization framework, leading to the definition of risk and risk measurement, define a world with $1, 2, \dots, n$ possible states associated to probabilities $p_i = p_1, p_2, \dots, p_n$. The expected value is defined as

$$E(x) = \sum_{i=1}^n p_i x_i$$

Dispersion (variance) is measured as

$$\text{Var}(x) = \sum_{i=1}^n p_i (x_i - E(x))^2$$

Example 1.3: A stock has a 25% probability, in one year, of being worth €400 and a 75% probability of being worth €200. The expected value is

$$E(x) = 0.25 \times 400 + 0.75 \times 200 = €250$$

and the variance is

$$\text{Var}(x) = 0.25 \times (400 - 250)^2 + 0.75 \times (200 - 250)^2 = 7,500$$

By the standard theory of utility, a utility function on the real domain $U|_{\mathbb{R}}$ has an expected utility form if it is possible to assign values u_1, u_2, \dots, u_n to the outcomes of a simple lottery. The expected value of the lottery is then given by

$$E(x) = \sum_{i=1}^n p_i u_i$$

where

p_i is the probability of outcome i in the simple lottery.

Consider also the compound lottery defined as $(l_1, l_2, \dots, l_J; \pi_1, \pi_2, \dots, \pi_J)$ being the set yielding the lottery l_j with probability π_j . A utility function has the expected utility form if and only if

$$u\left(\sum_{j=1}^J \pi_j l_j\right) = \sum_{j=1}^J \pi_j u(l_j)$$

The shape of the utility function determines the different relationships between expected outcomes and the utility they give. In particular, for a lottery with n outcomes, the main distinction is between the expected value of the utility, defined as

$$E[u(x)] = \sum_{i=1}^n p_i u(x_i)$$

and the utility of the expected outcome, which is given by

$$u[E(x)] = u\left(\sum_{i=1}^n p_i x_i\right)$$

The risk premium involved in the choice is defined as the difference between the wealth after entering the gamble, and the certain amount.

Example 1.4: Suppose an investor with an initial wealth $w = €100$ and utility function $U(w) = \sqrt{w}$. The risk premium associated to a gamble with 50% probability to get to a wealth of €120 and 50% of lowering the wealth to €80, is given by calculating the expected utility first, as

$$E[u(w)] = 0.5\sqrt{120} + 0.5\sqrt{80} = 9.95$$

Since $u(w) = \sqrt{w} \Rightarrow w = [u(w)]^2$, the wealth associated with it is given by

$$w = 9.95^2 = €98.99$$

And the risk premium is given by

$$RP = 100 - 98.99 = €1.01$$

The relationship between the expected utility and the utility of the expectation determines the risk attitude of the investors. It turns out that if

$$E[u(x)] = u[E(x)]$$

where

$u(\cdot)$ is a concave utility function.

The investor is risk neutral, if

$$E[u(x)] > u[E(x)]$$