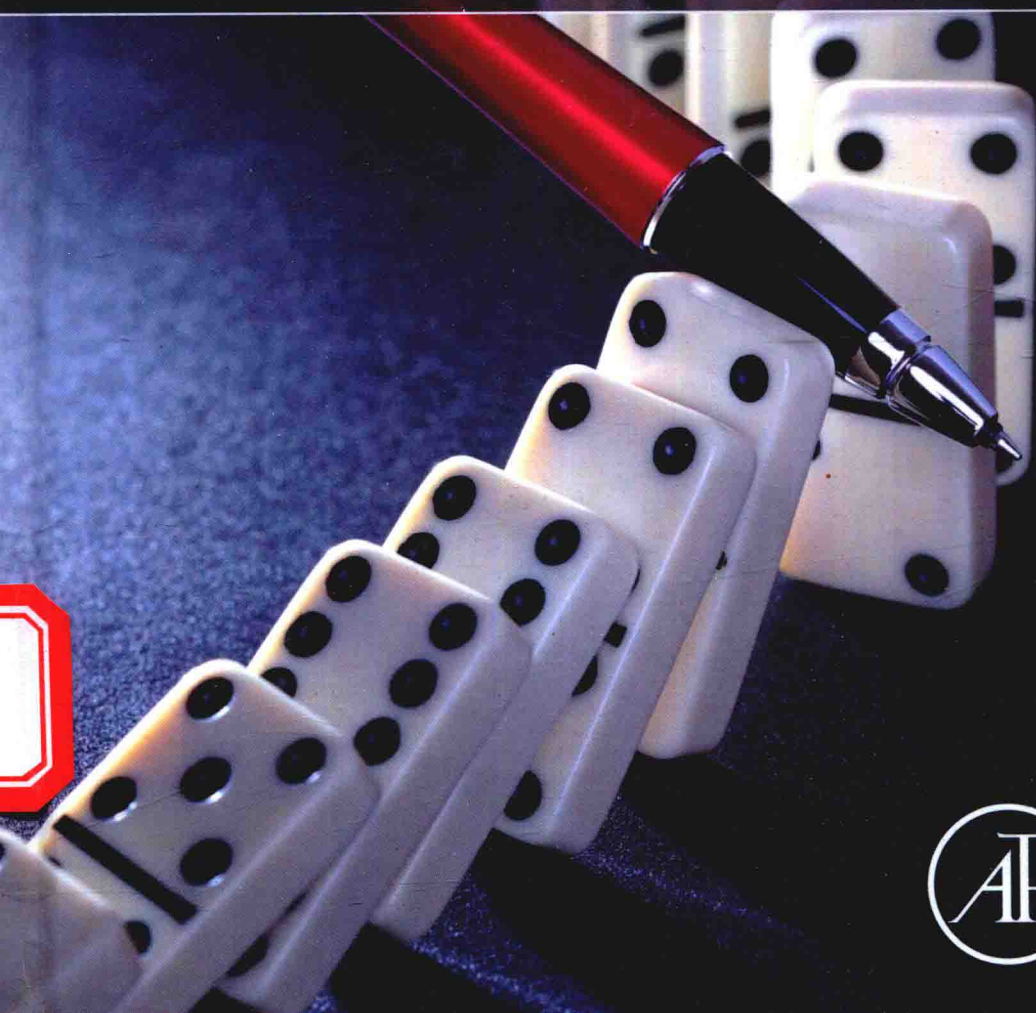


STRESS TESTING AND RISK INTEGRATION IN BANKS

A Statistical Framework and Practical Software
Guide (in Matlab and R)

TIZIANO BELLINI



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Tiziano Bellini



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Stress Testing and Risk Integration in Banks

Dedication

Ai miei genitori, Patrizia e Leonardo

Tiziano Bellini's Biography

Tiziano Bellini received his PhD degree in statistics from the University of Milan after being a visiting PhD student at the London School of Economics and Political Science. He gained wide risk management experience across Europe, in London, and in New York. He currently holds a senior management position at EY Financial Advisory Services in London. Previously he worked at HSBC's headquarters, Prometeia, and other leading Italian companies. He is a guest lecturer at the London School of Economics and Political Science. Formerly, he served as a lecturer at the University of Bologna and the University of Parma. He has published in the *European Journal of Operational Research*, *Computational Statistics and Data Analysis*, and other top-reviewed journals. He has given numerous training courses, seminars, and conference presentations on statistics, risk management, and quantitative methods.

Preface

This book provides a comprehensive view of stress testing and risk integration in banks. Statistical tools are used as a guide to assess how adverse economic conditions may affect economic and financial resilience. A first focus is on links connecting macroeconomic variables and bank-specific conditions. Time series are studied as part of the scenario analysis that is the very heart of the process. An asset and liability management frame is the other necessary ingredient to represent balance sheet and profit and loss dynamics under stress.

The text is aimed at graduates, master students, and practitioners. Examples and business cases are included in all chapters. The analysis of a stylized bank (i.e., Bank Alpha) highlights the interconnections among the key areas of risk management interest all over the book. As an additional practical aspect, software examples in MATLAB and R enable readers to familiarize themselves with empirical implementations. The choice of these tools is driven by their wide use both in academia and in banks. Their flexibility in dealing with time series, Monte Carlo simulations, and other statistical models is an additional advantage experienced throughout the text.

When dealing with an overall stress testing exercise, one may be dragged into the details of a specific topic. The risk is to lose the broader picture behind it. On this subject, the book presents a global view of a bank. The toolkit encompasses a wide range of instruments such as statistical techniques, accounting rules, and regulatory standards.

A special focus is devoted to bank vulnerabilities. On this subject, it is worth quoting the following from the *Financial Times* (Sep. 14, 2008):

Deal or no deal? ... Without a buyer, or collective action by the bank's peers to save it, Lehman seemed poised to become the latest big casualty of this financial crisis. As possible saviors such as Barclays and Bank of America pulled back from talks, the implications for Lehman appeared dire. Bankruptcy would be a tragic ending for an institution known for its fighting spirit.

Both long- and short-term peculiarities are examined. In this regard, the final goal of the book is to study how to integrate risks and perform a reverse stress test. In line with the need to manage risk interdependencies, top-down and bottom-up risk integration approaches are investigated. More specifically, a bottom-up framework aligned with a wide stress testing mechanism is used to integrate market, credit, interest rate, and liquidity risks through the lenses of an asset and liability management structure. On this, reverse stress testing

constitutes a critical instrument to guide a strategic risk management process. Macroeconomic analysis combined with what-if enquiries are cutting-edge tools qualifying a risk management practice operating in a global economy.

The book is structured as follows. Chapter 1 introduces stress testing and risk integration by pointing out their role within a regulatory and managerial framework. As a necessary ingredient of the overall analysis, Chapter 2 introduces the key concepts related to time series analysis. The focus is on statistical techniques such as vector autoregression, vector error-correction, and global vector autoregression models. Forecasting, scenario enrichment, and Monte Carlo simulations are explored as an initial step of the stress testing process. Chapter 3 outlines the key concepts related to asset and liability management. Bank Alpha is described in detail in this chapter. Margin and liquidity risks are studied by consideration of the entire balance sheet structure. Then the focus shifts to the trading book through the proposal of the most common value at risk methods. Chapter 4 illustrates how to model credit portfolio losses. A bridge is built between the portfolio modeling literature and Basel II Accord regulatory capital requirements. Moreover, a macroeconomic transmission mechanism is illustrated as a key process driving balance sheet and economic (profit and loss) projection as detailed in Chapter 5. In this regard, Bank Alpha is extensively used to show how balance sheet projections feed profit and loss, risk-weighted assets, and eventually, capital and liquidity ratios. Chapter 6 collects the results of the preceding chapters to assess capital ratios, leverage, and liquidity indices under stress. Finally, Chapters 7 and 8 describe how to integrate risks and perform a coherent reverse stress testing analysis.

Tiziano Bellini
London, May 2016

Acknowledgments

This book is the fruit of a long journey that started with my graduation in business and economics from the University of Parma, enriched with a doctorate in statistics from the University of Milan and enhanced through experience gained working in the financial industry across Europe, in London, and in New York.

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My greatest thanks are addressed to my parents, who supported me when I despaired of my ability to combine research and professional activities. Their quiet and continuous help gave me the strength to continue pursuing my ideas even when this appeared to be impossible. I also thank my sister for her warming admiration. I dedicate this work to her and my nephew Leonardo, the most energizing and adorable creature that God donated to my family.

Contents

Tiziano Bellini's Biography	xiii
Preface	xv
Acknowledgments	xvii
1. Introduction to Stress Testing and Risk Integration	1
1.1 Antidote to the Crisis	1
1.1.1 What Went Wrong	2
1.1.2 Regulatory Responses	4
1.2 Stress Testing, Risk Integration, and Reverse Stress Testing	7
1.2.1 Stress Testing	7
1.2.2 Risk Integration and Reverse Stress Testing	12
1.3 Book Structure at a Glance	15
1.3.1 Organization of the Book	17
1.4 Summary	22
References	23
2. Macroeconomic Scenario Analysis from a Bank Perspective	25
Key Abbreviations and Symbols	26
2.1 Introduction	26
2.2 Autoregression and Moving-Average Modeling	27
2.2.1 $AR(p)$ Analysis	28
2.2.2 $MA(q)$ Analysis	28
2.2.3 $ARMA(p, q)$ Analysis	29
2.2.4 Box-Jenkins Time Series Analysis	31
2.3 Vector Autoregression and Vector Error-Correction Modeling	34
2.3.1 Vector Autoregression and Vector Error-Correction Analysis	34
2.3.2 Vector Autoregression and Vector Error-Correction Forecast	42
2.3.3 Impulse Response Analysis	46
2.4 Global Vector Autoregression Modeling	47
2.4.1 Introduction to the Global Vector Autoregression Model	47
2.4.2 Global Vector Autoregression Analysis	48
2.4.3 Global Vector Autoregression Forecast	51
2.4.4 Generalized Impulse Response Analysis	52
2.5 Stress Testing Scenario	53
2.5.1 Scenario Design	54
2.5.2 Conditional Forecasting	55

2.5.3	Bank Alpha's Stress Testing Scenario	57
2.5.4	Macroeconomic Modeling and Satellite Frameworks	58
2.6	Summary	60
	Suggestions for Further Reading	60
	Appendix. Robust Vector Error Correction Model: A Forward Search Approach	61
	Exercises	69
	References	70
3.	Asset and Liability Management, and Value at Risk	73
	Key Abbreviations and Symbols	74
3.1	Introduction	75
3.2	Margin at Risk	77
3.2.1	Margin at Risk Estimation	81
3.2.2	Interest Rate Sensitivity Analysis	90
3.2.3	Term Structure of Interest Rates	93
3.2.4	Margin at Risk Under a Stress Testing Scenario	97
3.2.5	Bank Alpha's Stress Testing Margin at Risk	98
3.3	Value at Risk	99
3.3.1	Variance-Covariance Value at Risk	103
3.3.2	Monte Carlo Simulation Value at Risk	105
3.3.3	Historical Simulation Value at Risk	106
3.3.4	Stress Testing and Regulatory Value at Risk	107
3.3.5	Bank Alpha's Market RWA	109
3.4	Liquidity Analysis	109
3.4.1	Bank Alpha's Liquidity Analysis	111
3.5	Summary	114
	Suggestions for Further Reading	114
	Appendix A. Kalman Filter for Affine Term Structure Models	115
	Appendix B. Robust Kalman Filter: A Forward Search Approach to Estimate Affine Term Structure Models	117
	Exercises	119
	References	120
4.	Portfolio Credit Risk Modeling	123
	Key Abbreviations and Symbols	124
4.1	Introduction	124
4.2	Credit Portfolio Modeling	125
4.2.1	Credit Loss Distribution	126
4.2.2	CreditMetrics	131
4.2.3	Credit Portfolio Modeling With Copulas	138
4.3	Credit Risk-Weighted Assets	142
4.3.1	Standardized Credit Risk-Weighted Assets	142
4.3.2	Internal Ratings-Based Credit Risk-Weighted Assets	144
4.3.3	Bank Alpha's RWAs for Credit Risk	148

4.4	How to Link Credit Risk Parameters and Macroeconomic Variables	148
4.4.1	Default Probability and Macroeconomic Variables	149
4.4.2	Loss Given Default and Macroeconomic Variables	151
4.5	Portfolio Credit Risk Stress Testing	152
4.5.1	Stress Testing Risk-Weighted Assets	152
4.5.2	Portfolio Credit Stress Testing	154
4.6	Summary	155
	Suggestions for Further Reading	156
	Appendix A: Default Probability Estimation Via Logit Regression	156
	Appendix B: The Forward Search for Elliptical Copulas	158
	Exercises	160
	References	161
5.	Balance Sheet, and Profit and Loss Stress Testing Projections	163
	Key Abbreviations and Symbols	164
5.1	Introduction	164
5.2	Balance Sheet Projection	165
5.2.1	Credit Life Cycle	166
5.2.2	Performing Portfolio Projection	169
5.2.3	Nonperforming Portfolio Projection	172
5.2.4	Trading Book, Other Assets, and Liabilities Projection	173
5.2.5	Bank Alpha's Stress Testing Balance Sheet	176
5.3	Profit and Loss Projection	179
5.3.1	Profit and Loss Mechanics	179
5.3.2	Bank Alpha's Stress Testing Profit and Loss	183
5.4	Conduct and Operational Risk Stress Testing	187
5.4.1	Projection of Conduct and Operational Losses	187
5.4.2	Risk-Weighted Assets for Operational Risk	187
5.4.3	Bank Alpha's Stress Testing Operational RWA	190
5.5	Summary	191
	Suggestions for Further Reading	191
	Exercises	192
	References	193
6.	Regulatory Capital, RWA, Leverage, and Liquidity Requirements Under Stress	195
6.1	Introduction	196
6.2	Regulatory Capital	198
6.2.1	How to Compute the Regulatory Capital	199
6.2.2	Bank Alpha's Stress Testing Regulatory Capital	203
6.3	Risk-Weighted Assets and Capital Ratios	208
6.3.1	Bank Alpha's Risk-Weighted Assets (From a Silo Perspective)	208
6.3.2	Risk-Weighted Asset Aggregation	211

6.3.3	Bank Alpha's Stress Testing Capital Ratios	213
6.4	Leverage and Liquidity Ratios	216
6.4.1	Leverage Ratio	216
6.4.2	Bank Alpha's Stress Testing Leverage	217
6.4.3	Liquidity Coverage Ratio	219
6.4.4	Bank Alpha's Stress Testing Liquidity Coverage Ratio	220
6.4.5	Net Stable Funding Ratio	222
6.4.6	Bank Alpha's Stress Testing Net Stable Funding Ratio	224
6.5	Summary	227
	Suggestions for Further Reading	232
	Exercises	232
	References	234
7.	Risk Integration	235
	Key Abbreviations and Symbols	236
7.1	Introduction	236
7.2	Top-Down Risk Integration Modeling	238
7.2.1	Basic Integration	238
7.2.2	Top-Level Integration	239
7.2.3	Base-Level Integration	244
7.3	Bottom-Up Economic Capital Integration Modeling	246
7.3.1	Economic Capital Integration	246
7.3.2	Integration Process	247
7.3.3	Bank Alpha's Integrated Economic Capital	254
7.4	Bottom-Up Liquidity Integration Modeling	256
7.4.1	Risk Integration: Liquidity (Short-Term Perspective)	257
7.4.2	Bank Alpha's Integrated Liquidity	261
7.5	Summary	262
	Suggestions for Further Reading	262
	Exercises	263
	References	263
8.	Reverse Stress Testing	265
	Key Abbreviations and Symbols	266
8.1	Introduction	266
8.2	Reverse Stress Testing Objective Function	267
8.2.1	Reverse Stress Testing: Economic Capital Versus Liquidity Mismatching	267
8.3	Integrated Risk Modeling and Vulnerability Thresholds	269
8.3.1	Long- and Short-Run Risk Integration	269
8.3.2	Vulnerability Thresholds	270
8.4	Bank-Specific Disastrous Event Fact Finding	273
8.4.1	Trading Book	273
8.4.2	Banking Book	277
8.4.3	Liquidity and Overall Financial Structure	279

8.5	Exploration of Ruinous Macroeconomic Scenarios	281
8.5.1	Long- and Short-Run Ruinous Scenarios	281
8.5.2	Conditional Mean and Hull Contours	283
8.5.3	Bank Alpha's Ruinous Scenario Analysis	287
8.6	Summary	287
	Suggestions for Further Reading	289
	Exercises	289
	References	289
	Index	291

Chapter 1

Introduction to Stress Testing and Risk Integration

Chapter Outline

1.1 Antidote to the Crisis	1	1.2.2 Risk Integration and Reverse Stress Testing	12
1.1.1 What Went Wrong	2	1.3 Book Structure at a Glance	15
1.1.2 Regulatory Responses	4	1.3.1 Organization of the Book	17
1.2 Stress Testing, Risk Integration, and Reverse Stress Testing	7	1.4 Summary	22
1.2.1 Stress Testing	7	References	23

Since the 2007–09 crisis, increasing attention has been devoted to capital adequacy and balance sheet integrity. Banks have been required to improve the quality of their own funds, strengthen their liquidity structure, and enforce their risk management processes. As a starting point, this chapter outlines the regulatory response to the recent financial crunch. On this subject, stress tests and risk integration are useful tools to enhance bank resilience against adverse conditions. Then, Bank Alpha’s illustrative example is introduced to show how an international bank runs its business. It serves to outline throughout the book all complex challenges one needs to face when modeling risks. As in an executive summary, this introductory chapter shows some of Bank Alpha’s main stress testing and risk integration results. Finally, a practical guide to explore the text is provided. It serves as a map for the reader looking for orientation during the deep-dive journey.

1.1 ANTIDOTE TO THE CRISIS

A series of failures recently sharpened the question about the role of banks in a modern economic system. On this subject, two ways may be followed to connect savings and investments. Firstly, fund suppliers may directly meet the financial demand by acquiring equity positions or debt instruments. However, the wide range of costs associated with direct finance justifies a second way to link money supply and demand. Financial intermediaries screen, monitor, and diversify risks by providing credit to those needing resources.

It is worth noting that, in the recent past, banks progressively moved from their traditional institutional background to a more marked economic value

creation perspective. This evolution raised a possible conflict with their social role by highlighting the potential for systemic breakdown. In this regard, given the nature of their operations, banks never hold sufficient capital to guarantee full deposit withdrawals. Additionally, the opaque nature of financial investments does not allow analysts to distinguish the problems specific to one intermediary from those affecting the industry as a whole. As a result, the distress of one entity may lead to runs on others as well. These are the reasons why laws and regulations govern financial intermediation, as detailed in the following sections.

1.1.1 What Went Wrong

Many economic crises in history originated as failures of financial intermediaries. A few banks became bankrupt during the 2007–09 crisis, and many more had impaired operations. Nevertheless, major disruptions occurred among new segments of financial intermediation. A run on asset-backed commercial paper (ABCP) liabilities was one of the main issues experienced during the recent crisis. These short-term funding instruments were used to finance asset portfolios with long-term maturities. ABCP issuers (conduits) performed a typical financial intermediation function but they were not banks. In many instances, banks were the driving force behind ABCP funding growth. They sponsored these activities and provided the required liquidity. However, this new structure shifted a component of financial intermediation away from its traditional location. Additionally, money market mutual funds experienced a run on their liabilities. This event, in turn, triggered an even bigger run on ABCP issuers. The Lehman Brothers Business Case 1.1 exemplifies some of the above-mentioned financial intermediation failures.

Business Case 1.1 Lehman Brothers

Since the early 1900s Lehman Brothers had developed its banking practice, becoming a well-known investment bank. In the first decade of this century, the company widely expanded its services. The most complex products developed in the wake of the financial deregulation belonged to its business. During the period from 2006 to 2007, Lehman Brothers initiated a new strategy. The company aggressively bought real-estate assets. At the end of its 2007 fiscal year, Lehman Brothers held \$111 billion in commercial or residential assets and securities, more than double the \$52 billion it held at the end of 2006, and more than four times its equity. Market illiquidity and massive losses in this business caused rating agencies and investors to express concerns in 2008. During that summer, the financial situation of Lehman Brothers becomes unsustainable. The crisis became public. On the weekend of Sep. 12–14, 2008, the government communicated its intention not to bail out the firm. A meeting with the major Wall Street investment banks was organized. A private solution similar to that for the Long-Term Capital Portfolio L.P. structured in 1998 was planned. Despite the interest from Bank of America and Barclays, the discussions ultimately failed. Suddenly, Lehman

Brothers realized that it would not be able to raise enough funds to open for business the next day. Its board of directors voted to file for Chapter 11 bankruptcy protection on Sep. 15, 2008. The bank was granted an opportunity to have certain parts of its operations dismantled in an orderly fashion overseen by a bankruptcy court.

The Lehman Brothers case revealed the major issues encountered during the crisis:

- **Level and quality of capital (capital ratios).** The crisis showed there was an insufficient level of regulatory capital to cover losses and write-downs of some banks. Inconsistencies in the definition of *capital* across countries prevented markets from assessing banks' capital quality. A number of banks continued to make large distributions. There were dividend payments, share buybacks, and generous compensation payments even though financial conditions were deteriorated. These losses destabilized the banking sector and exacerbated a downturn in the real economy.
 - **Risk coverage of capital (leverage).** High leverage operations and complex securitization exposures were major sources of losses for many banks. Nonetheless, their capital framework did not substantially capture these risks.
 - **Illiquidity (liquidity ratios).** Before the crisis, funding was readily available at low cost. The rapid reversal of market conditions highlighted how quickly liquidity could vanish and this could last for an extended period. Many banks experienced difficulties managing their liquidity. Central banks needed to take action to support both the functioning of money markets and, in some cases, individual institutions. Business Case 1.2 focuses on Northern Rock's causes of distress.
-

Business Case 1.2 Northern Rock

Northern Rock was a building society (i.e., a mutually owned savings and mortgage bank) until its decision to go public in 1997. This bank was a regionally based institution, serving its local customers. Its success was mainly related to the revitalization of the North East of England following the decline of traditional industries, such as coal mining and shipbuilding. Northern Rock had larger ambitions. In the 9 years after it had gone public to the eve of the crisis in Jun. 2007, its total assets grew from £17.4 billion to £113.5 billion. Its liability structure reflected this unusual dynamic by depending heavily on nonretail funds. By the summer of 2007, only 23% of its liabilities were in the form of retail deposits. The rest of its funding came from short-term borrowing in the capital markets, or through securitized notes. ABCP was the favored means to fund Northern Rock's growth.

In the summer 2007 the subprime crisis started affecting banks' balance sheets. The demise of Northern Rock dated from Aug. 9. The news that BNP