

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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I am immensely indebted to Katarzyna Marciak, Daniel Ruediger, Charity Muhangi, and Alessandra Luati for their encouragement and precious help in reviewing earlier versions of the manuscript.

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.

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Chapter 1

Introduction to Stress Testing and Risk Integration

Chapter Outline

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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