Macrofinancial Risk Analysis
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Macrofinancial Risk Analysis

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and
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John Wiley & Sons, Ltd
I dedicate this book to Cheryl, Ryan, Marie, and Colin.

DFG

I dedicate this book to the memory of my father and greatest friend, John Malone.

SWM
# Contents

Foreword xv
Preface xix

1 Introduction 1

PART I OVERVIEW OF FINANCE, MACROECONOMICS, AND RISK CONCEPTS 7

2 An Overview of Macroeconomics, and Why the Theory of Asset Pricing and Contingent Claims Should Shape its Future 9
  2.1 An overview of macroeconomics 10
  2.2 How uncertainty is incorporated into macroeconomic models 13
  2.3 Missing components in macro models: balance sheets with risk, default, and (nonlinear) risk exposures 15
  2.4 Asset-pricing theory, financial derivatives pricing, and contingent claims analysis 17
  2.5 Autoregression in economics vs. random walks in finance 19
  2.6 Asset price process related to a threshold or barrier 21
  2.7 Relating finance models and risk analytics to macroeconomic models 23
  2.8 Toward macrofinancial engineering 24
  2.9 Summary 25
References 26

3 Macroeconomic Models 29
  3.1 The Hicks–Hansen IS-LM model of a closed economy 29
  3.2 The Mundell–Fleming model of an open economy 33
  3.3 A dynamic, stochastic, five-equation, small open economy macro model 38
  3.4 Summary 42
References 42
4 Stochastic Processes, Asset Pricing, and Option Pricing
  4.1 Stochastic processes
  4.2 Itô’s lemma
  4.3 Asset pricing: Arrow–Debreu securities and the replicating portfolio
  4.4 Put and call option values
  4.5 Pricing the options using the Black–Scholes–Merton formula
  4.6 Market price of risk
  4.7 Implications of incomplete markets for pricing
  4.8 Summary

Appendix 4A Primer on relationship of put, call, and exchange options
Appendix 4B Physics, Feynman, and finance

References

5 Balance Sheets, Implicit Options, and Contingent Claims Analysis
  5.1 Uncertain assets and probability of distress or default on debt
  5.2 Probability of distress or default
  5.3 Debt and equity as contingent claims
  5.4 Payoff diagrams for contingent claims
  5.5 Understanding why an implicit put option equals expected loss
  5.6 Using the Merton model and Black–Scholes–Merton formula to value contingent claims
  5.7 Measuring asset values and volatilities
  5.8 Estimating implied asset value and asset volatility from equity or junior claims
  5.9 Risk measures
  5.10 Summary

References

6 Further Extensions and Applications of Contingent Claims Analysis
  6.1 Extensions of the Merton model
  6.2 Applications of CCA with different types of distress barriers and liability structures
  6.3 Risk-adjusted and actual probabilities using the market price of risk, Sharpe ratios, and recovery rates
  6.4 Moody’s-KMV approach
  6.5 CCA using skewed asset distributions modeled with a mixture of lognormals
  6.6 Maximum likelihood methods
  6.7 Incorporating stochastic interest rates and interest rate term structures into structural CCA balance sheet models
  6.8 Other structural models with stochastic interest rates
  6.9 Summary

Appendix 6A Calculating parameters in the Vasicek model

References
10 Macrofinance Modeling Framework: Financial Sector Risk and Stability Analysis

10.1 Calculating risk indicators for individual banks or financial institutions
10.2 Time series of financial system risk indicators
10.3 Snapshot of system risk
10.4 Expected loss as a portfolio of implicit put options
10.5 Using a structural Merton model with stochastic interest rates for capital adequacy estimates
10.6 Factor model to assess key drivers of system risk and for scenario analysis
10.7 Multifactor risk analysis using copulas
10.8 Household balance sheet risk
10.9 Linking banking sector loans to corporate, household, and other borrowers
10.10 Foreign-currency-denominated loans and the impact of the presence of foreign banks on banking system risk
10.11 CCA models, financial stability indicators and links to macro models
10.12 Summary

Appendix 10A CCA model for banks and borrowers with foreign-currency-denominated debt and lending spreads based on credit risk

References

11 Macrofinance Modeling Framework: Extensions to Different Exchange Rate Regimes

11.1 Floating exchange rate regimes, interest rates, and the sovereign balance sheet
11.2 Fixed exchange rate regimes, interest rates and the sovereign balance sheet
11.3 The impact of capital flows on the CCA sovereign balance sheet
11.4 Role of quasi-public entities in exchange rate management
11.5 Summary

References

PART III LINKING MACROFINANCIAL AND MACROECONOMIC FRAMEWORKS

12 Sovereign Reserve, Debt, and Wealth Management from a Macrofinancial Risk Perspective

12.1 Reserves adequacy and asset allocation: moving from simple rules to a national framework
12.2 CCA for a firm with a subsidiary and its wealth management
12.3 Constructing contingent claim balance sheets for the national economy
12.4 Macro risk and wealth management
12.5 Summary

References
| Appendix A | Mundell–Fleming with a Risk Premium | 311 |
| A.1 | The model | 311 |
| A.2 | Equilibrium | 315 |
| A.3 | Monetary and fiscal policy | 317 |
| A.4 | Summary | 321 |
| References | | 322 |

Index | 323 |
The arrival of *Macrofinancial Risk Analysis*, with its new perspective on how investors, bankers, risk managers, economic overseers and policymakers can measure and analyze risk in both emerging market and developed economies, could not have been better timed. We are amidst a perplexing financial crisis of banking and credit risk which is directly affecting the United States, United Kingdom and Europe. At the same moment, many emerging market countries, often the sources of financial crisis, appear remarkably strong, with large reserves and trade surpluses. How it will play out in the impending future, we do not know. But what we do know is that over the past five to ten years, the interconnected risks among emerging and developed market countries have become significantly greater, reactions in financial markets across geopolitical borders are considerably more rapid, and the complexity of the risk structures in every domain has increased dramatically. Happily, the collection of market-proven risk measurement and risk management techniques has also become proportionally richer. Dale Gray and Samuel Malone provide a prime exemplifying case by applying the financial engineering tools of contingent claims analysis (CCA) to create an innovative and substantial addition to the measurement, analysis, and management of the financial risks of a national economy. From its 1970s origins in measuring the risk and pricing of derivative securities, CCA has continuously found ever broader applications in the mainstream of finance and risk management. This book extends this type of analysis to help us better understand and evaluate risk flows among sectors and across economies and links this new approach to traditional macroeconomic analysis.

The core analytical tool employed is the CCA risk-adjusted balance sheet, which quantifies the risk sensitivity of a country or sector’s assets and liabilities to external “shocks.” At the national level, the corporate, financial and governmental sectors of an economy are viewed as interconnected portfolios of assets, liabilities, and guarantees – some explicit and others implicit. Traditional sovereign-risk models have difficulty in analyzing how risk exposures can be rather benign at a point in time and then without any apparent change in asset or liability holdings, those exposures increase rapidly and erupt into a full-blown crisis. Such behavior is however well-understood by risk managers of a derivatives book in which the non-linear nature of the derivative prices relative to the underlying fundamentals can cause rapid and radical changes in the risk characteristics of the book without any changes in the actual positions held. Both the assets and liabilities of the various macro-sectors exhibit non-linear derivative-like structures. The CCA approach is well-suited to capturing the impact of such non-linearity and quantifying the risk effects of asset-liability mismatches within and across institutions. Gray and Malone apply CCA at the level of the government sector to develop risk measures that help gauge the probability of systemic crises. Risk-adjusted CCA balance sheets are used to facilitate simulations and stress testing to evaluate the potential impact of policies to manage systemic risk. This approach to evaluating risk on the
balance sheets of the macroeconomic sectors represents an enhanced framework for macro
risk analysis distinct from, and complementary to, traditional macroeconomic analysis based
primarily on flow variables.

The approach also applies modern risk management and finance techniques to the macro-
economy to achieve a richer method of assessing country vulnerability, as well as the
valuation of sovereign debt, contingent liabilities, equity and other contingent claims on
sector assets. It can be used to help formulate relative-value investing and trading strategies,
including sovereign capital structure arbitrage and cross-sector and cross-country arbitrage.
In addition, the framework can enrich analysis and management of sovereign wealth funds
and to inform the design of new instruments and contracts to control or transfer risk between
economies.

Section I begins with two chapters that provide an overview of the evolution of selected
models from macroeconomics and finance, and make the case for why a new generation of
macrofinance models are needed that integrate the two types of models. Chapter 3 reviews a
few core macroeconomic models used for evaluating policy. Chapter 4 proceeds to explain
the basic analytical tools used in finance, including a primer on stochastic processes and
option pricing models. Chapters 5 and 6 describe contingent claims analysis and its extensions
that are used throughout the book.

Section II begins by laying out the basic macrofinance framework with contingent claims
balance sheets of interlinked sectors (sovereign, financial, corporate, and household) and
the risk transmission between sectors in Chapter 7. Chapter 8 discusses how sovereign
contingent claim balance sheets can be calibrated using current financial market prices and
used to calculate sovereign credit risk indicators. It describes how this new tool can be used
for policy analysis, including debt and reserves management as well as fiscal policy. Chapter
9 discusses the relationship between models of interest rates in macroeconomics, as in the
Taylor rule in macroeconomic policy models, and term structure of interest rates models in
finance, with a view towards reconciling these different approaches. In Chapter 10, financial
stability indicators are developed that are linked into macroeconomic models in the chapters
to follow. Chapter 11 discusses the adaptation of the macrofinance framework to fixed and
floating exchange rate regimes.

Section III begins with Chapter 12 on new applications of macrofinance to sovereign
reserve, debt, and sovereign wealth management, which is certainly a hot topic at the moment
and promises to continue to be so into the indefinite future. Chapter 13 shows how to relate
the risk-adjusted, contingent claims balance sheets of macrofinance to the standard flow-
of-funds and national accounting balance sheets used in macroeconomic analysis. Among
other things, it shows how traditional macroeconomic flow-of-funds can be derived as a
special case of contingent claims pricing relationships in the limit as uncertainty disappears.
Chapter 14 discusses several ways to link macrofinance outputs to monetary policy models,
Dynamic Stochastic General Equilibrium (DSGE) models, and macroeconometric Vector
Autoregression (VAR) models.

Section IV focuses on analyzing financial distress and crisis in economies, beginning
with an overview in Chapter 15 of the existing economics literature on financial crises.
Chapter 16 discusses four important “destabilization mechanisms”, or potentially danger-
ous interactions of nonlinear effects, that can cause crises to occur in the context of the
macrofinance model. These mechanisms rely on the valuation formulas of contingent claims
analysis applied to the macroeconomic sectors, and as such, are contributions to the the-
ory of financial crises. Chapters 17 and 18 are devoted to an empirical application of the
macrofinance model to study the Asian crisis of 1997–98 and the Brazilian crisis of 2002, respectively.

Section V applies the insights of the macrofinance approach to selected topics relevant to senior managers in international financial institutions, staffs of finance ministries, and global investors. Chapter 19 uses the macrofinance model to focus on the new international global environment and the potential impact of international shocks and risk transmission. Chapter 20 looks at alternative policies, contracts, and tools that can be used to transfer and mitigate risk on the sovereign balance sheet and the economy. It points out how the modern techniques of Alternative Risk Transfer (ART) can be adapted and applied at the sector, economy, and international level. Chapter 21 offers several ideas for investment and trading strategies, including sovereign capital structure arbitrage using relative-value techniques based on contingent claims and macrofinance model. Chapter 22 closes the book with a summary look at the “bigger picture” surrounding macrofinance and lays out several suggestions for future research ideas, which will surely be of interest to those working in both macroeconomics and finance.

*Macrofinancial Risk Analysis* is a bold and largely self-contained offering of an integration of finance and macroeconomic modeling to help us to better understand, measure and manage risk in the evolving global economic system. Whether prime researcher, experienced public policy maker, or seasoned private-sector practitioner, the reader is in for a treat: *Bon Appétit!*

Robert C. Merton
Harvard Business School
The initial sense of the need to bring finance and risk management insights to bear on macroeconomics, as described in this book, was the outcome of one author’s (Dale Gray’s) experience in the International Monetary Fund (IMF) during the Asian and Russian crises. The failure of traditional macroeconomic flow and stock models to deal with the credit risk and balance sheet aspects of the Asian and Russian crises was so evident that it was clear that a new framework blending risk analysis and balance sheets with macroeconomics was long overdue. When we first met and worked together in the International Capital Markets (ICM) department of the IMF, during the summer of 2005, we decided to write this book. It is the product of years of work and fascination, on both our parts, with the idea that concepts from finance and risk management can, and should, be applied to improve our understanding of important issues and policy questions in macroeconomics – in particular those relating to financial crises as well as sovereign risk and wealth management. A related motivation for this work is the belief of the authors that finance and macroeconomics can be unified within an appropriate overarching mathematical framework.

Several people deserve thanks for their many helpful and insightful conversations related to this material during the past several years. In particular we would like to thank Robert Merton and Zvi Bodie for all their help and support. We would also like to thank Carlos Medeiros, Matthew Jones, Mike Gapen, Cheng Hoon Lim, Ying-bin Xiao, Mark Swinhurne, Chris Towe, Andrea Maechler, and John Odling-Smee of the IMF, Dan Russell and Simon Jiang (Moody’s Investors Service), David Vines (Oxford), Gustavo García (IESA), Enrique ter Horst (IESA), Stephen Kealhofer (MKMV), Joe Zou (Taconic), Emanuel Derman (Columbia University), Pijus Verkitus and Ben Heller (HBK), and Erwin Martens (TIAA-CREF) whose support and confidence in this project has helped to make it possible. Additionally, we would like to express our appreciation for the hard work of the team at John Wiley & Sons, including Samantha Hartley, Aimée Dibbens, Caitlin Cornish, Pete Baker, and Sunita Jayachandran at Integra. Finally, we would like to thank those macroeconomists (primarily in the IMF) who were so certain that finance has absolutely nothing to offer macroeconomics, on the level of theory or practice, that it gave an added impetus to carry this work forward for the sake of both.
In this book we will:

• Provide a new framework for risk and policy analysis using quantitative risk-based tools for:
  — evaluation of financial institution risk and financial system stability;
  — improving ratings and vulnerability analysis for firms, banks, and sovereigns;
  — reserve, fiscal, and debt management;
  — assessing benefits of risk mitigation policies and transfer contracts;
  — linking macroeconomics with finance in a more unified framework.

• Apply modern risk management and finance techniques to the macroeconomy so as to better assess country vulnerability, and the valuation of debt, contingent liabilities, equity, and other contingent claims on sector assets.

• Analyze the impact of shocks, both domestic and external, on the macroeconomy using a framework based on the analysis of risk-adjusted, interlinked balance sheets of the major economic sectors. The new framework measures non-linear risk transmission between the sectors of the economy and from abroad.

• Provide a new framework for relative valuation, investing, and trading, including sovereign capital structure arbitrage and cross-sector and cross-country arbitrage. The framework allows for analysis and management of sovereign wealth funds and the design of new instruments and contracts to control or transfer sovereign risk.

The fields of macroeconomics and finance have both experienced great innovations during the past thirty-five years. Unfortunately, some of the most important advances during that period are only just beginning to percolate between the two fields. Despite their apparent differences in subject matter, the two fields have a substantial natural area of overlap. Both are concerned with interest rates and the determination of prices. Finance focuses on the prices of assets, whereas macroeconomics focuses on the prices of goods. The major entities that make up the economy – households, governments, firms, and banks – hold portfolios consisting of both types of assets, however, and must be concerned with both asset and goods prices.

Moreover, the entities in the economy are linked by the fact that the assets of one entity form part of the assets of other entities. Changes in the value of assets induce changes in the fair value of the liabilities backed by those assets, and this, in turn, changes the market value of the assets and liabilities of the entity that owns those liabilities. These valuation linkages are crucial in the macroeconomy, especially when default on liabilities is a real possibility. Most current macroeconomic models, and especially those used for policy analysis, however, routinely ignore both valuation linkages and the possibility of default. One major goal of this book is to provide a framework that can be used to help overcome these limitations in our analysis of the macroeconomy.
The directionality of our contribution in this book, in theoretical terms, will be first from finance and risk management to macroeconomics. As we will see later in the book, the integration of these two fields provides new insights for financial activities – investing, trading, risk mitigation, and risk transfer arrangements. The results we believe will be of interest to finance professionals and macroeconomists alike. Our framework is based on the method of contingent claims, which was pioneered by Robert Merton in the early 1970s. The “Merton model”, as it is popularly known in finance, is a structural model of the firm built upon the observation that the value of a firm’s liabilities, whether debt or equity, is linked directly to the value of the firm’s assets. Debt and equity are different types of claims, and because of their different payoff structures, will share differently the value of the firm’s assets, depending on the level and volatility of those assets, the interest rate, and the face value of the debt, among other factors.

Adapting risk management and contingent claims analysis to the sectors of the macroeconomy, and linking it with macroeconomics, requires considerable work; to do it properly requires nothing less than a book. With that said, the reader will see clearly that several parts of what follows contain a variety of ideas for future research. Our goal in this work is to lay out the basics of the “macrofinance” approach, as we like to call it, in a very clear way that can be adapted for policy-making, for a course on this or a related subject in economics departments, and for courses in business schools.

We believe that an analytical framework that takes into account both balance sheets and risk exposures is a necessary part of any analysis of macroeconomic and sectoral vulnerability. We make the argument on a theoretical and empirical level that such an analytical platform is well suited to explaining a variety of past crises, and could be invaluable in anticipating and diffusing new ones.

The book is organized into five parts. Part I begins with Chapter 2, which lays out an overview of macroeconomics and finance. It discusses how shocks and volatility are handled in macroeconomic models but not uncertainty and risk. A conspicuous omission in macroeconomic models has been risk exposures, in particular default risk, as well as risk transmission between sectors and the behavioral nonlinearities to which these features give rise. Finance, and the closely related field of risk management, contain the appropriate tools to quantify and measure risks in the macroeconomy, as well as risk transmission within and between economies. It points out the need for a new generation of macrofinance models that combine the two types of models into an integrated system – a system of equations which are part macroeconomic equations and part finance/option-based equations. Chapter 3 provides an exposition of three types of models that are instrumental for evaluating macroeconomic policies. The three models are the IS-LM model of the closed economy, the Mundell–Fleming model of the open economy, and a dynamic macroeconomic model, which is a simplified DSGE model used to guide monetary policy in many central banks today. We will make reference to these models later in the book, in the generalized macrofinance framework incorporating stochastic interest rates, and when discussing ways to incorporate the outputs of the macrofinance framework into monetary policy models.

Part I then proceeds to explain basic analytical tools used in finance, including stochastic processes, the Black–Scholes–Merton option pricing formula, and related concepts in Chapter 4. Chapter 5 describes the contingent claims theory that will be used throughout the book. The contingent claims approach provides a framework for formulating risk-adjusted balance sheets of interlinked sectors in an economy and a way to measure risk exposures and risk transmission. It overcomes the limitations of statistical crisis prediction models in
the policy arena that rely heavily on “vulnerability ratios”, such as debt-to-GDP or debt-to-exports, that are drawn from the national accounting and income statements published by country authorities. We make the analogy between these sorts of measures and the well-known accounting-based Altman Z-score measures developed in the 1960s by Edward Altman to aid in the prediction of firm bankruptcies. Over the last two decades, since the early 1990s, the cutting edge of finance has moved forward to the commercial adaptation of the Merton model to assess default probabilities of firms and financial institutions around the world (commercial applications were pioneered by KMV in the 1990s, and KMV has since been bought by the rating agency Moody’s to form Moody’s-KMV). Chapter 6 describes extensions and applications of the contingent claims approach, which is in widespread use for credit risk modeling, vulnerability assessment, and relative value capital structure investment strategies. The benefits of this structural method are harnessed throughout the book to produce better results in the analysis of macro risk, vulnerability of economies, and valuation.

Part II begins with Chapter 7, which lays out the basic macrofinance framework with contingent claims balance sheets of key sectors (sovereign, financial, corporate, and household) and the risk transmission between sectors. The rest of Part II is then devoted to a closer examination of various important aspects of the framework. Chapter 8 provides a closer look at the sovereign balance sheet, how sovereign contingent claim balance sheets can be calibrated, and the calculation of useful credit risk indicators for sovereign foreign currency and local currency debt, as well as other public sector risk exposures. It describes how this new tool can be used for policy and vulnerability analysis (debt and reserves management as well as fiscal policy). Chapter 9 discusses the relationship between models of interest rates in macroeconomics, as in the Taylor rule in macroeconomic policy models, and term structure models of interest rates in finance, with a view towards reconciling these different approaches. Chapter 10 focuses on the analysis of financial sector risk and linkages to firms and households. Financial stability indicators are developed, which can be used for vulnerability assessments and which will be linked into macroeconomic models in following chapters. Chapter 11 discusses the adaptation of the macrofinance framework to fixed and floating exchange rate regimes for the sovereign, and looks at the impact of capital flows and problems that can arise from the use of quasi-public entities to hide contingent liabilities on the sovereign balance sheet.

Part III contains three chapters, each of which treats one facet of how to relate the macrofinance framework to the framework of macroeconomics. Chapter 12 discusses sovereign reserve, debt, and wealth management from the macrofinancial risk perspective. Chapter 13 shows how to relate the risk-adjusted, contingent claims balance sheets of macrofinance to the standard flow-of-funds and national accounting balance sheets used in macroeconomic analysis. Among other things, we show how the traditional budget constraint of macroeconomics can be derived as a special case of contingent claims pricing relationships when volatility goes to zero. Chapter 14 discusses several ways to link macrofinance outputs to monetary policy models, DSGE models, and macroeconometric vector autoregression (VAR) models.

The four chapters that comprise Part IV focus on distress and crisis in economies. Chapter 15 provides a relatively brief, guided tour of the economics literature on financial crises that highlights the recognition that balance-sheet-based vulnerabilities have been crucial in past crisis episodes. More generally, this chapter also takes care to discuss why an explicit accounting for crucial nonlinear effects in economic models is necessary if those
models are to be reasonable crisis models. The models in the crisis literature make clear that this is so, and we note the relationship of our work to that literature.

Chapter 16 discusses four important “destabilization mechanisms”, or potentially dangerous interactions of nonlinear effects, that can cause crises to occur in the context of the macrofinance model. These theoretical mechanisms rely on the valuation formulas of contingent claims analysis applied to the macroeconomic sectors, and in particular to the sovereign, and, as such, are contributions to the theory of financial crises.

Chapters 17 and 18 are devoted to an application of the macrofinance model to the Asian crisis of 1997–98, and the more recent crisis episode in Brazil in 2002, respectively. We discuss how, in both of these episodes, the destabilization mechanisms analyzed in Chapter 16 are real and can be very important in provoking or exacerbating crises.

Part V, which concludes the book, applies the insights of the macrofinance approach to three topics highly relevant to international financial institutions, finance ministries, and international investors. Chapter 19 focuses on the new international global environment and the potential impact of international shocks and risk transmission using the macrofinance model. It looks at the impact of both high-frequency shocks and low-frequency shocks. Chapter 20 looks at alternative policies, contracts, and tools that can be used to transfer and mitigate risk on the sovereign balance sheet. Chapter 21 lays out several ideas for corporate and sovereign investment and capital structure arbitrage using the relative value tool of the contingent claims and macrofinance model. This is written in particular for those in the private sector who may be interested in using our ideas to generate trades and investment
strategies. Chapter 22 closes the book with a look at the “bigger picture” surrounding macrofinance, and lays out a summary of the book accessible to a wide audience, along with several suggestions for future research ideas based on the material, which we hope will be of interest to those working in both macroeconomics and finance.

The main applications of the tools provided by the macrofinance perspective are summarized in Figure 1.1. The ability of macrofinancial risk analysis to improve vulnerability analysis, risk management, and policy is also highly relevant to investors, whether those on the asset management side or hedge fund managers interested in taking advantage of arbitrage opportunities based on assessments of relative value. In addition, the outputs of the macrofinance model have the potential to inform and improve the state of the art of macroeconomic and macroeconometric modeling.
Part I
Overview of Finance, Macroeconomics, and Risk Concepts