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Risk Finance and Asset Pricing

VALUE, MEASUREMENT AND MARKETS

Charles S. Tapiero

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To Carole, Oscar, Bettina, Scarlett, Laura-Julia,
Talya, and not least, Arielle

Introduction

At both theoretical and practical levels, finance theory has made extraordinary intellectual strides while contributing immensely to economic development. At the same time it has enriched the many financial engineers able to innovate and trade in financial products that create greater liquidity, predict and price assets, manage financial risks, and contribute to the growth of financial markets.

Today, risk finance and engineering is confronted with immense challenges and opportunities. They include:

- Bridging theory and practice following the important contributions made these past decades by Kenneth Arrow and Gerard Debreu's fundamental theory of asset pricing and its many uses to better comprehend the working of financial markets and price assets and their derivatives.
- Reconciling the doubts raised by assumptions of fundamental finance and opportunities to profit by the initiated who can appreciate the pro and cons of these theories.

The motivation for this book arose in the course of my lectures in the Department of Finance and Risk Engineering at the New York University (NYU) Polytechnic Institute following the financial meltdown of 2008–2009. This was a year when risks and all their financial manifestations struck at the heart of financial citadels and world economies. No firm was too big to fail, and risks hitherto conceived of theoretically, ignored, or only dreamed of have revealed their potency. This was also a year when extreme events have come into their own: ex ante ignored, but factual and painful ex post for all those who ignored the unlikely. The whole world was hurting: Unemployment, deflation of assets, and times of reckoning with greed, regulation, constraints, and finiteness of resources have become the underlying tune of financial discourse. Both persons and institutions have questioned the validity of financial models and their practical implications. On the academic front, challenging questions have been raised against the fundamental and complete markets dogma of finance, claiming that models can default and that incomplete markets are far more prevalent than theoretical finance would have us believe.

The financial meltdown of 2008–2009 has also ignited a far greater concern for the underlying purposes of finance, not only as a means to get rich but to confront the risks that beset us—whether predictable or not. These include population growth, environmental challenges, globalization of finance, infrastructure, wellness, and so on. These are real problems of common and personal importance. Financial transparency is called for to be part of the answer. The intent of this book is to provide an accessible formulation of theoretical financial constructs embedded in a broad variety of real and useful problems.

The crisis of 2008–2009 has revealed that risks borne by those uninitiated in the complexity of financial products and markets can be very costly. It has also become apparent that corporations and financial firms, traditionally managing real resources, have gradually shifted their economic activity by turning to financial manipulations, acting as intermediaries, with losses assumed by uninformed investors. These firms have capitalized on leverage and short-term returns while strapping healthy corporations with a debt they may not be able to bear. Governmental institutions have not been spared either. They, too, have turned to financial markets to seek the funds needed for investments in infrastructure or to meet their financing needs. Pandora's financial box has been opened, and finance—for all the good and the risks it deals with and manages—has at the same time the potential to cause great damage if not understood.

Further, there is an increased awareness that financial systems are changing. For example, the traditional role of banks to provide liquidity to borrowers and business firms may have been jeopardized in their pursuit of (short-term) profits. These financial institutions have become marketers of financial products and intermediaries to ever-growing financial markets, rather than filling the role of providers of liquidity which underlies their charter granted by society and its governments. In the pursuit of profits, new financial institutions and previously nonfinancial firms have emerged and converged in new enterprises that both offer financial services and manage their own economic interests. These firms, such as insurance companies, provide liquidity and are transforming the financial system. In these processes, financial engineers remain the means to provide financial products and help decide how and where to invest and how to manage risks. The insurance-finance convergence has also afforded a means to assure buyers and sellers and thus contribute to the liquidity needed. The creation of a global insurance exchange in New York to cover complex risks, modeled after Lloyd's of London, is just such an example. Finally, the recent financial crisis has revealed that liquidity matters very much and the future may be unpredictable. Non-transparency, complexity and ambiguity have combined with greed to induce "Management's Risks" as being able to derail financial sustainability and produce financial models that are not efficient. These revelations have increased our awareness that financial expectations can and do falter. This renewed awareness may alter the financial regulatory environment, financial markets, financial attitudes and by extension the future challenges of financial risk engineering. In such an environment, we may be confronted with new problems and new opportunities to provide the solutions needed by financial, corporate firms and individuals.

WHO THIS BOOK IS FOR

This book is intended for both beginning and practicing financial engineers and seeks to engender an appreciation for and understanding of pricing of real financial problems. Throughout my classes I have become aware that many concepts transparent to mathematically savvy students are not understood by others. Inversely, many students with an extensive mathematics background fail to understand that financial engineering is not about mathematics but about complex relationships between buyers and sellers acting in financial markets, imputing values and prices to just about everything that can be traded. To better appreciate what financial engineering

is, can do, and its limitations, it is necessary to have a strong footing in principles of economics and finance, data and statistical analysis, personal utility, and their behavioral manifestations in financial markets and financial modeling. In particular, financial modeling provides a means to interpret implied values and prices such as options, credit derivatives, and so on.

In this sense, financial engineering is both real and virtual. Its usefulness is fueled by the needs of financial parties and by its potential contributions to investors, speculators, and society at large. The perspectives of this book, unlike many important books in financial engineering and mathematics, are thus: to bridge theory and practice; to study financial engineering as a means and not only as an end to make money; and to emphasize a real finance that can provide the support needed to meet both individual and collective needs. At the same time, the book emphasizes an intuitive and comprehensive approach to the foundations of risk finance and its many applications to asset pricing, real financial problems, and financial risk management. In such a frame of mind, the book's theoretical frameworks for expected utility, the Arrow-Debreu foundations of fundamental finance, and basic statistical manipulations of data and financial modeling, are shown to be useful, relevant, and complementary.

HOW THIS BOOK IS STRUCTURED

Theoretical concepts and theories applied mindlessly can have dire consequences. Thus, understanding the underlying rationales that financial engineers use in financial modeling, optimization, and decision making is important. By the same token, financial engineers cannot be the canary in the coal mine and ought to recognize that there is an inherent social and ethical responsibility that need not contradict the pursuit of wealth and money. There are as many opportunities to profit by contributing to economic sustainability—via investment in needed infrastructures, preventing booms and busts, reducing social inequities, pointing to market potential defaults and failures, and so on—as there are opportunities to profit from the design of complex and marketable financial products that provide greater and needed financial liquidity, and from seeking arbitrage opportunities and better forecasting financial market prices.

The many applications treated in this book, drawn from a variety of financial, engineering, and business professions, include insurance, pricing corporate loans and managing their risks, pricing safety and reliability, pricing franchises, operations risks, environmental quality and its control, infrastructure pricing, pricing water, pricing the insurance of rare events and uncommon risks, and more. These applications are used to establish a motivation and a background for a greater appreciation of finance and its risk engineering. Throughout the book, simplifications are made to focus greater attention on the problem-solving rationality financial engineers use. The required quantitative level needed for the book is kept at a consistent and introductory level. Some sections, however, require a slightly more advanced mathematical background; these are marked with an asterisk (*) in the table of contents and offer an added motivation to ambitious students. Additional extensions to each of the book chapters and problems solved are relegated to a web site companion, www.charlestapiero.com. This web site introduces as well in far greater detail

facets of continuous-time finance that this book has sought to avoid as a price for simplicity.

The book is structured as follows. Chapters 1 and 2 provide an introduction to the business of finance, risk, and their many applications. Issues such as ethics and finance are discussed.

Chapters 3 and 4 are an introduction to risk measurement and to various statistical approaches to doing it. These chapters use data to measure risk and to estimate financial trends, financial volatility, and the many terms that make up the essential content of basic financial applications. These two chapters introduce the student to the need to confront the measurement, the *quantification* of finance, and to perform basic analyses using financial data. Chapter 4 is of a more advanced nature, however, and emphasizes the problems of dependence including statistical dependence, complexity, contagious risks, latent risks, and black swan risks. The rationale for introducing these complex issues prior to a thorough study of financial and economic constructs used by financial engineers is to point out the true complexity of quant finance, which cannot always be explained by available theories. Allowing students to grapple with complicated issues sooner rather than later offers a challenge that is similar to the concerns and the manner in which we proceed to financial risk management.

Chapters 5 and 6 introduce the concept of utility and financial risk management. Many theories applied in financial economics are applications of or interpreted in terms of utility concepts. These include risk aversion, portfolio selection, certain equivalents in financial valuation, the capital asset pricing model (CAPM), kernel pricing, insurance, and utility-based risk management. These applications are still profusely used (explicitly or implicitly) in many practical problems. The presumption that financial engineering is essentially concerned with options pricing is, I believe, misguided. These chapters will show through applications that underlying financial theory there are almost always three issues to reckon with: the rationality of the parties to a financial transaction, their private and common information, and the market price. In many cases, any two would imply the other. In other words, any model in fundamental finance implies in fact an underlying rationality—which when violated leads to model defaults.

Chapter 7 outlines the Arrow-Debreu framework in discrete states and time for assets and derivatives (options) pricing. An intuitive introduction to martingales and their importance for asset pricing is included in the appendix to Chapter 7. Chapter 8 provides a review of financial markets and optional portfolios used to manage and trade risks. These two chapters present the basic concept of fundamental finance. The theory is discussed, criticized, and applied to many examples. To keep this introduction tractable (without losing its essential implications and applications) simple binomial, multinomial, and discrete state models are used. Extensions to continuous-time finance are considered briefly, and specific problems are posted on the book web site, www.charlestapiero.com. Applications to a variety of problems including derivatives pricing, default bonds, pricing insurance contracts, stochastic volatility models, multiple sources of risks models, and a plethora of problems commonly treated in practice and in advanced texts are also presented simply to explain the rationale that the Arrow-Debreu financial framework uses to solve such problems. Throughout these chapters, issues and instruments of current interest, such as the financial meltdown of 2008, volatility and chaos, globalization, outsourcing, and

so on, are used to explain these important facets of financial practice and the limits of the current theoretical models of finance.

Chapters 9, 10, and 11 can be seen as a whole that can be delivered as one course on credit risk. Chapters 9 and 10 deal with credit risk and scoring, multi-name credit risk, and credit derivatives. Several approaches to pricing credit risk are outlined. Following the credit crisis, a greater awareness has developed that these risks ought to be better regulated. Chapter 10 focuses on multi-name credit risk portfolios and structured financial products such as collateralized debt obligation (CDO), collateralized mortgage obligation (CMO), and collateralized loan obligation (CLO). Finally, Chapter 11 addresses the important and practical problems in calculating an implied volatility and an implied risk-neutral distribution. Three approaches are emphasized: parametric, a-parametric, and a utility-rationality–based approach.

Chapters also include:

- *Examples and problems.* These highlight both some of the techniques used in asset pricing and their very broad applications.
- *"Test Yourself."* Most chapters end with a series of questions to test your newfound knowledge.

WHAT'S ON THE COMPANION WEB SITE

At www.wiley.com/go/tapiero (password: risk) you will find a number of additional resources for this book, including:

- Additional examples, errata, and updates to the book.
- Links to the author's other publications.
- Recommended reading.
- Information about the author's classes at the New York University Polytechnic Institute.

The Instructor's site includes answers to the problems and "Test Yourself" material found in the book, as well as PowerPoint slides and other materials for classroom use.

Contents