finance and the economics of uncertainty

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Blackwell Publishing

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BLACKWELL PUBLISHING
350 Main Street, Malden, MA 02148-5020, USA
9600 Garsington Road, Oxford OX4 2DQ, UK
550 Swanston Street, Carlton, Victoria 3053, Australia

First published 2006 by Blackwell Publishing Ltd

1 2006

Library of Congress Cataloging-in-Publication Data

Demange, Gabrielle.
[Finance et economie de l'incertain. English]
Finance and the economics of uncertainty / Gabrielle Demange and Guy Laroque; translated by Paul Klassen.
p. cm.
Includes index.
ISBN-13: 978-1-4051-2138-5 (hardcover)
ISBN-10: 1-4051-2138-6 (hardcover)
ISBN-13: 978-1-4051-2139-2 (pbk.)
ISBN-10: 1-4051-2139-4 (pbk.)
1. Uncertainty. 2. Finance—Mathematical models. I. Laroque, Guy. II. Title.

HB615.D4613 2006
338.5—dc22

2005021158

A catalogue record for this title is available from the British Library.

Set in 10/12.5 pt Dante
by Newgen Imaging Systems (P) Ltd, Chennai, India
Printed and bound in Great Britain
by TJ International, Padstow, Cornwall

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List of main symbols

$e \in \mathcal{E} = \{1, \ldots, E\}$	States of nature
$\pi(e)$	Probability of state e
$q(e)$	State price or price of the Arrow–Debreu security corresponding to state e
$k = 1, \ldots, K$	Index of risky securities
$k = *$	Index of risky-free securities
$z = (z_k)$	Portfolio
p_k	Price of security k
$p = (p_k)$	Column vector of security prices
$p'z = \Sigma_k p_k z_k = z'p$	Value of portfolio z
$a_k(e)$	Income (payoff) served by one unit of security k in state e
$\tilde{a}_k = (a_k(e)) \in \mathbb{R}^E$	Row vector of contingent income accruing to the owner of one unit of security k
$\tilde{a} = (a_k(e))$	$K \times E$ matrix of securities payoffs
$\tilde{c}_z = z'\tilde{a}$	Contingent incomes associated with z
r	Riskless rate of return (interest rate)
$\tilde{R}_k = \tilde{a}_k / p_k$	Gross return of security k
$\tilde{r}_k = \tilde{R}_k - 1$	Net return of security k
$d_k(e)$	Dividend per unit of security k in state e
$x_k = p_k z_k / (\Sigma_h p_h z_h)$	Share of security k in portfolio z
$x = (x_k)$	Portfolio composition
$i = 1, \ldots, I$	Index of investor
c	Income or consumption
$c^i, z^i \ldots$	Investor i's decision (superscript)
z^m	Market portfolio
u, v	Von Neumann Morgenstern utility indices

δ	Psychological discount factor
j such that $\delta = 1/(1+j)$	Psychological discount rate
ω_0	Nonfinancial income at date 0
$z(0)$	Initial portfolio at date 0
$\tilde{\omega}_1$	Random nonfinancial income at date 1

Contents

Introduction

A large number of economic decisions have implications on the future and are made under uncertainty. This is the case, for instance, of individual saving, insurance and portfolio choices, and investment decisions of firms. A variety of institutional arrangements and financial tools facilitate these decisions and allow risk taking and risk sharing: insurance companies, stock exchanges, futures and derivatives assets, to name a few. Research in finance and the economics of uncertainty aims to understand the emergence of these tools, their functioning and adequacy to allocate risks.

Uncertainty is ubiquitous. An investment requires a certain time lag before it yields an income, which in turn depends on random events that impact upon prices of raw inputs, production processes, and competition. The future financial resources and needs of households vary owing to illness, family composition, or unemployment. At the macroeconomic level, uncertainty is also pervasive making forecasts on future aggregate variables prone to errors.

In order to cope with resources and needs that fluctuate over time, economic agents, whether households or firms, save and borrow for *intertemporal income smoothing*. A more uncertain future may induce households to save more for what is called a *precautionary* motive. It may also lead to the creation of institutions to allow risk sharing between economic agents. Futures markets, for instance, simplify the management of risks stemming from changes in the supply and the price of commodities. Mutual corporations and insurance companies specialize in covering individual risks, such as car accidents, house fires, and the like. Stock markets enable entrepreneurs to finance their activities by going public. Stockholders invest by buying a stake in the company (*stocks*) and share future profits or losses, which often entail too much risk for a small number of individuals to assume. Thus, the public becomes involved while benefiting from the expertise and economies of scale associated with an activity that can be conducted more effectively by professionals than by amateurs. More generally, stock markets allow

risky participations in productive activities to be *diversified* through appropriate portfolio choices. Finally, derivative financial instruments (options, swaps, etc.) have recently experienced a prodigious expansion, linked to *hedging* requirements of the investors vis-à-vis movements in interest rates and stock market prices.

How do these institutions work? Are they well designed? What is the role of financial markets? These questions have given rise to a very large body of work, especially in the past 30 years, in both finance and economics. Initially, each discipline worked separately, developing its own models and approach, to treat uncertainty.

Finance is marked by two pioneering works: the Black and Scholes's method for establishing the value of an option by *arbitrage*, and the equilibrium relationships of Sharpe and Lintner's *capital asset pricing model* (CAPM), which relate the expected returns of financial securities to simple statistical characteristics. Professionals soon recognized the practical values of these contributions, which facilitated the proliferation of derivatives and the development of quantitative portfolio management techniques.

Economics took the path of extending the general equilibrium theory to an uncertainty framework, building on the decision models under risk proposed by von Neumann and Morgenstern. As the works of Arrow and Debreu, among others, made clear, the usual welfare properties of equilibrium cannot be taken for granted. The absence of markets, more precisely their *incompleteness*, was, and remains, the focus of a great deal of attention. Why are some markets not viable? What implications does that have?

In the 1980s, whereas the links between the two bodies of works were better understood, it became clear that a crucial piece was missing. Indeed, both approaches assumed all stakeholders to have access to identical information. Everyone was supposed to evaluate future prospects in the same way, to use the same model with the same probabilities of the evolution of the economy, the dividend process, or the bankruptcy of the firms. This is known as the *symmetric information* framework. Since then research in both economics and finance has emphasized the differences in the information available to economic agents, how news is disseminated, and the role this plays in price setting, in risk undertaking, and in financial contracting. In particular, the concept of *rational expectations*, introduced by Muth, made possible the study of the transmission of information through prices.

This book has two main goals. The first is to present the fundamental principles of risk allocation in a unified framework, assuming symmetric information. Models employed in this book are as simple as possible so as to underscore the

relationships between the techniques currently used in finance and the economic analysis of risk. The second goal is to look into information dissemination and thus identify some key limits of the basic models. Are financial markets, as some maintain, the ideal locations for the exchange of information? Should insiders' use of privileged information be controlled? Is the release of information always a good thing?

The book is divided into three parts.

After a brief description of the most common financial instruments, Part 1 presents the notion of arbitrage and the derived techniques of valuation by duplication. Chapter 1 gives a basic introduction to stocks, bonds, interest rates, and the spot rate curve and describes some derivatives (options and futures). It explains how markets operate with emphasis on futures markets for commodities and financial instruments. Derivative securities have proliferated in the past 20 years. They are built on preexisting assets using formulas that are often quite complex. It is important to understand how they are most often priced and the assumptions that underlie their valuation. This is the goal of Chapter 2, which deals with the fundamental principle of *absence of opportunities for arbitrage* and valuation by *duplication*. Duplication of a derivative is possible when its risky payoff can be reproduced with financial instruments available on the markets. It turns out that this very simple idea yields surprisingly strong conclusions that are abundantly (and sometimes abusively?) used in financial practice.

Part 2, the heart of the book, deals with exchanges of risks. The basic model is that of an economy in which future income, possibly random, is to be divided between the economic agents (also called investors). How do markets for financial assets perform this division? Is the resulting allocation optimal? Can market participants benefit from insider information?

To answer these questions, a first step is to describe how individual investors behave in an uncertain environment. Some basic concepts such as attitudes toward risk, how expectations are formed, and the value of information are introduced in Chapter 3. The guiding principles of portfolio choice (hedging and speculation) and risk diversification are derived in Chapter 4.

Once the individual's behavior is set, market functioning at the aggregate level can be studied. The traditional economic approach to optimality and equilibrium under symmetric information is the subject of Chapters 5 and 6. The optimality of risk-sharing contracts between a group of individuals quite naturally leads to separate individual idiosyncratic risks from macroeconomic risks. Optimality implies spreading individual risks providing the rationale for their *mutualization*. Macroeconomic risks, on the other hand, are unavoidable. Allocating them efficiently

among economic agents requires taking into account their individual attitudes toward risk. The incomes of those who are most risk averse will scarcely be affected by the vagaries of the macroeconomy, while the less risk averse will accept wide fluctuations, perhaps compensated by a higher average income than the former.

A natural question is whether the existing financial markets lead to an optimal allocation. The answer is positive if markets are complete. This is the case when there is a sufficiently large number of derivatives, especially on market indexes. In terms of positive analysis, we examine how – complete or incomplete – asset markets function and allocate risks in the mean–variance CAPM framework. Introducing risky nonfinancial incomes allows us to bridge the most widely used model in finance with the standard equilibrium approach in economics.

Whereas financial markets play an important role for trading goods and allocating risks over time, the casual observation of the day-to-day movements of the markets leads to emphasize their sensitivity to the arrival of new information. News often motivates transactions and causes market prices to move. Chapter 7 addresses this issue. A new piece of information modifies the perceived probability of occurrence of the future events. It may be available to all participants (*public* information), or only to a selected few insiders (*private* information). The analysis is conducted in a framework characterized by *rational expectations* – a concept that is illustrated with several examples (including Muth's celebrated case) – in which investments made today change the distribution of prices tomorrow. Insurance dissipates as events become public knowledge. Allowing insiders to trade a stock on which they have access to relevant information in advance of the general public may create adverse selection effects: non informed investors who are aware of the presence of insiders may feel duped and may withdraw from the market. Finally, Chapter 8 is devoted to intertemporal dynamics and discusses the *equity premium puzzle*, as well as speculative bubbles.

The firm and how it is financed are the subject of the last part of the book (Chapters 9 and 10). The issues addressed here are at the frontier between management, corporate finance, and economics. The interaction between decision making and the financial structure of the firm is emphasized. Building on a simplified representation of balance sheets, the famous Modigliani and Miller theorem is presented. Most often the liability of the stockholders is limited to their original outlay. Several issues are investigated in this context. The risk of bankruptcy, the relationship between the values of the various securities issued by the firm, and the potential sources of conflict between the various stakeholders in the event of bankruptcy are investigated. The functioning of the credit market is also affected

by limited liability, which may induce borrowers (entrepreneurs) to choose investments that are increasingly risky as the nominal interest rate rises. We conclude with a look at the issue of asymmetric information between an entrepreneur and her financial backers, whether stockholders or banks, and present a rationale for prohibiting insider trading.

This book is based on lectures given at the École polytechnique and at the DEA Analyse et politique économiques of the École des hautes études en Sciences Sociales. We wish to thank our students and our fellow staff members, some of whom occasionally moderated exercise sessions, for their remarks and suggestions. We are particularly indebted to Isabelle Braun Lemaire, Bruno Jullien, and Bernard Salanié.

part 1

Valuation by Arbitrage