STRATEGY, VALUE AND RISK

A GUIDE TO ADVANCED FINANCIAL MANAGEMENT

JAMIE ROGERS

GLOBAL FINANCIAL MARKETS

THIRD EDITION

Strategy, Value and Risk

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Strategy, Value and Risk

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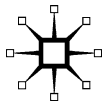

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Contents

List of Figures and Tables viii
Preface xi
Acknowledgments xv
List of Acronyms xvi

Introduction 1
The external environment 1
Strategy, value and risk 3
References 5

Part I The Evolution of Strategy, Value and Risk

1 Strategy 9
1.1 Innovation and the entrepreneur 9
1.2 The evolution of industry sectors 12
1.3 From corporate planning to shareholder value 17
1.4 Strategy and value 19
Appendix – classifying industry sectors today 20
References 21

2 Value 23
Overview 23
2.1 The accounting foundations 24
2.2 Stocks and flows 25
2.3 Ratio analysis 28
2.4 Investments 30
2.5 Firm value 39
2.6 Optimizing the firm structure 44
Appendix – modularity 46
References 47

3 Risk 49
3.1 Investment risk 49
3.2 Why manage risk 51
3.3 Defining and measuring risk 52
3.4 The risk drivers 53

3.5 Value and risk 55
References 56

Part II The Analysis of Performance and Investments

4 The Analysis of Performance 59
4.1 Valuation 59
4.2 Residual earnings 64
4.3 Free cash flows 65
4.4 Pro forma analysis 66
References 74

5 The Analysis of Investments 75
Introduction 75
5.1 Software 76
5.2 Energy 82
5.3 The pharmaceutical industry 106
5.4 A growth firm 116
5.5 Firm abandonment 135
5.6 The sale of corporate real estate assets 145
References 158

Part III Quantitative Analytics and Methods

6 Data Analysis 163
6.1 Data and information 163
6.2 Time series analysis 163
6.3 Volatility 166
6.4 The lognormal distribution 169
6.5 Which volatility? 171
References 172

7 Derivatives 173
7.1 Futures, forwards and options 173
7.2 The replicating portfolio and risk-neutral valuation 177
References 180

8 Option Pricing Methods 181
8.1 A model for asset prices 181
8.2 The Black–Scholes formula 182
8.3 Numerical techniques 185
References 192

9 Implementing Derivative Models 193
9.1 Spot price models 193
9.2 Forward curve models 197
9.3 Alternative real options methods 202
9.4 Model risk 205
9.5 Real options portfolios and complex payoffs 207
Appendix – parameter estimation for the Heston stochastic volatility model 210
References 213

10 Conclusion and Practical Implications 215
References 217

Index 218

List of Figures and Tables

Figures

2.1	The stocks and flows of a firm	27
4.1	Free cash flow as a function of growth	72
4.2	ROCE as a function of the change in the debt to equity ratio	73
4.3	ROIC as a function of the change in growth	73
5.1	World energy consumption, 1990–2035	83
5.2	World energy consumption by fuel, 1990–2035	84
5.3	Power forward price curve	88
5.4	Natural gas forward price curve	88
5.5	Spark spread forward curves	95
5.6	Schwartz single factor model futures prices	95
5.7	Power and natural gas volatility curves	96
5.8	Volatility of futures prices in the Schwartz single factor model	97
5.9	Power volatility and volatility function term structures	101
5.10	Natural gas and volatility function term structures	101
5.11	Spread option and DCF intrinsic values by month	105
5.12	New drug revenue streams by quality category	109
5.13	Global carbon emissions from fossil fuel burning, 1751–2009	125
5.14	The rise in atmospheric carbon dioxide concentration, 1744–2011	126
5.15	Trends in global fossil fuel carbon dioxide emissions from human activity, 1751–2008	127
5.16	Asking rents in San Francisco office market	151
5.17	San Francisco office market – rent forecast	151
5.18	San Francisco office market – vacancy forecast	152
5.19	Early exercise boundary	156
6.1	S&P 500	166
6.2	S&P 500 returns	167
6.3	Histogram of the S&P 500 returns	168
6.4	The simulated series	170
6.5	The natural log of the simulated series	170
6.6	The simulated log returns	171
7.1	Payoff to a long forward position	174
7.2	Payoff for a call option	175
7.3	Payoff for a put option	176
7.4	Payoffs for European options	176
7.5	Binomial model of an asset price and call option	178
8.1	A four-step binomial tree for an asset	188
8.2	Trinomial model of an asset price	189

8.3 A trinomial tree model of an asset price 190
9.1 Illustration of 100 simulated GBM paths 194
9.2 Illustration of 100 simulated mean reversion paths 195
9.3 A negative exponential volatility function for forward prices 199
9.4 EUR-USD implied volatility surface 212

Tables

0.1 The industrial waves and accelerating cycles 2
1.1 Industry sector weights based on the 1899 classification system 12
1.2 Industry sector weights based on the 2001 classification system 13
1.3 Industry sector weights for the largest 100 firms by profits – 1955, 1975, 2000 14
2.1 Comparison between a call option on a stock and a real option 34
4.1 The pro forma example data 68
4.2 The pro forma income statement and balance sheet 69
4.3 The pro forma free cash flow forecast 70
4.4 Forward P/Es, book value, residual earnings, ROCE and ROIC forecasts 70
4.5 Free cash flows and financing flows 71
4.6 Valuation of equity from free cash flow to equity 72
5.1 IT software restructuring DCF analysis 78
5.2 Software restructuring cash flows: invest immediately 80
5.3 Software restructuring binomial tree cash flows (1) 80
5.4 Software restructuring binomial tree cash flows (2) 81
5.5 Discounted cash flow analysis 90
5.6 Estimation of the power and natural gas alpha parameters 100
5.7 Mean reversion rates and the corresponding half-lives 102
5.8 Monte Carlo simulation of the two-asset energy spread option 103
5.9 Revenues by quality category 109
5.10 R&D stage (pre-tax) costs, durations and conditional success probabilities 110
5.11 Additional cash flow parameters 111
5.12 NPV of a drug at the discovery stage 112
5.13 ENPV of a NME drug in the discovery phase 114
5.14 The 14 step Binomial Tree for the commercialization cash flow asset 117
5.15 The Binomial Tree NME drug call option payoffs with success probabilities equal to one 118
5.16 The Binomial Tree NME drug call option payoffs with the probabilities of success 119
5.17 Condensed financial statements for Wave Nouveau 122
5.18 Residual earning trend for Wave Nouveau 122
5.19 Wave Nouveau's compound option variables for firm market value (V) 134
5.20 Sunset Inc. liquidation analysis 139

5.21	Condensed income statements for Sunset Inc.	143
5.22	PVCF earnings projections	144
5.23	At-the-money abandonment option PVCF earnings projections	145
5.24	Preliminary sales analysis	149
5.25	Estimated property NOI	154
5.26	Value calculations	154
5.27	Benchmark option model inputs	155
5.28	Sensitivity analysis-capitalization rates	156
9.1	The Heston parameters	213

Preface

The objective of *Strategy, Value and Risk* is to provide a framework that integrates financial management with a firm's external environment. This framework is examined in the context of creating value through a firm's operating, financial and strategic decisions.

The strategy section reviews the past to provide a foundation for how and why markets changed, how firms respond to change, and how firms can adapt to change in the future. 'Innovation as strategy' is a term used increasingly today across all industry sectors. A recent *Wall Street Journal* article noted that the term was mentioned more than 33,000 times last year in financial reports, a 64% increase over the previous five years. In this book innovation is used within the context of its influence on the evolution of industry sectors over the 19th and 20th centuries to where they are today, the shift in the economy from the dominance of industrials to information and services, and how firms used innovation to compete and adapt to change.

The value section frames a firm's short-term and long-term objectives. In the short term the focus is on assessing current performance. A firm's financial statements reflect its business model and where and how firm value is derived. Free cash flows are defined within the context of stocks and flows, and return on common equity (ROE) and return on invested capital (ROIC) measures are discussed. In the long term the focus is on making capital investments in assets that generate value and ensure firm continuity. Firms seek to maximize firm value by investing in assets that yield a positive net present value, with risk reflected in the appropriate discount rate.

As a substantial part of value rests on corporate decisions, it is essential to bridge strategy and value. Established valuation methods such as net present value and return on investment have limitations in capturing the value in strategic investments. These valuation approaches are applied to static scenarios while the business environment today is anything but static. Real options analysis is a valuation, project management and strategic decision paradigm that applies financial option theory to real assets. Real options provide a framework for managing and creating value, and therefore provide a linkage between strategy and value. Real options theory and its relationship to strategy, value

and risk are discussed, and the concepts and methods developed as a way to respond to an increasingly dynamic business environment and address the potential limitations with the status quo. Firm value is also discussed in the context of corporate finance theory and capital structure.

The performance section covers valuation issues around intangible assets, debt and equity, and pro forma analysis of the financial statements, free cash flow and performance metrics. Investments are then evaluated in the context of strategy. Six case studies cover a corporate IT investment, a media business model migration, climate change and new energy, pharmaceutical drug research and development, a power-generating asset and commercial real estate. These case studies illustrate the established investment valuation methods such as discounted cash flow and accounting analysis, and advanced methods that include real options methods based on accounting, management science and advanced derivative techniques. Risk is extended from discount rates to advanced derivatives that include spread options, compound options and binomial trees to illustrate the advanced valuation methods. Finally a quantitative analysis and methods section discusses the techniques and issues around data analysis, derivatives, advanced valuations and risk management.

Who should read this book?

The external environment continues to present a range of issues in the aftermath of the 2008 financial crisis. While the effects of globalization and information technology continue to shape the business environment, a number of additional issues include managing exposure to value volatility, the use of leverage, access to capital markets, and defining and managing risk. In this environment managers require not only an understanding of the market, customers, investors and the industry dynamics of the firm, but also the operational drivers of success. Managers organize a firm's resources so that there is a clear integration between a firm's objectives and the changes occurring in markets and the external environment. Developments in concepts such as resources and capabilities, dynamic analysis and advanced financial analysis are providing frameworks to manage and cope with these changes.

The role of the CFO is undergoing a transformation, expanding from a focus on external reporting and fiduciary duties to becoming a partner with other key business partners such as operations, marketing and executive management. This requires an analysis on the business

drivers of success and operational strategies that integrates finance into business and strategy. CFOs can enhance corporate value by promoting the use of a well-designed set of financial tools and guidelines to secure assets to maintain and increase value. By defining a new set of capabilities as a provider of strategic analysis and metrics, the CFO can increase the value-adding activity of the finance function.

Investment analysts and management consultants work in numerous areas that involve financial and economic concepts. These include projects of a strategic nature where valuation is essential. An analyst is required to see the larger economic setting and environment in which a firm competes, assess a firm's industry and its position within that industry, understand which projects best serve its broad strategic goals and recognize a firm's capabilities and options. In addition, the analyst must translate these broad insights and communicate them to management and investors.

Finally the book offers a number of potential areas that could be further explored in academic research. These include how value flows from intangible assets and their valuation, and the free cash flow relationship in regards to the optionality in real assets flowing into cash flow from operations and the timing of investment outlays.

The content covers disciplines and functions as diverse as accounting, finance, economics, econometrics, quantitative finance and management science. These subjects have their own bodies of knowledge, and there are limitations on how much of the material can be covered in one text. The content is a guide to quantifying strategy and financial management. As in other quantitative disciplines, much of the value of the analysis is in the process as opposed to just producing an end number.

Organization of the book

The book is divided into three parts:

- *Part I* looks at innovation and the entrepreneur, and their influence on the evolution of industry sectors over the 20th century to where they are today. Corporate strategy, how it adapted to the external environment, and strategy and value are also discussed. The value section covers the financial statements, their analysis, and firm investment methods. Finally there is a discussion on risk.
- *Part II* covers the analytical methods for performance and investments. The performance section addresses valuation issues, financial

statement analysis and metrics and their pro forma forecasts. The investment concepts are illustrated in six case studies, an IT investment, an energy power generating asset, pharmaceutical research and development, firm growth, firm abandonment and the sale of real estate assets.

- *Part III* covers the quantitative methods and applications that are relevant to corporate valuation and risk analysis.
- Finally the conclusions and practical applications are discussed.

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I dedicate this book to my mum and the memory of my dad and grandmother. I would also like to thank my wife Meg for her continued patience, guidance, and support.

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List of Acronyms

ADF	augmented Dickey–Fuller
AGLT	adjusted generalized log-transformed
ARCH	autoregressive conditional heteroskedasticity
BLA	Biological License Application
BSM	Black–Scholes–Merton
Btu	British thermal unit
C	cash flow from operations
CAPM	capital asset pricing model
CCF	commercialization cash flow
CFAR	cash flow at risk
CI	capital invested
d	net cash flow to shareholders
DA	decision analysis
DCF	discounted cash flow
EMM	equivalent martingale measure
EMV	expected monetary value
ENPV	expected net present value
EP	economic profit
EPS	earnings per share
F	net financing flows
FCFE	free cash flow to equity
FCFF	free cash flow to the firm
FDA	Food and Drug Administration
GARCH	generalized autoregressive conditional heteroskedasticity
GBM	geometric Brownian motion
GOV	growth option value
I	investment
IPR	intellectual property rights
IRR	internal rate of return
MVA	market value added
MWh	megawatt hour
NDA	New Drug Application
NME	new molecular entity
NOI	net operating income

NPV	net present value
NOPAT	net operating profits after tax
P/B	price-to-book ratio
P/E	price-earnings ratio
PV	present value
PVCF	present value of cash flows
RE	residual earnings
RADR	risk-adjusted discount rate
rNPV	risk-adjusted net present value
ROA	return on assets
ROCE	return on common equity
ROE	return on equity
ROI	return on investment
ROIC	return on invested capital
SDE	stochastic differential equation
V	(firm) value
VAIP	value of assets in place
VAR	value at risk
VGO	value of growth opportunities
WACC	weighted average cost of capital

Introduction

The external environment

Technology is defined as the processes by which an organization transforms labor, capital materials and information into products and services of greater value. All firms have technologies. Innovation refers to a change in one of these technologies. So spectacular was the wave of innovation in the late 19th century that the Commissioner of the United States Office of Patents recommended in 1899 that the office be abolished with the words 'Everything that can be invented has been invented.' History is littered with such predictions about technology, and with companies that failed to stay on top of their industries when confronted with changes in markets and technologies.

The economist Joseph Schumpeter recognized and analyzed the dynamic interaction between competition and industry structures. Schumpeter focused on innovation as the central component of competition and the driving force behind industry evolution. A normal healthy economy was described by Schumpeter as one not in equilibrium as in classical economics, but one that is constantly being disrupted by innovations in technology. The entrepreneur's or innovator's role is to act as a catalyst in the process of creative destruction, allowing the economy to renew itself.

In Schumpeter's view each long wave of economic activity is unique, driven by entirely different clusters of industry. Each upswing stimulates investment and an expansion of the economy, resulting in a boom. Each long boom eventually peters out as the technologies mature and investors' returns decline. After a period of slower expansion comes the inevitable decline, only to be followed by a new wave of innovations that destroy the old methods and create the conditions for a new upswing.

In Table 0.1, the third cycle of Schumpeter's 'successive industrial revolutions' had already run its course by 1950. The fourth cycle, driven by oil, electronics, aviation and mass production, is now rapidly winding down, if not already gone. The evidence suggests that a fifth industrial revolution, based on semiconductors, fiber optics, genetics and software, is not only well under way but even approaching maturity. Another issue illustrated by Table 0.1 is the increasing speed of

Table 0.1 The industrial waves and accelerating cycles

First wave: 1785 60 years	Second wave: 1845 55 years	Third wave: 1900 50 years	Fourth wave: 1950 40 years	Fifth wave: 1990 30 years
water power textiles iron	steam rail steel	electricity chemicals the internal combustion engine	petrochemicals electronics aviation	digital networks new media

Source: *The Economist*, 20 February 1999.

industrial structural change, with the economic waves shortening from 50 to 60 years to around 30 to 40 years. During the third wave in the early part of the 20th century governments, firms and entrepreneurs began to search systematically for new technologies capable of creating whole new markets and the next wave.

In the last quarter of the 20th century a number of fundamental changes emerged in the global economy. The burst of innovation in information technology reduced the cost of communications, which in turn facilitated the globalization of production and capital markets. This laid to the groundwork for the use of innovative new business models. A new knowledge economy also emerged, driving the transformation from an industrial to a post-industrial economy centered around intangible assets and services. This led to the growing significance of intellectual assets relative to physical assets. Finally there was a shift from closed to open innovation systems. As a result of these factors stock market indexes are now dominated by service industries such as information technology, financial services, pharmaceuticals, telecommunications and retail industries that leverage technology and science.

Today the event that dominates the external environment is the 2008 financial crisis and its continuing influence on the global economy. The crisis also has had an effect on a number of business areas. The first is that many of the underlying assumptions in financial, economic and management theory have been called into question. These include shareholder value as a focus for management, a re-evaluation of risk management, and questions in regards to strategy frameworks that assume stability in the external environment.

The second is that there are indications that the large public stock markets no longer serve their original purpose. Stock markets have long performed a vital function in the global economy by matching

investors with entrepreneurs, which financed successive waves of innovation in the primary markets and provided a forum for trading shares in the secondary market. There is evidence today that the stock markets no longer serve this purpose, in either assisting firms in the efficient raising of capital, or have the capability to mobilize the investment in corporate growth and innovation.

The third is that many firms are now relying on cash surpluses and retained earnings instead of raising capital either from banks or in financial markets. Firms have accumulated huge cash reserves while at the same time delivering an unprecedented smaller percentage of earnings as dividends. The S&P 500 pay-out ratio of dividends to earnings is now its lowest since 1900. Businesses are being run for cash instead of making the necessary investments to increase revenues and enhance growth. Cash currently makes up more than 6% of balance sheet assets of non-financial US firms, the highest in at least 60 years. As the uncertainty in the external environment continues, firms are unwilling to distribute this excess cash to shareholders as either dividends or share buybacks.

Strategy, value and risk

Regardless of recent events, shareholder value still dominates the management agenda in much of the business world. The demands of shareholders and investors continue to create strong pressure on management to maximize returns, and their influence determines how capital is allocated.

Strategy as a search for value is the discovery and development of sources of profitability to maximize firm value. To achieve sustainable shareholder value firms have to simultaneously manage and deliver on operations in the short term while investing to maintain long-term continuity. The issue then becomes the durability of a firm's competitive advantage to maintain a rate of return on the firm's assets greater than its cost of capital. A firm's external business and industry environment presents the value opportunities, while a firm's internal resources and capabilities determine how to leverage these opportunities.

The response to external change has become essential as a source of competitive advantage as markets have become increasingly volatile. Firms have a number of options to ensure their long-term survival, which include consolidation, growth through innovation and acquisitions, the metamorphosis of its business model to align with change or some combination of these. Managing firm value in both the short

and long term therefore requires a framework that considers both operations and investments.

The framework in the short term includes identifying the stocks and flows that generate value, ROCE and ROIC performance measures, and growth in both book value and residual earnings. A pro forma analysis provides a forecast of the financial statements, performance metrics and free cash flows, and where a firm will be in future years. Changes in business conditions and the choices available to management can be evaluated in pro forma statements and metrics. Risk can be analyzed through different scenarios, with the base case plus the best and worst possible scenarios considered to find the margin of safety.

In the long term, investment decisions have to be made to ensure the firm's survival. Many investment decisions are made today in business environments where market size, development costs and competitor reactions are unknown, and therefore subject to risk and uncertainty. Labor and material costs, prices, quantities, competitive behavior, market size, share and growth, taxes, inflation and project life cycles all introduce uncertainty into investment projects. Investments are also subject to unexpected changes in microeconomic factors such as new entrants and competitors, and macroeconomic events in areas such as technology, globalization, and financial markets.

Investment metrics and strategic planning emerged over the past 50 years as complementary but unrelated systems for corporate decisions and investment. The discounted cash flow (DCF) method has become a popular approach for valuing projects, assets or firms. The method when applied to corporate assets essentially focuses on optimization, with management decisions based on a static business case of one future scenario that ignores any ability to respond. Managers often have many alternatives in managing future cash flows and not just accepting or rejecting one static measure. DCF methods do not have the flexibility to take advantage of opportunities as they arise in the future, or the potential to manage downside risks.

Valuing these options considers the uncertainty or volatility associated with the investment. Real options analysis is a valuation, project management and strategic decision paradigm that applies financial option theory to real assets. The concept can value the flexibility to adapt and revise management decisions made in the future with the benefit of better information. Real options can also provide a framework for managing and creating shareholder value, and therefore provide the link between strategy and value.

Although the current large cash levels held by firms are the result of market uncertainty, an upside of cash reserves is that they provide flexibility. Growth and abandonment are both influenced by leverage. Firms with large cash reserves are able to more readily respond to market and industry conditions and exercise real options when compared to firms with high debt ratios and external funding requirements.

The real options approach is a guide to strategy under uncertainty that is more or less quantifiable. With or without quantification, however, it is likely to produce different results to more conventional thinking about strategy and investment.

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Part I

The Evolution of Strategy, Value and Risk

1
Strategy

1.1 Innovation and the entrepreneur

Business cycles as defined in contemporary economics are the recurring levels of economic activity over time. These cycles are described as varying in frequency, size and length, with each stage defined as growth, peak, recession, trough and recovery and each having an influence on inflation, bond yields, short-term interest rates, and commodities. Business cycles were once described, however, as having long predictable durations. Kondratiev waves, named after the Russian economist Nikolai Kondratiev, are long macroeconomic cycles lasting 50 to 60 years that Kondratiev theorized existed in capitalist economies.

One legacy of Kondratiev's long waves is its influence on Joseph Schumpeter, who formed his theories around long technology waves. In Schumpeter's theory of business cycles and economic development the circular flow of income, an economic model depicting the circulation of income between consumers and producers, is stationary. Entrepreneurs disturb this equilibrium through innovations, and in doing so create the economic development that drives the economic cycle.

Schumpeter formed two theories in regards to entrepreneurship. The first was that individuals and small firms were more innovative, which he expanded in a second theory in which large firms drive innovation by investing in research and development (R&D) through their access to capital and resources. Schumpeter's 'gale of creative destruction' is the fundamental driver of new industries or industry combinations, the result of entrepreneurs producing innovative new products, processes or business models across markets and industries that either partially or entirely displace inferior innovations. Entrepreneurship can therefore be framed as recognizing, valuing, and

seizing opportunities and applies to either individuals, small firms or large institutions.

The term 'innovation' was defined by Schumpeter as:

- The commercialization of all new combinations based upon the application of new materials and components, the introduction of new processes, the opening of new markets, and the introduction of new organizational forms (quoted in Jansen, 2000).

Schumpeter also saw a fundamental difference between invention and innovation:

- Invention is the creation of new products and processes that is made possible through the development of new knowledge, or more typically from new combinations or permutations of existing knowledge, while
- Innovation is the initial commercialization of invention, either through the production and marketing of a new product or service, or through the use of a new production method.

Transformations in technology have been driven by momentum from needs and end users in some cases, and developers and system builders in others. The firm, however, has played a consistent role as a participant, and while not always the initiator has been a leading player in innovation as invention and research developed into processes in the 19th century. In the early 20th century many firms had internalized innovation and focused on efficiency and rationalization as a means to secure their technologies. Other firms had leveraged innovation to pursue new products or processes, which became an important development that while riskier was potentially more rewarding.

Over the course of the 20th century, innovation and R&D were institutionalized, which influenced both the trends and speed of change in technology throughout the industrial and industrializing worlds. The principal driver of technology change over the 20th century was the exploitation of science by US industry, which is reflected in the shifts in the research environment. The industrialization of research began with the establishment of centralized research laboratories at the turn of the 19th century at large US industrial and telecom firms. These new science based firms were confronting hostile environments that included new competing technologies for expiring patents

and antitrust activities, and these laboratories were established as a defense.

In the period between the first and second world wars US corporate laboratories pushed the limits of innovation strategies. In the 1920s the focus was on optimizing and rationalizing production, which reflected the last phase of scientific management. The 1930s saw the Depression and a shift from engineering departments to corporate laboratories as the principal focus for innovation, with new products being given the utmost priority. This trend laid the foundations for the post World War 2 recovery.

Corporate interest in technology as a driver of development appeared after World War 2 by tying technology investments to strategy. Numerous science-related products emerged from corporate laboratories that were also driven to some extent by huge increases in military spending. This created the linear model of innovation that existed for a number of decades. Persuaded by large World War 2 projects such as the atom bomb and radar, many US firms in the 1950s and 1960s embraced the concept that R&D investment was all that was required for commercial innovation. The linear innovation model reinforced this perception, with the innovation process starting with a scientifically developed concept followed by methodical development stages. The perception was that by basing innovation on science, large payoffs could be expected through the opening of new markets.

Cynicism with this approach began in the US industry during the 1970s and followed soon after in Europe. Up to the 1960s demand from the reconstruction of the industrialized economies and the lack of any major competition resulted in a focus on the optimization and enhancing of system operations as opposed to productivity and innovation. A large component of US R&D was also derived from government funding in the high tech sector, especially the military.

By the 1980s it became obvious in many sectors that an innovation system based on research had problems in executing the later phases of innovation. Another issue was that the expectations of significant new products based on science had been overstated, with final success often elusive. Invention on demand did not fit the process model, with a number of product failures challenging corporate research and management calling into question R&D expenditure levels.

Today open innovation systems have gained attention, with global firms successfully coordinating design and manufacturing communities to deliver their requirements with speed, efficiency and flexibility. Networks have led to successes in innovations and have typically

included both small and large firms that swap expertise and information. Innovation prospers on the diversity and flow of information, and therefore having access to knowledge networks has proven to be far more valuable than the centralized corporate laboratory with its long project cycles and large overheads.

1.2 The evolution of industry sectors

The successive technology waves over the 19th and 20th centuries are reflected in the transformations of the listed stock market industry sectors. Table 1.1 illustrates the industry shifts in the US and UK indexes for the years 1899, 1950 and 2000. The table is based on the industry classifications in use in 1900, with a few additional sectors that although minor in 1900 grew to significance through to 1950.

Railroad companies were the first true industrial giants at the beginning of the 20th century. As they gradually became regulated and nationalized, however, the industry was marginalized by new industries such as steel, chemicals, rubber, mechanical engineering, machinery and consumer durables.

Table 1.1 Industry sector weights based on the 1899 classification system

	United States			United Kingdom		
Sectors	1899	1950	2000	1899	1950	2000
Railroads	62.8	4.2	0.2	49.2	–	0.3
Banks and finance	6.7	0.7	12.9	15.4	9.7	16.8
Mining	–	1.1	–	6.7	5.3	2.0
Textiles	0.7	1.3	0.2	5.0	3.3	–
Iron, coal, steel	5.2	0.3	0.3	4.5	5.4	0.1
Breweries and distillers	0.3	0.7	0.4	3.9	8.8	2.1
Utilities	4.8	8.3	3.8	3.1	0.2	3.6
Telegraph and telephone	3.9	6.0	5.6	2.5	–	14.0
Insurance	–	0.4	4.9	1.9	11.5	4.4
Other transport	3.7	0.3	0.5	1.4	1.7	1.5
Chemicals	0.5	13.9	1.2	1.3	6.3	0.9
Food manufacturing	2.5	2.0	1.2	1.0	4.6	2.0
Retailers	0.1	6.7	5.6	0.7	7.3	4.4
Tobacco	4.0	1.5	0.8	–	13.1	1.0
Too small	4.8	52.6	62.4	3.4	22.8	46.9
	100.0	100.0	100.0	100.0	100.0	100.0

Notes: UK 1899 and 1950 sector weights are based on the largest 100 stocks. 2000 sector weights indicate the entire market; US 1899 weights include all NYSE and New York City banks. 1950 and 2000 weights reflect the entire US market.
Source: Dimson, E. Marsh, P., and Staunton, M. (2002).

Another trend is that some sectors that were insignificant in 1900 grew to dominance through to 1950 and then declined by the year 2000. One example is the chemical industry, with US growth increasing from 0.5 to 13.9% in weighting between 1900 and 1950, and then declining to 1.2% by 2000. The UK chemical sector followed a comparable pattern, with a huge weighting increase from 1900 to 1950 followed by a dramatic decline by 2000.

Table 1.2 illustrates the same firms classified under current industry sector definitions and listed according to their US significance. In 2000 the six largest sectors are information technology, banks, pharmaceuticals, telecommunications, retailers, and oil and gas, which combined account for nearly two-thirds of the present-day US market share. Sectors such as oil and gas and pharmaceuticals were nearly nonexistent in 1900, and information technology had a zero weight in the years from 1900 to 1950. In 1950 pharmaceuticals were still relatively insignificant, while oil companies in the US had achieved dominance and then declined in relative weighting. The telecommunications sector while relatively small in 1900 grew to approximately 6% of the US market where it has since remained. The UK telecommunications sector was nationalized up to the 1980s when it was then privatized, ultimately reaching 14% of the UK market.

Table 1.2 Industry sector weights based on the 2001 classification system

	United States			United Kingdom		
Sectors	1899	1950	2000	1899	1950	2000
Information technology	–	–	23.1	–	–	4.7
Banks and finance	6.7	0.7	12.9	15.4	9.7	16.8
Pharmaceuticals	–	0.8	11.2	–	0.4	11.0
Telecommunications	3.9	6.0	5.6	2.5	–	14.0
Retailers	0.1	6.7	5.6	0.7	7.3	4.4
Oil and gas	–	16.4	5.2	0.2	12.9	11.0
Diversified industrials	–	2.0	5.1	–	1.0	–
Insurance	–	0.4	4.9	1.9	11.5	4.4
Utilities	4.8	8.3	3.8	3.1	0.2	3.6
Media and photography	–	1.0	2.5	0.6	0.4	5.9
Breweries and distillers	0.3	0.7	0.4	3.9	8.8	2.1
Mining	–	1.1	–	6.7	5.3	2.0
Too small	84.2	55.9	19.7	65.0	42.5	20.1
	100.0	100.0	100.0	100.0	100.0	100.0

Source: Dimson, E. Marsh, P., and Staunton, M. (2002).

The composition of the stock market indexes has always been shifting. Over the first 75 years of the 20th century these shifts were gradual, with new industrials replacing older ones and manufacturing dominating. US industrials, however, began a relative decline after the mid-1950s, with the decline accelerating in the 1970s due to soaring energy costs and increased competition domestically and from overseas. On the supply side US industrials were facing low cost foreign competitors that were producing products that were increasingly improving in quality. On the demand side growth in the US domestic market had ceased, with demand for industrial goods diminishing by the close of the 1960s.

The final quarter of the 20th century saw a significant change in the US economy with the decline in manufacturing and growth in service industries, and most of all a shift to information technology, a revolution that also significantly expanded the extent of services. Table 1.3 illustrates the transformation of the 100 largest US firms as measured by revenues for the years 1955, 1975 and 2000. The 1955 and 1975 lists show a relatively small decline in manufacturing, sales and market value and the rise of financial services, information technology, and pharmaceuticals and health care. Both lists are fundamentally the same, with manufacturing firms dominating. By 2000, however, manufacturing had declined significantly, with financial services, information technology, and telecoms and media dramatically increasing as measured by revenues.

There were a number of fundamental changes in the US economy over the last quarter of the 20th century. The first was the appearance

Table 1.3 Industry sector weights for the largest 100 firms by profits – 1955, 1975, 2000

Sector	1955	1975	2000
Consumer discretionary	7	8	13
Consumer staples	17	14	14
Energy	17	19	6
Health care	–	2	9
Industrials	37	37	11
Materials	20	18	3
Information technology	1	1	10
Financials	–	–	24
Telecommunications services	1	1	7
Utilities	–	–	3
Total	100	100	100

Source: Fortune 100 – 1955, 1975, and 2000.

and growth in the components of a new knowledge economy. These included computer hardware, software and services, providers of internet services and content, and the telecoms that develop and manage the infrastructure over which information flows. The combination of these components created an information revolution equivalent to the industrial revolution that generated the expansion of the industrial economy. Analogies can be drawn between firms in the information economy and those from the industrial economy, with chips the equivalent of basic materials such as metals and plastics, software equal to process control and electrical mechanical systems, and telecommunications infrastructure and services the equivalent to transportation and related services. These information economy firms have grown significantly and now have considerable influence, as did their industrial equivalents, as information technology diffused and integrated into the economy.

The second is the growing significance of intellectual assets compared to physical assets. The foundations for value generation in industrial firms are physical assets such as plant and factories. In the knowledge economy, science and technology are increasingly driving business, as firms in all industries use these factors to create a competitive advantage. This is reflected in how firms manage R&D and commercialize innovation, with the shift to the formation of networks, partnerships, and other structures to exploit discoveries and mitigate R&D risks.

The third attribute was the manner in which new entrants were financed compared to their industrial counterparts. Risk capital was provided by venture capital, which financed entrepreneurs and laid the foundation for the rise of new information technology and biotechnology firms with a relatively small amount of initial capital. The fourth was the use of innovative new business models. The fifth was the emergence of a new economic focus. While economies of scale and scope, the primary drivers of industrial growth, continued to be significant, network economies rose to become of equal importance and included the drive for standards and alliances.

The result of all these factors was the shift of large industrial firms from the center to the fringe of the modern global economy. The forces that created the new knowledge economy will continue to drive the transformation from an industrial economy, with its foundations in physical assets and production, to a post-industrial economy centered around intangible assets and services.

The shift in the economy has also influenced the turnover in the composition of the major stock market indexes. Foster and Kaplan (2001) analyzed the continuity of organizations over the 20th century, using business publications, market indices and corporate performance data. The focus of the analysis was on the limitations of long-term corporate performance that result from the inevitable changes in the business environment, which Foster and Kaplan called 'discontinuities'. A comparison of ranked US companies illustrated these discontinuities. In 1917 Forbes published their first list of the 100 largest American companies which were ranked by assets. Forbes revisited its initial 100 list in 1987 and compared it to its then current list of top organizations. Sixty-one of the original 100 companies had not survived, with 18 of the remaining 39 companies managing to stay in the top 100. These 18 companies, however, earned an investment return that was 20% less than the total market between 1917 and 1987.

The same result was found for Standard & Poor's (S&P) 500. Changes in the S&P 90 index were relatively slow for the first 20 years after its initial start in the 1920s, with an average turnover of 1.5% per year. A firm that was included in the index during this period would remain there for an average of more than 65 years. By 1998 the rate of change in the S&P index had shifted dramatically, with an increase to nearly 10%. The time a firm spent in the index over the last 70-plus years had decreased from an average of 65 years to 10 years. Over the last 40 years only 74 of the original 500 firms that comprised the S&P 500 in 1957 still remained on the index in 1997. Only 12 of these 74 firms outperformed the S&P index over the period from 1957 to 1998.

The analysis raised the question as to why do indices such as the S&P 500 perform better in the long run than nearly all of the major corporations of the 20th century. Foster and Kaplan concluded that the capital markets and their benchmark indices support the formation of firms and allow their continuation if they remain competitive. However, the capital markets will eliminate any firms that fail in their capacity to perform, a process Schumpeter referred to as 'the perennial gale of creative destruction'. Other factors that influenced the turnover in the indexes include the unbundling of existing firms as a result of the information revolution, the growth in the information and telecommunications sectors in which innovation is especially important, and service industries having less barriers to entry than manufacturing.

Firms in the 20th century were managed on the assumption of continuity, reinforced by techniques that focused on sources of efficiency

such as economies of scale, labor specialization, cost controls and vertical integration. Innovations and changes in demand patterns are causing many industry barriers to break down, making a sustainable competitive advantage an increasingly difficult proposition. Barriers to entry are being eroded through competition that is the result of improved capital markets, globalization, political transformations and the developments in communications and information. The inevitable end result of these developments is that economic profits are becoming less sustainable, and therefore it is becoming almost impossible to develop a long-term strategy based on the notion of continuity.

1.3 From corporate planning to shareholder value

Strategy is defined as the process by which a firm deploys its resources and capabilities within its business environment in order to achieve its goals. Corporate strategy is concerned with *where* a firm competes; business strategy is concerned with *how* a firm competes.

The development of business strategy over the last 60 years was initially driven more by business practicalities than theory. The business environment in the 1950s and 1960s was relatively stable, and organizations focused on growth through diversification, vertical integration, mass marketing, efficiencies through scale and long-term investments. Corporate planning grew in popularity as a result of the increasing size and complexity of these organizations and the problems associated with management and control. Although financial budgeting offered some means for addressing these issues, the main strategic objective was the long-term planning of investments, which required a longer time horizon than that provided by annual budgets.

In the 1970s, analytical concepts such as portfolio planning matrices became popular strategy and resource allocation frameworks. The matrix approach was designed to assess business unit performance and strategies, and the corporate portfolio's performance in general. Boston Consulting Group's growth-share matrix was an innovation in corporate strategy and became a principal framework for resource allocation in diversified organizations. Strategic alternatives were based on the comparison, using industry appeal and competitive position as the criteria, of the strategic positioning of the various business units within the matrix.

The matrix consisted of four quadrants, defined as stars, cash cows, dogs and question marks, that showed cash flow patterns and potential

strategies, and two dimensions that consisted of the market growth rate, which focused on capturing a business's potential use of cash, and relative market share, a proxy for competitive position and therefore a business's ability to generate cash. Examining the position of a business unit as defined by its asset or revenue base within the matrix provided an analysis of the flow of financial resources within a diversified organization.

A number of economic events during the 1970s ended the post-war period of relative stability. The oil shocks, high interest rates and the increased international competition from Asia and Europe created an unstable environment in which diversification and planning no longer provided the expected synergies. As a result organizations moved towards more flexible strategic management methods that focused on competitiveness, with competitive advantage becoming the main strategic objective. This had a significant impact on strategic concepts at the beginning of the 1980s. One development pioneered by Michael Porter was the use of industrial organization economics in the analysis of profitability, which emphasized an organization's competition, market environment and industry structure. Capital market developments and the profit incentives in reviving non-performing corporations also created a fertile environment for the emergence of corporate raiders and leveraged buyout firms. The activities of these players exposed the vulnerability of many large diversified corporations, which led to several takeovers.

As a result of these developments management became focused on the stock market valuations of their corporations. In the 1990s shareholders and the financial markets continued to pressure management to maximize shareholder returns, and as a result the shareholder value concept was included in all aspects of strategy. Growth strategies such as diversification, vertical integration and corporate planning developed over the previous 30 years were replaced with a focus on profitability.

Shareholder value theory holds that value is created when a firm earns a return greater than the cost of capital employed to generate that return through the efficient management of resources. A firm can also be viewed as a portfolio of assets valued as the sum of the net present values of each asset's cash flows. The value of a firm's equity is the net present value of the firm's cash flows that are accessible to shareholders, with shareholder value derived from the discounted cash flows associated with the firm's investments.

1.4 Strategy and value

The objective of all organizations is the creation of value. An organization's strategies describe how it intends to create value over an immediate time frame, and the value opportunities it is searching for over the long term. Value, however, has different meanings to different stakeholders. Organizations manage resources to create value through their capabilities to deliver products or services that provide customer value, maintain relationships with resource providers and customers, and organize activities through governance, management systems and processes. To do this an organization has to create an equitable balance between stakeholders such as management, customers, employees, financiers, unions, suppliers, shareholders, government and society in general. Although value has to be established and maintained by organizations in order to offer incentives to various stakeholders, a premium is associated with value creation for customers and shareholders. The creation of value for other stakeholders is dependent on the success of creating value for customers and the incentives offered to shareholders, the residual stakeholders. Offering unsuitable incentives to stakeholders, however, is likely to lead to the destruction of shareholder value.

An organization's success in achieving its strategies depends on its capabilities to execute them over the short and the long term. An organization's strategic portfolio defines the extent of an organization's products or services through the identification of customers, competitors, assets, investors, competitive environments, value creation and any associated risks. Although identified the portfolio is also dynamic. In the short term the portfolio is sustained through the efficiency of operations and incremental improvements. In the long term, however, lies a range of opportunities that are yet to be understood, created and realized.

An organization can recognize and define these options by establishing capabilities to search for the potential value in opportunities that lie in the future. Strategy will therefore need to focus on an organization's *portfolio of real options* and the associated value in opportunities that can be maintained within the portfolio. An organization's strategy will therefore consist of two components. The first is the customer value provided through the organization's strategic portfolio, while the second is the value opportunities created by the organization's real options portfolio. These two portfolios have to be maintained

simultaneously, and so an organization will need the capabilities to manage both the known and the unknown as it positions itself for the future.

Managing value in both the short and long run will require the management and governance capabilities to steer strategy, innovation, resource allocation and the restructuring of organizations and processes through an external environment of continuous and accelerating change. Transforming an organization to create sustainable competitive advantage and value will therefore need the capabilities to manage a portfolio of real options to sustain value creation. A real options framework has the potential to link value analysis to the problems of uncertainty, discontinuity, resource allocation, management flexibility, managing innovation, and communicating strategy to stakeholders and financial markets.

Appendix – classifying industry sectors today

Industry classification systems categorize firms into groups using a number of different factors, which can include similar production processes, products, or financial market behavior. In general industries are identified with relatively broad markets, while markets themselves refer to specific products. The rise of the information and service economies, however, has blurred the boundaries between manufacturing and services and has created an issue in how to define an industry's boundaries.

One distinction is the difference between high technology and mature industries. High technology or technology intensive industries are science-based manufacturing industries that have above average relative R&D levels. Measures for high technology industries include the level of R&D intensity, derived by dividing industry R&D expenditures with industry sales, and levels of patent activity. Examples of high tech industries include the information technology sector, aerospace, pharmaceuticals and communications.

Mature industries are those that have moved through the emerging and growth phases and have reached a stage in their life cycle where they grow in line with the economy. Examples include financial services, insurance, food, energy, construction, automotive, tobacco, steel and textiles. R&D expenditure is typically less than 1% of sales, which compares to high technology industries where R&D spending can be up to 65% of sales.

In 1999, Standard & Poor's and Morgan Stanley Capital International (MSCI) together launched the Global Industry Classification Standard (GICS) to establish consistent industry definitions. The GICS system was designed to classify firms into groups that have similar stock market behavior, and consists of 10 sectors aggregated from 24 industry groups, 62 industries, and 132 sub industries. The ten sectors are:

- consumer discretionary,
- consumers staples,
- energy,
- financials,
- health care,
- industrials,
- information technology,
- basic materials,
- telecommunication services, and
- utilities.

In reality, industry structures are constantly evolving, with the external forces of technology, demand, and economic growth, and the internal competitive strategies of firms within industries driving change. The rise of technology and services has also compressed industry and firm life cycles by reducing the barriers to entry.

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2
Value

Overview

To deliver sustainable shareholder value, management has to manage simultaneously operations in the short term while delivering on plans for the long term. Commitments in the short term include delivering on earnings and maintaining liquidity, while in the long term developing and executing on strategy and investments along with meeting creditor obligations. The following framework discusses the analytics that encompass current and future performance.

The accounting foundations describe how the financial statements translate a business model and provide a framework for identifying value. The articulation of the financial statements identifies their stocks and flows, which provide the means to identify how a business generates value. Financial ratios provide a lens into the current performance of a firm to identify the factors that drive value. Return on shareholders' common equity and return on invested capital ratios are examined within this context.

Investment methods are then reviewed. DCF techniques and its shortcomings in the assumptions and decision rules are discussed. The advantages of real options techniques that address these issues are then outlined. The valuation of real options covers the issues associated with this technique, followed by the various types and definitions.

The firm value section covers corporate finance theory and builds a framework that extends on the initial model with the inclusion of growth options, an abandonment option, modularity and financial options. Finally a firm's capital structure is discussed within this framework.

2.1 The accounting foundations

A business model provides a framework for identifying and creating value. Business models describe how the components of a business combine as a system. The phrase is widely used to describe the diverse features of a business, and its scope can include strategy, purpose, offerings, processes, operations, organizational aspects and trading practices. A good business model identifies the customer, what customers value, and how value is created in a business. The ability to identify how a business model functions and creates value provides a foundation for valuation.

Financial statements provide a framework for identifying how firm value is generated for shareholders and other stakeholders. The attributes of a business model are translated into accounting metrics that provide a lens into how and where value is created. Accounting principles define how financial statements are organized and, therefore, how value is measured. Firms generally issue three primary financial statements: the balance sheet, the income statement, and the cash flow statement. One additional report usually required is the statement of shareholder's equity.

The balance sheet itemizes a firm's assets, liabilities and shareholder equity. Assets are a firm's investments that are anticipated to generate future payoffs. Liabilities are claims to payoffs on the firm by non-owner claimants, while shareholders' equity is a claim on the firm by its owners. The balance sheet is therefore a statement of the firm's investments and the payoff claims on those investments. Assets and liabilities are also identified as being either current or long-term, where current defines those assets that produce cash or cash used to pay liabilities within one year. The balance sheet's three components are linked through the following accounting relationship:

$$\text{shareholders' equity} = \text{assets} - \text{liabilities}$$

This accounting equation states that shareholders' equity is the equivalent to a firm's net assets, or the net difference between the firm's assets and liabilities. Shareholders' equity is therefore the residual claim on a firm's assets after liabilities have been subtracted.

The income statement gives an account of the increases or decreases in shareholders' equity that result from a firm's operations and activities. The value that is added to shareholder value is described by convention as the bottom line, net income, net profit or earnings. The income statement also itemizes the firm's revenues and expenses

that are the foundation of net income. This is established through the following accounting relationship:

net income = revenues – expenses

The cash flow statement shows the cash generated and used by a firm over an accounting period. The various cash flows in the statement are identified as cash flows from operating activities, cash flows from investing activities and cash flows from financing activities. The total cash flows from the three definitions identify a firm's increase or decrease in cash activities:

change in cash = cash from operations + cash from investment + cash from financing

The statement of shareholders' equity explains how a firm's equity changed over an accounting period:

ending equity = beginning equity + total (comprehensive) income – shareholders' net payout

A firm's equity increases when value is added through operations as net income in the income statement, along with other comprehensive income and shareholders' investments, and decreases with payouts to shareholders.

2.2 Stocks and flows

The articulation of the financial statements describes their relationships or the manner in which they fit together. The balance sheet provides the stocks of owner's equity and cash at a point in time, while the cash flow statement accounts for how the stock of cash has changed over time. The statement of shareholder equity, which identifies the change in owner's equity or flows over two balance sheet dates, describes the relationship between the income statement and balance sheet. The income statement, adjusted for other comprehensive income in the equity statement, describes the change in owners' equity derived from the value added from operations.

Identifying the articulation of the financial statements reveals their stocks and flows, which provide a foundation for the analysis of how a business generates value. The balance sheet describes the stock of value in a firm at a point in time while the income statement and cash flow statement account for the flows, or change in stocks between two points in time in the balance sheet. The statement of shareholders' equity equation above is the *stocks and flows equation* for equity, as it

describes how the stock of equity have changed with the equity flows. The cash flow relations described in the cash flow statement equation above is the stocks and flows equation for cash.

The stocks and flows concept can be extended to define value, with the balance sheet providing the shareholders' net worth as a stock, while flows are the value added through a firm's operations in the income statement, and in the cash flow statement as changes in cash. Therefore the value that flows to a firm's owners is the change in equity over an accounting year.

The value of a firm should always equal the value of the claims on the firm:

$$\text{firm value} = \text{value of debt} + \text{value of equity}$$

This relationship illustrates that total firm value is distributed to the various claimants on that value. Firm valuation can therefore be defined as either valuing the firm itself, or valuing and summing the claims on the firm. The firm is also a portfolio of projects, with the value of the firm represented by the present value of the expected cash flows from operations, or free cash flows, from these projects. Firms seek continuity by investing in new projects while letting existing projects terminate. The cash generated from a firm's assets and operations flows to the claimants on the firm. Therefore the analysis of a firm's operations, financing activities and investments provides the foundation on how firm value is generated, and the sustainability of that value creation.

Figure 2.1 illustrates all the stocks and flows of a firm. The firm's debt and equity financing activities are transacted with claimants in the capital markets. At inception a firm begins with funding sourced as cash from shareholders. This cash is initially invested in liquid financial assets, such as short-term money market securities, before being invested in operating assets. Additional funds are also raised as debt to fund balance sheet assets. Cash that moves between the debt holders and the firm is reduced to the net debt financing flow F. This net cash flow consists of cash paid as interest and principal repayments to debt holders minus cash borrowed by the firm from its creditors. Similarly the net dividend to shareholders d represents cash paid as dividends and stock repurchases minus capital cash injections from shareholders.

Firms divest the cash in financial assets to invest in operating assets, described by the firm's investing activities I. These cash flows can move in either direction, with investments in financial assets also

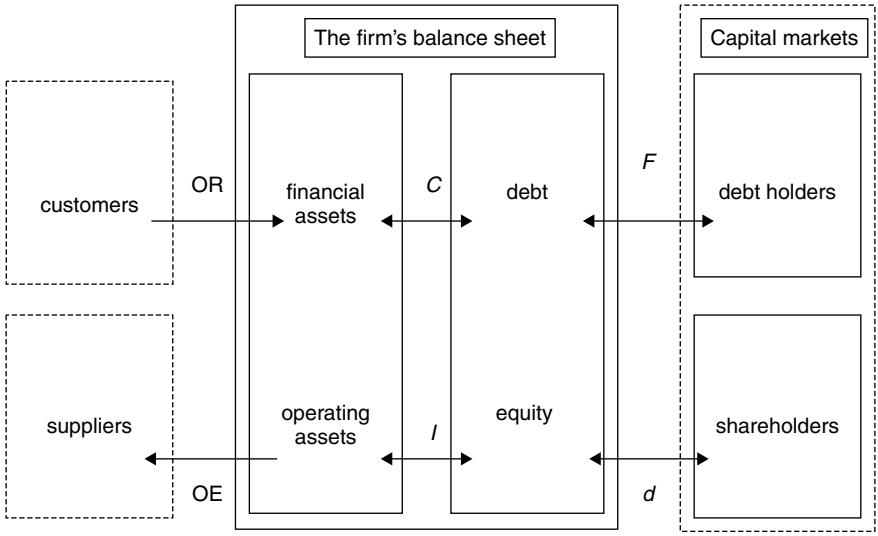

Figure 2.1 The stocks and flows of a firm

flowing from the proceeds of liquidating operational assets such as discontinued operations. Net cash flows are then generated from the operating assets, defined as cash from operations C, through the operating income generated by operating revenues OR minus the operating expenses OE. This cash from operations is then invested in liquid financial assets, and so the cycle continues.

An important identity is the cash conservation equation, or sources and uses of cash equation. The four cash flows – cash flow from operations C, cash investment I, net cash flow to debt holders and issuers F, and net cash flow to shareholders d – always observe the relationship:

$$C - I = F + d$$

or free cash flow equals the net payments to debt holders and debt issuers plus the net dividends to shareholders. Cash flow from operations minus the cash investment in operations is therefore always equivalent to the net cash flows to debt holders and shareholders.

The left hand side of the relationship $C - I$ represents a firm's free cash flow. Free cash flow is positive if operations produce more cash than required for new investment and negative if operations create less cash than required for new investment. A positive free cash flow is either invested in financial assets F or distributed as dividends d. A negative free cash flow necessitates either the issuing of bonds, a negative F, or the issuing of stock, a negative d, to meet the cash shortfall.

2.3 Ratio analysis

Return on shareholders' equity (ROE), or more specifically return on shareholders' common equity (ROCE), measures the rate of return on common stock:

$$\text{ROCE} = \frac{\text{comprehensive income}}{\text{average CSE}}$$

The measure assesses a firm's profitability efficiency per unit of shareholders' equity or book value. ROCE can be decomposed into three drivers:

net profit margin × asset turnover × financial leverage;

or net income/sales × sales/total assets × total assets/average shareholder equity.

Net profit margin is a relative measure of the rate at which profitability is generated from operating assets, or the dollar of net profit generated from a dollar of sales revenue. Asset turnover measures the efficiency of operating assets and describes the relationship between the use of assets and profitability. The ratio focuses on the volume of sales generated from an investment in operating assets, or the dollar of sales revenue generated for each dollar invested in operating assets. Asset turnover centers on two operating asset groups: the working capital assets such as cash, inventory and receivables, and the fixed assets that include plant, property and equipment. The leverage ratio describes the degree to which a firm relies on debt to create profitability. A firm can increase its asset base through financial leverage or borrowing, which can enhance the returns to shareholders.

The first two ROCE drivers, net profit margin × asset turnover, define the return on assets (ROA) ratio. ROA establishes a firm's efficiency in the use of assets and is also a profitability measure. The DuPont Formula integrates the analysis of a firm's profitability and investments in assets and provides a window into the sources of a firm's profitability. High net margins indicate that customers are prepared to pay more for a firm's products, while a high asset turnover indicates that a firm uses its assets relatively more efficiently in generating sales, and therefore invests less capital. The return to shareholders can therefore be increased by either increasing the profit per dollar of sales, or increasing the sales dollars generated from the operating assets.

Return on invested capital (ROIC) measures a firm's success in generating cash flow relative to its invested capital. The measure is derived

as net operating profit after taxes (NOPAT) divided by invested capital, which includes working capital, debt, and common and preferred stock:

$$\text{ROIC} = \frac{\text{NOPAT}}{\text{invested capital}}$$

Firm value is created when the ROIC is greater than the cost of capital, and value lost if the spread is negative. ROIC provides a better metric for the analysis of a firm's performance than ROCE and ROA as it centers on a firm's actual operations. ROCE combines operations with leverage, while ROA understates a firm's profitability as it does not include the leverage from operating liabilities and does include the profitability from financial assets.

ROIC driver patterns reveal a fade rate or persistence where the ROIC reverts to a long run level. Economic factors typically influence firms in a comparable manner within industry sectors, and drivers tend to fade to levels that are representative for an industry.

In 'A long-term look at ROIC' McKinsey conducted an analysis of ROIC patterns specific to industries over time. The analysis was based on a sample of approximately 7,000 publicly listed non-financial US firms from 1963 to 2004. The first observation was that the average US firm returned its cost of capital over the sample period with the median ROIC, not including goodwill, averaging close to 10%. While technology firms that focus on innovation can initially earn above average returns, they ultimately pass on the margins to consumers as a result of competition. The second observation was that historically ROIC varies extensively by US industry. The pharmaceutical and consumer goods industries have sustainable barriers to entry such as brands and patents that result in the persistence of high returns on invested capital. Capital-intensive industry sectors that include basic materials and extremely competitive sectors such as retailing are inclined to have a low ROIC. This general variation in the ROIC persistence across industry sectors implies that individual firms should be compared to similar firms that operate in comparable industries.

The final observation was that the median or mean returns within industry groups could be deceptive due to the ROIC distribution within sectors, with differences within industries in some instances more striking than those across sectors. An example is the software industry, with a median ROIC of 18% and an average spread of 31% between the end quartiles. This variance implies that the software industry has many discrete subgroups that face significantly different competitive forces.

In contrast the utility industry has a ROIC of 7% and a variance of only 2% in best to worst firms. The McKinsey analysis implies that although revenue growth tends to fade rapidly to a mean level, the persistence of high ROIC can remain for extended periods.

2.4 Investments

2.4.1 Overview

Investment can be defined as the sacrifice of current dollars for future dollars (Sharpe, Alexander, and Bailey, 1999). Understanding how investments are valued is important for investors, finance executives or management generally. Assets are only worth what someone is willing to pay for them, and as that person could be an analyst, a trader, a fund manager or a competitor, a background in the available valuation methods is essential. Investment valuation is used for a wide range of real and financial assets, including companies, bonds, stocks, real estate and derivatives. Although most investment valuation models are generalized rather than specific to particular markets, it is also probably one of the most difficult tasks in finance.

Many volatile factors can have an impact on the value of investments. Errors in forecasts can result from unforeseen changes in factors such as financial variables, markets, competitors and technology. Unexpected changes in asset values can also result from factors that are completely unrelated to a company, an industry or the economy generally. Another major influence today on the value of investments is the corporate emphasis on short-term results. A company will be either rewarded or penalized every quarter through its share price, depending on whether earnings satisfy investor expectations. A consequence often seen is the corporate behavior of managing quarterly financial results to reduce share price volatility.

The basis for an investment will depend on the investment philosophy. Generally the value of an asset should be a function of the cash flows it is expected to produce. A wide variety of models are used for investment valuation with various levels of complexity; however, there are some common features. Two common approaches are DCF valuation and relative valuation, which is similar to DCF in the sense that the value of an asset is derived from the cash flows of comparable assets. DCF analysis can be performed either from the viewpoint of equity holders, in which case the expected cash flows to equity are discounted, or by considering the firm from all perspectives and discounting the firm's expected cash flows.

2.4.2 DCF valuation

Studies of corporate investment practices (Seitz and Ellison, 1995) carried out over the last 40 years have shown that the payback and accounting rate of return approaches were the preferred decision methods in earlier years. By 1988, however, over 75% of companies were using the DCF approach to calculate the net present value (NPV) of potential investment outlays and inflows.

There are two basic approaches to discounted cash flow methods, the net present value and the internal rate of return (IRR). The NPV is the difference between the present value of the net cash inflows generated by the project, and the initial cash outlay. The IRR is the rate of return that equates the present value of the net cash inflows generated by the project with its initial cash outlay. The IRR is the equivalent to interest rates quoted in financial markets. The NPV approach is the most popular and has the following features:

- NPV recognizes the time value of money.
- NPV is a function of the future cash flows from an investment and reflects the opportunity cost of capital.
- Net present values can be aggregated as they are measured in today's values.

The NPV of an investment is the sum of the present values of the expected benefits, generally in the form of cash flows, from which the present values of all expected cash outlays are subtracted. The variable k is defined as the rate of return that can be earned on an alternative investment. If I_0 is defined as the initial outlay, and CF_t the cash flow at the end of period t, the net present value is:

$$NPV = \frac{CF_1}{(1+k)^1} + \frac{CF_2}{(1+k)^2} + \ldots\ldots\ldots\ldots + \frac{CF_n}{(1+k)^n} - I_0 \qquad (2.1)$$

2.4.3 The net present value rule

The net present value rule is to accept investments that have positive net present values, that is, when the present value of the investment's cash inflows are at least as large as the present value of the cost outlays. There are some implicit assumptions underlying the NPV method (Dixit and Pindyck, 1994):

- The investment can be reversed or unwound and any outlays recovered if circumstances prove to be less than expected, or

- the choice is either a now or never decision, even if the investment cannot be reversed. If the investment is not made immediately then it cannot be made in the future.

Most investments actually do not meet these requirements. Instead the majority of investment decisions have three central features that interact at various levels:

- The investment cannot be reversed, if not totally then as least to some degree, in which case the initial investment is to some extent a sunk cost, or a cost that cannot be recovered.
- The investment's future payoffs have an associated uncertainty.
- There is some flexibility in the investment timing. There is an opportunity to delay a decision until further information becomes available.

The opportunity to delay and the inability to reverse an investment decision are significant features found in most investments. NPV valuations, however, compare investing immediately with never investing, and reflect a static value derived from assumptions that only consider a single scenario. A NPV analysis does not recognize any flexibility management has to assess and react to future circumstances that were not initially anticipated. The NPV approach assumes a static commitment to a static strategy. Any business case based on NPV analysis will therefore ignore management's potential to modify a decision alternative in the future.

Although the NPV approach assumes a predetermined path no matter how events materialize, the business environment today is anything but static. NPV techniques are not designed to capitalize on future opportunities when they arise, or to manage any potential down side risks. NPV valuation methods do not include the value of the opportunity to wait and act in the future as more information becomes available. NPV valuations also imply that risk is a single dimension that reduces value. All uncertainties and decisions are reduced to one single scenario that is adjusted for risk through the level of a discount rate.

2.4.4 Real options

Strategic flexibility has become a critical management issue in the dynamic business environment that exists today. Management concepts and methods will need therefore to be able to identify and

include opportunities that may develop, and losses that may result from adverse market developments. Expanding a strategic analysis so that it includes the value of potential upside gains and downside losses will enhance management's capabilities to adapt to future market conditions. A better strategic framework would consider a range of opportunities, opportunities defined as options, rights but not obligations to some particular action in the future. Corporate strategy should therefore include in any analysis the concept of a portfolio of options, rather than just a portfolio of predetermined cash flows.

Real options analysis is a valuation and strategic decision paradigm that applies financial options theory to real assets. Stewart Myers (Myers, 1987) first referred to the term in a discussion about the gap between strategic planning and finance theory. DCF analysis, developed from finance theory, made sense when applied to businesses such as 'Cash Cows'. However the discontinuities associated with today's business environment are putting limitations on the life of businesses such as these and therefore the DCF techniques used to analyze them. Risk can also be leveraged to create rather than suppress value. Hedges can protect investments from downside risks while an exposure is maintained to any upside potential. Real options offer a framework and the metrics for managing strategy, value and risk in today's business environment.

Organizations will typically invest in projects that generate a return greater than a hurdle rate. Hurdle rates can, however, be often observed at three to four times the cost of capital (Dixit and Pindyck, 1994). One explanation is the implied option value, or opportunity cost associated with a capital investment. Rather than the investment decision being that (discounted) cash inflows must equal or exceed (discounted) cash outflows as per the NPV rule, the investment's cash inflows must exceed the cash outflows by the value of keeping open any optionality in the investment. If a decision is made to proceed with an irreversible investment the opportunity to delay the investment is forfeited, and so the rights to any option implied in the investment are exercised. This opportunity cost should therefore be included in the valuation of an investment.

The NPV rule should therefore be revised by subtracting the opportunity cost of exercising any options, and then invest if the modified NPV is positive. The alternative is to keep the conventional NPV and the option value distinct. The investment framework can therefore include two identified value components: the NPV and the real options

value. A strategic NPV can therefore be defined as (Trigeorgis, 1996):

$$\text{Strategic NPV} = \text{Standard NPV} + \text{Option Premium}$$

The modified NPV rule is now to invest if the strategic NPV is greater than zero.

2.4.5 Valuing real options

Financial options are asymmetric relationships, where the option holder has a right but not the obligation to transact at a contracted price (the exercise price) on or before a predetermined date (the exercise or maturity date). A call option is the right to buy, and a put option the right to sell the underlying instrument at the exercise price. A European option can only be exercised at the end of its life, while American options can be exercised at any time during its life. In the case of a real option it is the right but not the obligation to act, such as deferring, expanding, contracting, or abandoning a project or investment at a predetermined cost (the exercise price) for a predetermined period of time (Trigeorgis, 1996; Copeland, 2001). Value is created in a financial option from the volatility in an underlying financial asset, and the same concept is applied to real options, where value is derived from the uncertainty or the volatility associated with a real asset. Table 2.1 compares the variables found in a financial option with the real option equivalents.

A relatively simple argument has been developed in financial economics to price an option under the assumption is that no arbitrage opportunities exist. An economy exists that has an abundant set of traded assets from which a portfolio can be created. This portfolio consists of buying a specific number of shares of a stock, against which a certain amount is borrowed at a risk free rate such that the portfolio replicates an option's returns in any state of nature. In the absence of any arbitrage opportunities, or risk free profits, the option and the

Table 2.1 Comparison between a call option on a stock and a real option

Call option on stock	Real option on project
Current value of stock	(Gross) PV of expected cash flows
Exercise price	Investment cost
Time to expiration	Time until opportunity disappears
Stock value uncertainty	Project value uncertainty
Riskless interest rate	Riskless interest rate

Source: Trigeorgis, Lenos. *Real Options: Managerial Flexibility and Strategy in Resource Allocation*, Table 4.2, ©1996 Massachusetts Institute of Technology, by permission of The MIT Press.

corresponding portfolio must sell for the same price as they provide the same future return. Therefore the price of the option is the equivalent to the cost of setting up the replicating portfolio.

The no-arbitrage replicating portfolio concept used to price options can be applied to real options by employing the assumptions used in deriving the NPV of an asset or project. The discount rate used in DCF analysis typically estimated using the capital asset pricing model (CAPM) is based on the price of a traded twin security with the same risk characteristics as the investment or project being analyzed. Therefore the same traded twin security can be used to replicate the real option's returns. This leads to an important assumption in valuing real options: that existing assets in the economy span the risks in the asset or project being valued. Capital markets must be adequately complete so that an asset exists such that its price is perfectly correlated with the asset underlying the real option. Real options, however, can have risks that are not priced or spanned in the financial markets. These risks that cannot be represented by the price of a traded security are known as private risks.

Incomplete markets can be found in all real asset markets, and even in financial markets. Incomplete markets are likely to remain in regards to a specific risk if the costs exceed the benefits of creating the securities required to span a specific risk, or if there are problems associated with making such securities legitimate. Other market imperfections include intermittent trading, sporadic price discovery and a lack of liquidity. Robert Merton (1998) presented a framework in his 1997 Nobel Prize lecture for determining the value and risk of a non-traded asset by using a portfolio of traded securities. Two aspects can be drawn from Merton's address. The first is that it is probable that some kind of tracking of the risks in a corporate investment can be established through a portfolio of traded securities, in spite of market imperfections. The second is the rigorous definition Merton offers of private risk. Merton defines and measures private risk as the size of the tracking error between the portfolio of traded securities and the value of the underlying asset. Private risk can therefore be identified through the data rather than through subjective breakdowns of market and private risks.

Other techniques that can be used when spanning does not hold are decision analysis and dynamic programming. Decision analysis is a structured quantitative approach for the evaluation of decisions that have complex alternatives, competing objectives and major sources of uncertainty. The origins of decision analysis began at Harvard Business School in the early 1960s as a continuation of the quantitative

advances in operations research and management science. Decision analysis combines systems analysis, which considers the interactions and dynamic behavior of complex situations, and statistical decision theory, which focuses on logic in simple uncertain situations. Merging these two concepts into decision analysis provided a focus on logic in complex dynamic and uncertain situations.

Real options and decision analysis both have the common goal of modeling the decisions and uncertainties associated with investments. Where there is a distinction between the real options and decision analysis method is in the definition of valuing risky cash flows. Valuation in decision analysis is derived from the values and preferences of an individual or organization, whereas valuation in real options is derived from prices in traded markets. As value in real options is based on markets, risk-neutral probabilities and risk free discount rates, the utility functions and risk adjustments to discount rates as used in decision analysis are unnecessary.

The holder of a financial option has an exclusive right over exercising that option. The same, however, is not always the case in real options. Some real options will be exclusive or proprietary, and therefore the holder of the real option will have sole exercise rights without the threat of competitors. Other investment opportunities, however, will have shared real options and may also be available to competitors or other potential participants. Other possible situations are where shared real options have no value as they collectively belong to a whole industry, or where they are a public good.

In options markets the best strategy for the holder of a non-dividend paying American call option on a stock is typically to delay the exercise until the option maturity. There is no benefit or opportunity cost associated with waiting to exercise the option, and therefore the holder of the call option would rationally wait as long as possible before exercising that option. If a stock does pay a dividend, however, its value will typically fall after the dividend payout, and so reduce the payoff for a dividend paying American call option if it is exercised immediately after the dividend payout.

There is therefore an associated opportunity cost in waiting to exercise if a stock option does pay a dividend, in which case early exercise would be a better strategy. In a similar sense if there were no opportunity costs associated with delaying an investment, the holder of a real option would wait until its maturity before exercising. In circumstances where competitors can enter a market however, the real option holder would forgo any potential value from waiting to exercise so as

to pre-empt competitors. Competitors entering a market can reduce the value of the cash flows from an investment made in that market, and therefore the value of any investment opportunities.

While there are many issues associated with identifying and valuing real options, in the final analysis the critical issue is to be able to think in terms of real options. Projects and investments can be conceptualized as portfolios of assets that have opportunities, option portfolios that can be managed dynamically as the future unfolds, uncertainty is resolved and new information becomes available. Real options analysis draws on a range of techniques that include market values, quantitative methods, and also qualitative assessment. Even if objective market based valuations are not always obtainable, a qualitative interpretation of real options is essential, as a real options framework provides management with a structure for decisions that have to be made in any case.

2.4.6 Types of real options

Real options can exist in almost every business decision, although they are not always easily identified. Many types of real options have been recognized and analyzed (Dixit and Pindyck, 1994; Trigeorgis, 1996), and the following is a summary of common categories:

Option to defer: The opportunity to invest can be more valuable than investing immediately, as it provides management with the flexibility to defer the investment until conditions become more favorable, or to cancel completely if they become unsatisfactory. The opportunity to defer is the equivalent to a call option on the value of a project. These investment opportunities can still be beneficial even though the investment may have a negative NPV.

Option to expand or contract: Options can exist in projects and operations to expand, to contract, and to shut down and restart. Management can expand production or increase resource deployment if the market environment develops more favorably than expected. This is the equivalent to a call option. On the other hand, operational scale can be reduced if market developments are less than initial expectations, which is the equivalent to a put option. The option to expand is specified as:

$$Payoff = \max\left[S_t - K, (1+x)\,S_t - K^*\right]$$

the option to contract is specified as:

$$Payoff = \max\left[S_t - K, \left(1+y\right)S_t - K^*\right]$$

and the option to temporarily shut down is specified as:

(a) temporarily shut down operations:

$$Payoff = \max(S_t - VC, C)$$

(b) restart temporarily closed operations:

$$Payoff = \max(0, S_t - VC)$$

where:

S_t = initial underlying value

K = investment cost at t

K^* = K plus the increase (expand) or decrease (contract) in the investment cost at t

x = the percentage increase in firm value

y = reduction in firm value

S = the project value

VC = variable costs

C = cash payout

Option to abandon: Management can abandon an operation if market conditions deteriorate and liquidate any capital and other assets. The option to abandon is the equivalent to a put option. If the value of the asset or project falls below its liquidation value, the owners or holder of the option can exercise the put.

Option to switch: Management can change a project or an operation by restarting an operation that has been shut down, the equivalent to a call option, or shut the operation down, the equivalent to a put option. The cost of starting up or shutting down is the equivalent to the strike of the call or put. The option to switch is specified as:

$$Payoff = (S_1 - S_2 - CS, 0)$$

where:

S_1 = the NPV of the current operating mode one

S_2 = the NPV of the current operating mode two

CS = the cost of switching from the first to the second mode

Growth options: Investments such as research and development, undeveloped land, oil and gas reserves and acquisitions and information networks connect a chain of interrelated projects and can create future growth opportunities such as new products or processes and new markets.

Compound options: Projects frequently involve a collection of options, with combinations of upside value and downside protection options present. The combined value of interacting options can differ from the sum of the separate parts due to their interaction. Some real options are relatively simple as their value, if exercised, is limited to the value of the underlying project. Other real options, however, can lead to further investment opportunities when exercised. These are *options on options, or compound options*, where the option payoff is another option.

Rainbow options: Rainbow options are options that have multiple sources of uncertainty. Options that have payoffs that depend on two or more assets are usually called rainbow options. In the financial world rainbow options can refer to the maximum or minimum of two or more assets, or other options, for example, where the payoff depends on the spread between two assets, the better of two assets and cash, portfolio options and dual strike options. In the case of real options numerous sources of uncertainty can exist in forms such as prices, quantities, technologies, regulation and interest rates.

2.5 Firm value

2.5.1 Overview

Corporate finance has the objective of optimizing firm value while minimizing the associated risks. This encompasses the management of real assets that create firm value, minimizing the costs associated with the financing of these investments, and maintaining the firm's working capital.

Corporate finance is also framed within short- and long-term domains. The short-term domain focuses on a firm's working capital, defined as the net of current assets and current liabilities, and includes cash management, inventory and short-term lending and borrowing. The goal of working capital management is to optimize a firm's liquid assets. The long-term domain focuses on the capital investment decisions that involve a firm's fixed assets and capital structure. These decisions involve capital expenditure, the balance sheet debt and equity financing choices and dividend decisions. Capital investment

decisions consist of an investment, a financing, and a dividend decision and are usually framed with the goal of maximizing firm value by investing in projects with a positive NPV.

Firm value is equivalent to the firm's total capitalization, which is equivalent to the market value aggregate of the firm's equity, bonds and any other claims, or the present value of all the claims on the firm. The value of the firm is therefore the present value of all free cash flows created from the firm's business model that are available to claimants on the firm. The concepts behind the analysis of real asset investments are equivalent for either the value for specific projects, or the firm itself, as the firm represents a collection of projects.

Capital structure is defined as the way in which a firm finances its balance sheet through the weighting of equity, debt and other security types. A firm's leverage is the ratio of firm debt to total financing. The goal of defining a firm's capital structure is to finance the assets to maximize firm value.

2.5.2 Theories of firm value

Initial theories of firm value were proposed by Miller and Modigliani, who examined the associations between a firm's operations in the real economy and its financing decisions in the financial economy. Miller and Modigliani showed that under an assumption of no taxes firm value is the same regardless of whether it is financed through equity or debt. The only impact that the type of financing made was on the distribution of a firm's value between its investor types.

Miller and Modigliani also suggested that establishing firm value enabled the valuation of the firm's stock, bonds and other claims on the firm. A firm is represented by the present value of the firm's free cash flows discounted at a risk adjusted interest rate, with the assumption that financing, the ratio of equity and debt, had no influence on the firm's operating cash flows and therefore on firm value. Once the value of the firm is established the market value of debt is deducted to arrive at the firm's capitalization.

A firm's capital structure defines the manner in which it finances its assets or structures its liabilities that include equity, debt and other claims. The Miller and Modigliani theory provides a foundation for the analysis of capital structure. Using the assumptions of perfect markets, no taxes, a universal borrowing interest rate, no bankruptcy or transaction costs and financing decisions not affecting investments, Modigliani and Miller drew two conclusions on capital structure. The first, defined as their first proposition, was that a firm's value is not

influenced by capital structure. Their second proposition was that a leveraged firm's cost of equity is the same as that of a firm with no leverage. Miller and Modigliani later revised some of the assumptions, in particular taxes.

The Modigliani–Miller theory provides a framework to examine how a firm's value is influenced by capital structure decisions and to determine optimal capital structures. The Modigliani–Miller representation is defined as the primitive firm, for which its value is represented by the sum of the expected free cash flows discounted by the weighted average cost of capital. The primitive firm represents the DCF model of the firm and provides a foundation for the analysis of a firm's financial structure through the financial options on the primitive firm.

Black, Scholes and Merton were the first to formalize the association between a firm's equity and debt. The insight from these researchers is that equity can be defined as an option on a firm's assets, with the value of debt being equivalent to the residual of the value of assets over the value of equity. The Black and Scholes theory of the firm considered equity as a call option with a strike equaling the notional value of zero coupon debt on the value of the primitive firm. Merton also considered equity as an option on a firm's assets to define the firm's debt value and credit risk. The model developed by Merton uses the value and volatility of the firm's assets and the notional value of debt.

Geske extended the Black and Scholes model by specifying the stock itself underlying a call option as an option of the firm's assets, or the equivalent to a compound option. Whereas the Black and Scholes model assumes that the volatility of a stock price is constant, the Geske model recognizes that volatility is not constant. The compound option model identifies volatility as a function of the level of the firm's stock price, or more fundamentally on firm value. To achieve this, the Geske model adds an additional variable, the firm's notional debt, to the Black and Scholes model, as it is financial leverage that influences the volatility or risk of a firm's equity.

The next development in defining firm value focused on the firm's actual underlying assets. Myers proposed that a firm's investments could be represented as options. Firm value had been defined as the primitive model, or a pool of projects that represents the present value of free cash flows. Investing in product markets can, however, produce cash flows from an initial investment and also value from growth options if a product market continues to expand. A firm's initial investments therefore provide a base for a sequence of potential follow-on investment decisions.

The identification of this time series of investments is an extension of the primitive firm, and these discretionary future investments were defined by Myers as real options, or options on real assets. Real options identify the investment decisions within a firm as a right without an obligation, or as state contingent decisions on real assets. A firm has the choice in the future whether or not to exercise the option on follow-on investments.

2.5.3 Developments in the theories of firm value

2.5.3.1 Overview

The theories of the primitive firm, financial options and real options can be combined to provide a framework for firm value that provides the flexibility required by a firm to adapt to its external environment. Copeland defines the combination as a 'three layer cake', with the primitive firm as the foundation, real options consisting of a portfolio of growth options and a firm abandonment option, and a portfolio of financial options. The three-layer framework identifies the relationships between a firm's real and financial options. A firm has both an optimal real options investment structure and an optimal capital structure, and there is a trade-off between the two. Therefore the firm's operating and financial decisions are not unrelated as per the Modigliani and Miller theory.

The following illustrates the components of the three layers which, when combined, offer a framework to manage firm value in an increasingly dynamic environment where operating and financial flexibility is critical.

2.5.3.2 Primitive firm valuation

The primitive firm is defined as an underlying security that represents the firm's business risks. The firm's value, market capitalization, debt and other claims are defined as contingent claims on this underlying security, the primitive firm itself. The valuation of the underlying security is represented by the expected free cash flows to the firm, $E(FCF_t)$ discounted at the cost of capital w with the assumption that systematic risk is the only risk factor. It is also assumed that the firm has no debt or other claims and is financed only with equity, and that the firm pays no taxes to segregate the tax issues from business risks. The value of the primitive firm V therefore is equal to V_0, the expected present value at $t = 0$ (see Copeland, 2007):

$$E(V_t) = \sum_{t=1}^{N} \frac{E(FCF_{i+1})}{(1+w)^{i-t}} \qquad t = 0, 1, \ldots . N. \tag{2.2}$$

The underlying assumptions for the primitive firm are naive, as firms will delay investments until uncertainty is reduced or divest. These investment alternatives can be reduced to growth and expansion, defined as a European call option, or abandonment, or the equivalent to an American put option.

The DCF examples in the Chapter 5 case studies illustrate the primitive firm concept.

2.5.3.3 Growth options

Given that it is possible to define the notion of a capital structure, it is also possible to define a firm's investment structure that includes its real options portfolio. This investment structure can be optimized to provide a firm the flexibility to adapt to its environment and includes growth options, an abandonment option, and a trade-off between scale and modularity.

The discretion a firm has on exercising its future investment opportunities is identified as call options on real assets. These options are growth options, and can be defined as a sequence of growth opportunities embedded in a firm's investments that have an impact on a firm's value.

Refer to the case study in Section 5.4 for an illustration of growth options.

2.5.3.4 Modularity

A firm's operational capacity is also a fundamental component of its investment structure. The firm has the option to expand capacity to meet increased demand, or not to expand if it has excess capacity. A firm's operating leverage is defined as the ratio of its fixed to variable costs. A high operating leverage is associated with less flexibility to adapt to change. Flexibility is therefore a function of a firm's operating leverage, and the capability to invest in modules has an impact on the firm's operating leverage.

The term modularity is defined as a specific design structure where within each unit or module the parameters and tasks are mutually dependent, whereas across each module they are independent. Modularity is a concept that can define a firm's operating leverage, or the degree to which the firm lacks flexibility due to its fixed costs. A firm's excess capacity is the variation between the firm's output capacity and expected output. The trade-off between modularity and economies of scale has an impact on a firm's excess capacity, and therefore its

investment and capital structure. Firm value can be optimized through its investments in growth, abandonment and also modularity.

Refer to Appendix (Modularity) for an overview on modularity.

2.5.3.5 The abandonment option

A firm has value in the decision to discontinue operations and liquidate the firm's assets. This liquidation value is the equivalent to an option to abandon the firm to the firm's investors, with the exit value equal to the firm's total collateral or the total cash proceeds from liquidation. This option is an American put option, with the value of the option increasing as the value of the firm's total collateral or exit value increases.

Refer to the case study in Section 5.5 for an illustration of the abandonment option.

2.5.3.6 Financial options

A firm's capital structure is defined by the financial options on the primitive firm as in the theories of Merton, Black and Scholes and Geske. The only decision variable in this case is the firm's debt policy, a choice that does not have an effect on primitive firm value. Under these assumptions the same value will be generated by a marginal investment no matter what debt policy is selected.

2.6 Optimizing the firm structure

An optimal firm structure that provides the flexibility and capabilities to adapt to its external environment consists of the primitive firm, an optimal investment structure, modularity, and an optimal capital structure. The optimal investment structure includes the real options in the European call option growth portfolio and the American put option to abandon the firm. A firm therefore has three layers that consist of the primitive firm, the real options portfolio and a capital structure consisting of debt and equity that is represented by financial options.

The variables of interest in an investment policy are:

- Capital structure, which is influenced by the trade-off between a firm's real options portfolio and debt ratio, and the tax benefits of leverage on equity. Copland presents a model for an optimal capital structure using the variables described here.

- Modularity, which can have a function in establishing a firm's investment structure. Flexibility in a firm's capacity provides the ability to adapt to changing markets and industries.
- Volatility, which creates value in real options along with a firm's ability to exercise these options. Volatility and flexibility also influence a firm's level of cash.

The variables of interest in an optimal financial structure are:

- The abandonment or collateral value, which has a positive relationship with firm value.
- A firm's debt policy, or leverage, which has an influence on growth and abandonment.
- Taxes, which will raise the value of the firm's equity if the balance sheet has debt due to tax benefits. This upside will, however, start to roll off or fall beyond a leverage threshold and ultimately goes to zero if the firm is abandoned.
- Cash and cash management, which are related to flexibility. Firms with large cash reserves are able to react quickly to market and industry conditions and exercise real options when compared to firms with higher debt ratios and external funding requirements. Growth through expansion and abandonment are both influenced by the level of a firm's debt, or its leverage.
- Volatility, which also has an influence on the firm's financial option values. Increases in volatility will influence the firm's debt costs and therefore the firm's capital structure.

A firm's investment and capital structure is ultimately a function of the industry in which it operates, its external environment and the firm's strategy. The interactions between a firm's investment structure, modularity versus economies of scale and capital structure create trade-offs in framing the firm's structure. Leverage will have an impact on the firm's equity when viewed as a call option on the firm's assets, and therefore its growth and abandonment options. The use of tax to optimize a firm's capital structure will influence the flexibility of its operations. A firm's overall structure should therefore consider a range of variables and trade-offs when defining its capabilities to adapt to its environment.

Appendix – modularity

The waves of innovation since the start of the industrial evolution have created an economic system that is increasingly sophisticated and complex. This economic system consists of objects that result from human intelligence and endeavors. These objects, or artifacts, include physical activities such as technologies and products, and intangible objects such as systems of law, organizations, strategies, science and designs.

Artifacts develop and evolve over time, as do the firms and markets that create and support these objects. These markets, technologies, products and firms evolve interactively to produce adaptive complex systems that ultimately become industries. An artifact is described by its design, and this designing of artifacts is a continuing process that accumulates at all levels to transform industries and economies.

Modularity is a theory of complex adaptive systems, design and industrial evolution that describes the creation of complex products and processes from smaller subsystems or modules that, although are independent in their design, nonetheless function together as a complete system. The modularity concept facilitates the management of complex systems by dividing them into smaller more manageable components. This is achieved by creating a particular design structure with a set of design principles that separate the knowledge and tasks required for complex designs and artifacts.

The modularity concept has numerous applications, which include production scale and scope, mass customization and organizational theory. An example can be found in computers, an artifact that has grown in complexity over the 20th century. In the 1970s the computer business evolved from a highly concentrated industry to modular clusters which manufactured components of larger computers systems. New designs created the opportunity for the emergence of new firms, which focused on manufacturing specialized components, or modules, that were linked by design rules for the creation of computer systems.

At the start of a modular design process mandatory design rules are established for all stages of design and production. These design rules allow pieces of a modular system to be changed without the need to change the system as a whole. This capability creates the flexibility for design to evolve at the module level, and therefore creates options for designers. These options provide opportunities for innovation and capabilities for firms to complete in today's environment.

At the start of the 21st century the dynamics of global commerce continue to accelerate. The new technologies, markets, products and competitors that emerge from this process present both risk and rewards. In this context modularity can address three issues: it increases the ability to manage complexity; it facilitates various components of a design to be worked on simultaneously; and it accommodates uncertainty. Modularity offers therefore the capabilities to manage the complexities and uncertainties in this environment and provide a framework for creating value, growth and innovation.

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3
Risk

3.1 Investment risk

Corporate management will typically develop strategies and allocate resources to increase shareholder value. Shareholders on the other hand will focus on the cash growth of their investments. As to whether there is value in any potential cash flow growth will depend on the risks associated with these investments. Investors will generally demand a higher rate of return from investments that are perceived to be relatively riskier. Corporate decisions are made in environments that are inherently risky and uncertain. The risks associated with corporate investments are found in variables such as prices, quantities, costs, competition, market share and project life cycles. These variables can be unpredictable and result in cash flow volatility, which will therefore have an impact on any NPV calculations.

The risk appetite of investors should therefore be included in investment analysis. As a result the cash flows used in NPV estimates are modified by a discount rate that reflects both the time value of money and any related cash flow risks. Risk is therefore represented in the discount rate determined from the risk appetites of investors and the financial markets. The hurdle rate is the discount rate that is the minimum acceptable rate of return that a firm will accept for a project. A number of methods have been developed to determine the discount rate used in NPV calculations. These include the Capital Asset Pricing Model (CAPM) and Risk-Adjusted Discount approach.

The foundations of quantifying risk can be found in Markowitz (1959), regarded as the origin of modern portfolio theory. Markowitz's solution was to assume that a portfolio could be structured as a function of the mean and the standard deviation of the portfolio return. His conclusions from this construct were that the risk of the portfolio would generally be less than the weighted average of the separate

asset risks, and the lower the correlations between the component asset returns the lower the portfolio risk (the diversification principle). Each asset's risk therefore consists of two components: the diversifiable risk, which will disappear through the right combination of assets, and the non-diversifiable risk, which will always be carried by investors. The portfolio selection problem can therefore be defined as consisting of maximizing the return while minimizing the risk.

Sharpe, Linter and Mossin extended Markowitz's portfolio theory with the assumption of homogeneous expectations, where all investors concur on expected returns, standard deviations and correlations and therefore choose the same portfolio. This concept led to the Capital Asset Pricing Model. The Capital Asset Pricing Model is a general model for formulizing an asset's risk and return. The variance of the return is defined as the risk measure, with only the non-diversifiable, or systematic component of the variance being rewarded. The relevant risk in pricing an asset is that part of an asset's risk, or variance of the assets return, that is correlated with the overall risk of a market, and not the overall risk of the of the asset. An asset's beta coefficient measures its systematic risk.

The CAPM model can be used to illustrate the businesses in which a firm should have operations. Diversifying a corporation over a portfolio of independent businesses decreases the variance of the combined cash flows if the cash flows of the various businesses are not completely correlated. Reducing risk would therefore be consistent from the perspective of shareholders as they are typically adverse to risk.

Shareholders, however, can reduce risk by maintaining diversified portfolios themselves. Individual shareholders can accomplish a broader diversification, typically at lower transaction costs, than that offered by the majority of firms diversifying through mergers and acquisitions. Creating shareholder value through diversification requires the existence of market imperfections that firms can exploit more efficiently than investors. As a firm can be described as a portfolio of assets and projects, the value of a new project would be conditional on the total risk of the firm, in which case NPVs would not be additive. If, however, a project's risks are not correlated to existing assets or projects, NPVs will generally then be additive.

As the value of a firm can be considered the value of all the firm's assets, the firm can therefore also be viewed as the value of all sources of financing. The weighted average cost of capital is a discount rate that represents the costs of the various sources of finance, which can consist of a firm's equity, debt and any hybrid securities. The cost of

equity can be derived using a CAPM model, the cost of debt from interest rates and bond ratings, and the cost of hybrid securities through the characteristics of each of their components. The weighted cost of capital can be used in project analysis decisions to determine which project NPVs do not change a firm's business risk, and also provide a hurdle rate for projects.

The objective of the risk-adjusted discount rate (RADR) method is to maximize a firm's market value by using discount rates from investments that have the similar risk characteristics as the investment projects under analysis. The NPV derived by discounting future cash flows at the RADR therefore reflects the opportunity cost of capital, or the rate of return required by the firm or investors for similar investments. The RADR includes the time value of money, the risk free rate and the discount risk premium. Conventional projects that have similar risk characteristics as existing businesses should not influence the aggregate risk of a firm and would therefore be discounted at the opportunity cost of capital. The discount risk premium is adjusted upwards for projects with above average risk, and down for projects with below average risk. The return of an investment project can also be compared to a hurdle rate to determine whether the project should proceed.

3.2 Why manage risk

Risk can be viewed as either a threat or an opportunity. Value is not created without risk, and innovation without risk is a contradiction. Attempting to entirely eliminate risk is not a practical exercise because of the associated costs, and so there has to be a trade-off between any benefits from reducing risk and the costs of doing so. Business risks are those that an organization willingly assumes to create a competitive advantage and add value. The motivation for organizations to better understand and measure risk is being driven by:

- The increasing awareness that earnings volatility can significantly affect stock price valuation and shareholder value.
- The increasing size and types of interrelated risk exposures organizations are facing due to the globalization of markets and the increase in international trade.
- Organizational requirements for improved exposure and risk related information to define management's risk appetite and improve decision-making.

Business risk management is a process where risk exposures are identified, measured, and managed where possible within the context of corporate finance and strategy, and is essentially a core competency of all business activity. The focus in risk management is moving from individual price exposures to the management of an organization's exposure as a portfolio of interrelated risks. An effective risk management framework can address issues such as:

- organizations requiring more transparent risk management methods to manage the external factors that can influence performance;
- risk management practices being increasingly scrutinized by analysts, investors and rating agencies;
- evaluating the potential impact of adverse market movements on a firm's capital;
- defining risk and return targets for businesses and projects;
- the use of risk adjusted measures to influence management decisions; and
- whether the rewards are adequate for a given level of performance.

3.3 Defining and measuring risk

Before defining, identifying and quantifying risk it is important to distinguish between definitions and measures of risk. Defining risk under the concept of diversifiable risk, non-diversifiable risk and the CAPM has been discussed above. Event definitions of risk differentiate risk types by the nature of the event that can cause a loss. Market risk is defined within an event risk framework as the changes in prices of assets, liabilities or financial variables that impact on cash flows. Risk factors are any market price, value or index that can have an influence on cash flows.

Financial theory defines risk as a dispersion of unexpected outcomes due to movements in market values or risk factors. Both positive and negative deviations are viewed as sources of risk. Changes can be expressed as either absolute or relative returns, and probabilities can be derived for the distributions of these returns. Risk can therefore be evaluated and measured in a probability context, where risk is conceptualized as the probability that an event will occur rather than in terms of the consequences of that event. Measures of risk can now be defined as the volatility of unexpected outcomes, such as the variance or volatility of an asset's returns.

Two risk measures, value at risk (VAR) and cash flow at risk (CFAR), are based on volatility. These measures of market risk use probabilities to interpret risk exposures as a potential loss. VAR summarizes the expected maximum loss over a target horizon within some confidence interval. However VAR is not always a suitable risk measure for many organizations, as it focuses on the potential loss in the market value of assets and liabilities over a short horizon. Many organizations have physical assets, brand names, and intangible assets such as capitalized research and development, for which market or liquidation values are only relevant for a small portion of the balance sheet. In these situations an alternative risk measure is CFAR, where an aggregate risk exposure is derived from the variability of projected cash inflows and outflows over a multi-year planning horizon.

3.4 The risk drivers

A number of factors, or risk drivers, that account for the volatility in value can generally be identified and analyzed within a framework:

- Financial risk: Financial risks are generally identified and classified as:
  - Market risk: the changes in prices of financial assets and liabilities.
  - Basis risk: the price difference between the forward and spot price, or the potential for loss resulting from a hedge and the instrument being hedged not being perfectly matched (correlation risk); and includes:
    - Spread risk: the risk relative to a particular group of securities.
    - Curve (or shape) risk: the changes in the shape of yield and forward curves.
  - Volatility risk: the sensitivity with respect to the volatility of securities (typical of options).
  - Currency risk: relates to adverse changes in currency rates.
  - Credit risk: the possible changes in credit ratings, outright defaults, or counterparties unwilling or unable to fulfill their contractual obligations.
  - Liquidity risk: liquidity risk has two forms; when a transaction cannot be conducted at prevailing market prices due to insufficient market activity; and the inability to meet cash obligations.

- Commodity risk: occurs when an organization is affected by fluctuations in the price of some commodity. A wide range of physical assets are considered as commodities:
  - Metals, such as gold and copper.
  - Agricultural products, such as wheat, timber, and wool.
  - Energy products, such as oil and gas.

  Commodities and energies are increasingly traded like financial instruments. The underlying price drivers, however, are fundamentally different from money markets. The dynamics of production and use, transport and storage, buying and selling, and advances in technology all add to the complexity of energy and commodity markets. Deregulation and innovation have created some additions to the commodity markets:
  - Deregulation is changing electricity markets from state-based monopolies to wholesale trading markets.
  - A limitation on carbon dioxide and other greenhouse gas emissions, one solution to global warming, is being promoted through the trading of emissions permits.
  - Weather is one of the biggest uncertainties facing many organizations, and the financial consequences can be substantial. Until recently there was no direct way of hedging a risk that can massively affect profits and costs. Weather derivatives are now available in financial markets.
- Legal risk: legal risk is the loss from an organization's activities judged to be outside the relevant legal and/or regulatory framework governing such activities and includes, but is not limited to, the enforceability of contracts. Legal risk includes disclosers, disclaimers, compliance and regulatory risks and can take the form of shareholder lawsuits against corporations that suffer large losses.
- Operational risk: the group of 30 defines operational risk as: 'the risk of losses occurring as a result of inadequate systems and control, human error, or management failure.' This definition includes fraud and regulatory risk. Disaster recovery, a contingency plan to cope with a disaster, is also included in operational risk.
- Strategic risk: corporate strategy is the pattern of decisions in a firm that determines and reveals its objectives, purposes or goals. Strategic planning processes include the identification of areas susceptible to changes within the firm's environment that can affect its future. Strategy includes identifying opportunities and threats in

the firm's environment and attaching some estimate of risk to the alternatives.

- Technology risk: technology can lower operating costs, increase profits and capture new markets. Technology risk occurs when the investments do not produce the anticipated cost savings in economies of scale (lower average costs of operations by expanding output), or scope (generate cost synergies through producing more than one output with the same inputs). Technology risk can result in major losses in competitive efficiency and can ultimately result in long-term failure.
- Product risk: production risk can take a number of forms. Products go through a life cycle, growing in sales, declining and eventually being replaced. The length of the product cycle is one risk faced by firms, while another is actual product failure.
- Political risk: political risks arise from actions taken by policy makers that can significantly influence the way an organization runs its business.

3.5 Value and risk

To continue to establish and maintain value in an increasingly competitive and dynamic environment, organizations will need to identify and manage sustainable competitive advantage. This requires the ability to select markets that match an organization's capabilities, and abandon markets where the organization is at a competitive disadvantage. In this environment value is created through the planning and management of an organization's strategic portfolio and its real options portfolio, where real options that have value are identified and exercised, and those do not are abandoned. An organization's capabilities will therefore include the ability to both manage and direct its strategic portfolio, and to effectively identify, value and manage its real options portfolio.

Strategy includes not only identifying opportunities but also attaching some estimate of risk to the alternatives. Financial risk can be defined within the dimensions of an organization's value, cash flows and/or earnings. An organization's value is a stock at a point in time, representing the discounted present value of all of the organization's future cash flows and option values of future opportunities. Cash flows and earnings are flows that occur over a period of time. Any one or

combination of risk factors can impact on value, and so what is at risk in an environment of discontinuity is the likelihood that organizations will be unable to sustain value creation.

VAR and CFAR focus on the risk of a potential loss in a portfolio of assets based on the volatility of those assets, whereas real options derive value from the volatility of the underlying real assets. Option-like exposures in an organization can be viewed as either sources of risk or sources of opportunity. A key distinguishing characteristic in the future will be found in those organizations with a risk management process that aims at value enhancement, where risk exposures are identified and managed in the context of strategy, investments and revenue optimization rather than just pure risk control. While an organization's real assets are a significant component of its risk profile, its real options can make a significant contribution to value. An organization can therefore enhance its capabilities by integrating real options analysis into its risk management as well as its corporate finance and strategic management processes.

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Part II

The Analysis of Performance and Investments

4
The Analysis of Performance

4.1 Valuation

Valuation is the process of determining the worth of an asset, liability or an entire firm, or an economic relationship derived from an underlying asset or liability. Valuation has an influence on investments, capital structures and dividend policies, and therefore on financial decisions. Valuation concepts are also used in the evaluation of business models and strategies, and in capital budgeting, financial reporting, merger and acquisitions, tax analysis and litigation.

One essential function of general management is to ensure that an appropriate performance measurement framework is in place for issues such as strategy analysis and capital allocation. It is also essential that general management understands how investment analysts translate management behavior into share prices. Management decisions based on valuation measures are made across such diverse areas as product development, finance, operations, restructuring, mergers and acquisitions and strategy. Different metrics, however, are used for these various valuations. Finance focuses on net present value (NPV) for capital budgeting and investments and return on equity (ROE) for performance evaluation, marketing focuses on increasing market share, operations on the payback period, while general management advocates earnings per share (EPS) for investor communications. As the various functions use a diverse range of valuation metrics, aligning strategy across an organization can be a complicated exercise.

Most corporate managers continue to support an accounting perspective of a company, with earnings per share being the main determinant of share prices. The goal of good corporate governance is therefore to maximize reported EPS. There is, however, a growing recognition that accounting metrics can give a distorted view of corporate value. Accounting metrics are essentially short term in nature,

and they are influenced by the interpretation of different standards for issues such as assets, liabilities, investments, research and development and taxation. Another problem is that accounting measures do not explicitly include a charge for the capital used by a business and fail to describe the relative risk of an investment.

Shareholder value is created only when the return on capital exceeds the cost of capital. Value is therefore primarily determined by economic, and not accounting, cash flows. Accounting metrics such as EPS and ROE focus on a company's previous performance, whereas economic value is concerned with maximizing future cash flows over time. There are a number of valid approaches for quantifying corporate value, and all are based on some form of the discount cash flow model. Economic profit and net present value are also closely linked, as the NPV is the present value of economic profit. The major difference is that economic value methods typically begin with accounting income as opposed to the net cash flows of NPV.

The shareholder value premise is that companies should be managed to maximize the worth of the owner's, that is, the shareholders, stake in the company. To maximize shareholder wealth, management creates, evaluates and selects strategies that will increase the value of the company. The same principles used in the DCF method for valuing individual projects to companies can also be applied to strategy analysis. Maximizing shareholder value is consistent with maximizing the NPV in the analysis of investments, projects, organizational units and the firm generally. Different strategies are compared, and the strategy that results in the highest NPV is the one selected.

Managements' mandate is therefore to maximize shareholder value by accepting all investments with a positive NPV, based on a discount rate that reflects the return available from equivalent investment opportunities. A firm would select the portfolio of proposed investments that have a positive NPV and reject those with a negative NPV. This is consistent with the premise of maximizing shareholder value, and also provides a focus on the management of a firm's capital. The value of a company is now defined as a function of the discounted future cash flows it is expected to generate for shareholders. As present values are additive, the value of the firm should equal the sum of the present values of all its subsidiaries, businesses and projects. The firm can therefore be thought of as a portfolio of projects or assets.

DCF strategy analysis does have some limitations despite the advantages. Accurate cash flows forecasts are required, and incorrect estimates of future returns from an investment can easily invalidate the

whole approach. Another limitation is the implied assumption that all investment proposals are independent. The independence assumption ignores the numerous interrelationships that typically exist across businesses and investments. Finally another problem is that the valuation of many long-dated assets is very difficult.

4.1.1 Firm valuation

Firm value typically has five interpretations:

- Book value – or net asset value, is an asset's value on a firm's balance sheet, recorded at the original cost minus any depreciation, amortization or impairments. By convention a firm's book value is derived as total assets less intangible assets and liabilities, although book value can also include goodwill and intangible assets.
- Break-up value – is the total of the business segment values of a firm.
- Economic value – represents the ongoing value of a firm, with value defined as the expected future cash flows generated by a firm that flow to its owners over its economic life.
- Liquidation value – is the value of a firm's assets when it goes out of business, or the current liquidation value for a firm or its parts. In some cases, book value may not be realized if a firm's inventory is exposed to obsolescence.
- Market value – is either a firm's market capitalization or its enterprise value.

Enterprise value is derived as the sum of a firm's market capitalization, market value of debt, minority interests and preferred shares, less total cash and cash equivalents. If strategy is defined in terms of maximizing firm value with the focus being profitability, then the goal becomes maximizing a firm's enterprise value.

As enterprise value is a capital structure neutral concept it provides a measure for the comparison of firms with diverse capital structures. Enterprise or unlevered price-to-book ratios and price-earnings (P/E) ratios also allow a focus on operations instead of the more typical levered ratios. Levered ratios such as price/earnings ratios, for example, are considerably more volatile in highly leveraged firms. Enterprise value is therefore able to neutralize a variety of risks and costs associated with various capital structures.

4.1.2 Asset valuation

The value of a firm as a going concern lies in its income stream, with its assets the resource that generates this value. The rise of the knowledge

economy has increased attention on the recognition and valuation of intangible assets on corporate balance sheets. Balance sheets explicitly exclude significant assets such as brands, distribution and supply chains, and knowledge, organization and human capital. This issue is especially relevant when firm value is derived more from intangible assets rather than tangible assets. The majority of intangible assets on balance sheets cannot be identified and independently valued from other assets, as their value is derived from the cash flow streams generated with other assets. Knowledge capital is used in processes, marketing and management; it does not exist without tangible assets, while value from organizational capital is derived from its combination with other assets. As such the firm itself is the asset, or an organization of assets that underlies a business plan to create value.

Asset values can, however, be determined from the income statement in addition to a balance sheet. The articulation of the income statement and balance sheet can reveal firm value, with each statement correcting for the shortcomings of the other. In the case of intangible assets an income statement or flow valuation is available when a balance sheet or stock valuation cannot be determined. Although intangible assets are absent from the balance sheet, the earnings from intangible assets still flow through the income statement. As such value can be determined by either measuring the asset value directly or through the capitalization of the earnings from that asset itself. Although a balance sheet does not provide a summary amount for the value of assets used in combination, the income statement in principle does so. Earnings measure the value added from tangible assets in conjunction with entrepreneurship, knowledge, organizational capital and brands. Identifying the intangible assets on a balance sheet therefore is not required, as the earnings generated by the business plan provide a summary measure of value.

Intangible assets when compared to tangible assets not only have no physical identity, they also cannot be identified for contacts to be written against them for delivery. Legal rights such as patents and copyrights and in some cases brands are exceptions, however. As firms move to more open models of innovation and external sources of knowledge, the management of intellectual property rights (IPR) has become a significant issue. Examples of IPRs that can be licensed include patents, copyrights and trademarks; however, patent licenses are the most frequent in technology exchanges. The increasing reliance on external sources of innovation means that it is essential to have consistent measurements of what is being traded.

Patent licenses bestow a licensee or technology buyer the use of rights in exchange for fees or royalties that flow to a licensor or the technology holder. The structure of patent licenses from the licensee's standpoint can be framed as an option. A licensee pays an initial fee or premium to buy an option when entering into a licensing contract for the rights or option to develop and commercialize a technology covered by the patent. The technology holder also has two options embedded in a patent: the option to use it exclusively or to license it to other parties. From the viewpoint of the technology buyer the option offers the flexibility as to whether to use the patent in both a technology's commercialization and its timing.

4.1.3 Debt valuation

The book value of debt is not a sufficient proxy for the market value of debt in deriving a firm's enterprise value. The market value of a firm's debt can, however, be implied from stock option prices. Geske (2009) implies the market value of a firm's debt from two simultaneous liquid at-the-money option prices that also accounts for a firm's capital structure. A firm's stock return volatility is a function of its stock price level which in itself is a function of the firm's value and is not assumed to be constant as in the Black and Scholes model. A firm's leverage ratio increases as the value of its stock declines, and therefore the equity's risk and consequently its volatility increase. Geske's approach therefore considers bankruptcy effects and includes Modigliani and Miller theorems.

4.1.4 Equity valuation

Equity is the residual claim on firm value after all other claims. A multiple is the ratio of the market price of a firm's stock to some accounting measure per share that is used as an estimate of relative value. A price multiple summarizes the relationship between a firm's stock price and a measure such as earnings, book value or sales per share.

The price-earnings ratio compares the current stock price with earnings and anchors a valuation to an income statement. The ratio is interpreted as:

- the price or numerator reflecting future earnings, or the market's expectations of value added from future sales, and
- earnings, the denominator, reflecting current earnings, or the value added from current sales.

The P/E ratio therefore evaluates the forecast of future earnings in relation to current earnings. Higher future earnings expectations relative to current earnings should result in a higher P/E ratio, while lower future earnings expectations relative to current earnings should result in a lower P/E. The P/E ratio is therefore an indication of anticipated earnings growth.

The price-to-book ratio, or P/B ratio, compares a firm's book value to its current market price. The P/B is derived in one of two ways:

- The ratio of the firm's market capitalization over the firm's total shareholder equity, or
- a per-share value, the ratio of the firm's current share price over its book value per share, or the ratio of the price per share over the net assets per share.

By convention book value does not include intangible assets.

A firm's book value represents the shareholders' investment in the firm, with the value derived on the expectations of how much the net assets will earn in the future. Book value can either increase or decrease, depending on the firm's future earnings expectations. While book value does not accurately determine value, the missing component is ultimately realized in the future earnings created by book value.

The stock price in the P/B ratio's numerator is based on expected future earnings. Therefore the higher expected earnings are in relation to book value the higher the P/B ratio. The book value rate of return, or profitability, is a measure that principally determines P/B ratios. The market price to book value ratio is the price-to-book ratio or the market-to-book ratio, while the intrinsic value to book value ratio is the intrinsic price-to-book ratio.

Equity can also be analyzed by breaking out a firm's market stock price into building blocks that identify the market's valuation:

- the book value,
- the value from short-term earnings, and
- the value the market places on subsequent speculative growth.

4.2 Residual earnings

Residual earnings (RE) is net income minus a deduction that represents the common shareholder's opportunity cost in generating net income. For each earnings period residual earnings is derived as:

$$\text{RE} = (\text{ROCE} - \text{required return on equity}) \times \text{book value of common equity}$$

where ROCE equals $\text{earnings}_t/\text{B}_{t-1}$ and is the rate of return on common equity. Two value drivers therefore determine residual earnings: the ROCE and the book value B_{t-1} for each period.

Firm value is generated over book value by increasing the ROCE spread over its cost of capital. Value is additionally increased by the growth in book value, or net assets, which earn at the firm's ROCE. A value strategy can therefore be framed as increasing firm value through investments and strategies that increase ROCE over the required return and grow book value or net assets.

4.3 Free cash flows

A firm and its equity can also be valued by discounting the free cash flow to the firm (FCFF) and the free cash flow to equity (FCFE). Free cash flow to the firm measures the net cash generated by a firm, while the free cash flow to equity measures the cash distributed to the firm's equity shareholders after all reinvestments, debt repayments and expenses: Both measures can be derived from the financial statements, from either the income statement or the statement of cash flows.

In the case of the income statement:

$$\text{FCFF} = \text{NI} + \text{NCC} + \text{IE}(1 - \text{tax rate}) - \text{IWC} - \text{IFA}$$

where:

$\text{NI} =$ net income, or profit after tax

$\text{NCC} =$ net non-cash charges

$\text{IE} =$ interest expense

$\text{IWC} =$ investments in working capital

$\text{IFA} =$ investments in fixed assets

In the case of the statement of cash flows:

$$\text{FCFF} = C + \text{IE}(1 - \text{tax rate}) - \text{IFA}$$

where:

$C =$ cash flow from operations

$\text{IE} =$ interest expense

$\text{IFA} =$ investments in fixed assets

Free cash flow to equity is derived from free cash flow to the firm as:

$$\text{FCFE} = \text{FCFF} - \text{IE}(1 - \text{tax rate}) + \text{NB}$$

where:

$\text{IE} = \text{interest expense}$

$\text{NB} = \text{net borrowing, or change in debt}$

Free cash flows also vary over the life cycles of products and firms. Product and firm life cycles are related in that the product life cycle is the demand side counterpart to the industry life cycle. Firm and products progress through the stages of emerging, growth, mature and decline, or in some cases can stay at a mature stage indefinitely. Some product cycles have a long lifespan, such as steel, paper and cement manufacturing, while products such as electronics and pharmaceuticals can have relatively short lifespans.

4.4 Pro forma analysis

Financial statement forecasts are referred to as pro forma statements and have a variety of applications. These include:

- strategic planning, such as merger and acquisition transactions and new capital investments;
- financial planning, including revenue and expenditure planning; working capital modeling, capital expenditure, capital structure analysis and short- and long-term borrowings;
- credit analysis for debt covenants such as debt to equity ratios and debt service reserve coverage; and
- the design and valuation of securities.

Pro forma financial statements provide an integrated projection of a firm's future operating prospects and financial condition based on the current financial statements. A pro forma income statement provides an earnings estimate, and a pro forma balance sheet provides the book value of equity as bottom line numbers. Forecasted free cash flows are derived from the pro forma cash flow statement, where net income and depreciation are used to construct the statement, which then provides data for the projected pro forma balance sheet. The pro forma cash flow statement is then available for forecasting free cash flows for use in financial planning, DCF analysis and liquidity analysis. Finally the pro forma statements are modeled for multi-year projections, the data

translated into values, and the projected firm value divided among the shareholders, debt holders and any hybrid security holders.

The consequences of changes in business conditions and the available choices in managing these changes can be analyzed in a pro forma. Scenarios that represent transformations in industries and the external environment can be integrated into an analysis of future performance. Building a pro forma requires identifying which factors are a function of business conditions and those that are management choices. These factors can include changes in products, markets, technologies and industries, and identifying the key drivers to which the firm is vulnerable.

Sensitivity analysis is the modeling of the set of possible future balance sheets and income statements and identifying what is at risk. Value is framed as to whether a firm can grow book value and where it will be in future years. Risk is analyzed by using different scenarios in the pro forma statements and includes the best possible and worst scenarios and the base case to find the margin of safety. Macro and micro economic effects and event risks can also be included in the scenarios. As financial reporting moves stock prices through earnings releases, the set of alternative accounting outcomes that will influence a firm's stock price can also be modeled.

A pro forma model framework can include quarterly intervals up to 12 months, followed by yearly intervals up to a five-year time frame. A pro forma analysis should include a focus on an industry's driver patterns, for example the fade rates, industry and economic forecasts, how a firm's key drivers will diverge from conventional patterns, management's options versus the external environment, and the firm's earnings forecasts, forward P/Es, growth in book value, residual income and ROIC drivers.

A percentage-of-sales pro forma example is used as an illustration, in which the following assumptions were made:

- the rate of sales growth is constant at 5%,
- cost of sales is 80% of sales,
- the current assets are 30% of sales,
- the fixed assets are also a ratio of sales at 100%,
- the parameters are assumed to be constant over the five-year forecast,
- a total of 1,000 shares are issued.

Table 4.1 summarizes the data for the pro forma analysis example.

Table 4.1 The pro forma example data

Operations		Assets		Financing	
Initial sales	1,000	Current assets (% sales)	30%	Interest expense	3%
Sales growth (annual)	5%	Current liabilities (% sales)	10%	Dividend payout ratio	65%
Cost of sales	80%	Fixed assets (net, % sales)	100%	Cost of equity	8%
Taxes	40%	Depreciation	10%	Debt/equity ratio	60%

Table 4.2 illustrates the pro forma income statement and balance sheet. The pro forma statements maintain the articulation of the accounting statements. Retained earnings, the last line of the income statement, represents the change in the retained earnings line item in the balance sheet, while the income statement and balance sheet changes form the foundation for the statement of cash flows. The operating and financing activities are also reflected in the sales activities and financing items on the balance sheet.

Table 4.3 shows the pro forma free cash flows. The calculations start with profit after taxes and reverse the accruals to arrive at free cash flow.

Table 4.4 shows the forward P/Es, book value, residual earnings, ROCE and ROIC pro forma forecasts. Book value is the sum of the balance sheet stock and retained earnings line items. Residual earnings is calculated as book value times the ROCE minus the cost of equity spread. ROCE is derived as net income divided by average shareholder equity, and ROIC is net income divided by the average total assets over two consecutive periods.

The GAAP Statement of Cash Flows mingles free cash flows with the flows from financing activities, where cash flow from operations minus the cash used for investing activities plus the cash from financing activities equals the change in cash and cash equivalents. Realigning the statement of cash flows draws a distinction that follows the four cash flows that were linked together in the cash conservation equation $C - I = F + d$ in Section 2.2, as illustrated in Table 4.5.

Table 4.6 shows the calculation of the valuation of equity from the free cash flows to equity. The valuation of equity using free cash flows is derived by discounting the equity cash flows for each year up to five years, with a terminal value added to the equity cash flow at year five.

The terminal value at year five is derived as a perpetuity, with the year five equity free cash flow projected beyond year five by multiplying by

Table 4.2 The pro forma income statement and balance sheet

Income statement	Y0	Q1	Q2	Q3	Q4	Y1	Y2	Y3	Y4	Y5
Sales	1000.0	262.3	262.4	262.6	262.7	1050.0	1102.5	1157.6	1215.5	1276.3
Cost of sales		(209.8)	(209.9)	(210.1)	(210.2)	(840.0)	(882.0)	(926.1)	(972.4)	(1021.0)
Interest		(3.0)	(3.0)	(3.1)	(3.1)	(12.2)	(12.8)	(13.5)	(14.1)	(14.8)
Depreciation		(1.4)	(1.4)	(1.4)	(1.4)	(5.6)	(5.8)	(6.1)	(6.4)	(6.8)
Profit before taxes		48.1	48.1	48.0	48.0	192.2	201.9	211.9	222.5	233.7
Taxes		(19.2)	(19.2)	(19.2)	(19.2)	(76.9)	(80.7)	(84.8)	(89.0)	(93.5)
Net income		28.9	28.8	28.8	28.8	115.3	121.1	127.2	133.5	140.2
Dividend		(19.0)	(19.0)	(19.0)	(19.0)	(76.1)	(79.9)	(83.9)	(88.1)	(92.5)
Retained earnings		9.8	9.8	9.8	9.8	39.2	41.2	43.2	45.4	47.7
Balance sheet	**Y0**	**Q1**	**Q2**	**Q3**	**Q4**	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Assets										
Current assets	300.0	303.7	307.4	311.2	315.0	315.0	330.8	347.3	364.7	382.9
Fixed assets	1111.1	1124.7	1138.6	1152.5	1166.7	1166.7	1225.0	1286.3	1350.6	1418.1
Depreciation	(111.1)	(112.5)	(113.9)	(115.3)	(116.7)	(116.7)	(122.5)	(128.6)	(135.1)	(141.8)
Net fixed assets	1000.0	1012.3	1024.7	1037.3	1050.0	1050.0	1102.5	1157.6	1215.5	1276.3
Total assets	1300.0	1316.0	1332.1	1348.5	1365.0	1365.0	1433.3	1504.9	1580.2	1659.2
Liabilities										
Current liabilities	100.0	101.2	102.5	103.7	105.0	105.0	110.3	115.8	121.6	127.6
Debt	387.5	392.3	397.1	401.9	406.9	406.9	427.2	448.6	471.0	494.6
Equity										
Stock	802.5	802.7	803.0	803.4	803.9	803.9	805.4	806.9	808.6	810.3
Retained earnings	10.0	19.8	29.6	39.4	49.2	49.2	90.4	133.6	179.0	226.7
Total liabilities	1300.0	1316.0	1332.1	1348.5	1365.0	1365.0	1433.3	1504.9	1580.2	1659.2

Table 4.3 The pro forma free cash flow forecast

	Y0	Q1	Q2	Q3	Q4	Y1	Y2	Y3	Y4	Y5
Profit after taxes		28.9	28.8	28.8	28.8	115.3	121.1	127.2	133.5	140.2
+ net non-cash charges (depreciation)		1.4	1.4	1.4	1.4	5.6	5.8	6.1	6.4	6.8
+ interest expense after taxes		1.8	1.8	1.8	1.9	7.3	7.7	8.1	8.5	8.9
− change in net working capital		(2.5)	(2.5)	(2.5)	(2.5)	(10.0)	(10.5)	(11.0)	(11.6)	(12.2)
− change in fixed assets		(13.6)	(13.8)	(14.0)	(14.1)	(55.6)	(58.3)	(61.3)	(64.3)	(67.5)
Free cash flow		15.9	15.8	15.6	15.4	62.7	65.8	69.1	72.5	76.2

Table 4.4 Forward P/Es, book value, residual earnings, ROCE and ROIC forecasts

Metric	Y0	Q1	Q2	Q3	Q4	Y1	Y2	Y3	Y4	Y5
Forward P/E		11.45	11.45	11.46	11.46	11.45	10.91	10.39	9.90	9.42
Book value	812.5	822.5	832.6	842.8	853.1	853.1	895.8	940.6	987.6	1,037.0
Residual earnings		12.6	12.4	12.1	11.9	49.9	52.4	55.0	57.8	60.7
ROCE		3.5%	3.5%	3.4%	3.4%	13.8%	13.8%	13.8%	13.8%	13.8%
ROIC		2.2%	2.2%	2.2%	2.1%	8.7%	8.7%	8.7%	8.7%	8.7%

one plus a perpetuity growth rate, and then dividing by the equity discount rate minus the growth rate.

The growth rate is derived as g = (1 − payout ratio) * ROCE and is assumed to be constant for illustration. The present value of the equity cash flows is derived as $FCFE_t/(r_e - g)$, where r_e is the cost of equity, which is divided by the number of shares to arrive at the value per share.

Figures 4.1, 4.2 and 4.3 illustrate a sensitivity analysis of the firm's free cash flow as a function of changes in growth, ROCE to changes in the debt/equity ratio, and ROIC as a function of changes in growth for the five-year forecast. Free cash flow is flat with zero growth, with no change in depreciation, working capital and fixed assets. The change in fixed assets significantly reduces free cash flows as growth increases, which is offset by the positive trend in interest after taxes and depreciation. ROCE increases in line with increases in the debt/equity ratio, from a ROCE of 13.1% for a 50% debt/equity ratio, to 13.8% for a 60%

Table 4.5 Free cash flows and financing flows

		Q1	Q2	Q3	Q4	Y1	Y2	Y3	Y4	Y5
Cash flow from operations	C	32.0	32.0	32.1	32.1	128.2	134.6	141.4	148.4	155.9
Investments	I	(16.1)	(16.3)	(16.5)	(16.7)	(65.6)	(68.8)	(72.3)	(75.9)	(79.7)
Free cash flow	$C-I$	15.9	15.8	15.6	15.4	62.7	65.8	69.1	72.5	76.2
Debt financing flows:										
Change in financial assets (net)		–	–	–	–	–	–	–	–	–
Financial asset interest		–	–	–	–	–	–	–	–	–
Debt issuance (net)		(4.8)	(4.8)	(4.9)	(4.9)	(19.4)	(20.3)	(21.4)	(22.4)	(23.6)
Debt interest expense		1.8	1.8	1.8	1.9	7.3	7.7	8.1	8.5	8.9
	F	(2.96)	(2.99)	(3.03)	(3.07)	(12.05)	(12.65)	(13.29)	(13.95)	(14.65)
Equity financing flows:										
Dividends and stock repurchases		19.0	19.0	19.0	19.0	76.1	79.9	83.9	88.1	92.5
Stock issuance		(0.2)	(0.3)	(0.4)	(0.5)	(1.4)	(1.5)	(1.6)	(1.6)	(1.7)
	d	18.9	18.7	18.6	18.5	74.7	78.5	82.4	86.5	90.8
Total financing flows	$F+d$	15.9	15.8	15.6	15.4	62.7	65.8	69.1	72.5	76.2

Table 4.6 Valuation of equity from free cash flow to equity

	Y0	Y1	Y2	Y3	Y4	Y5
Free cash flow		62.7	65.8	69.1	72.5	76.2
− interest expense after taxes		(7.3)	(7.7)	(8.1)	(8.5)	(8.9)
+ change in debt		19.4	20.3	21.4	22.4	23.6
Free cash flow to equity		74.7	78.5	82.4	86.5	90.8
Terminal value						2,423.5
Total cash flows		74.7	78.5	82.4	86.5	2,514.3
PV total cash flows		73.5	74.7	76.0	77.2	2,173.4
Cost of equity	8.0%					
Growth rate	4.7%					
Value of equity	2,474.8					
Value per share	2.47					

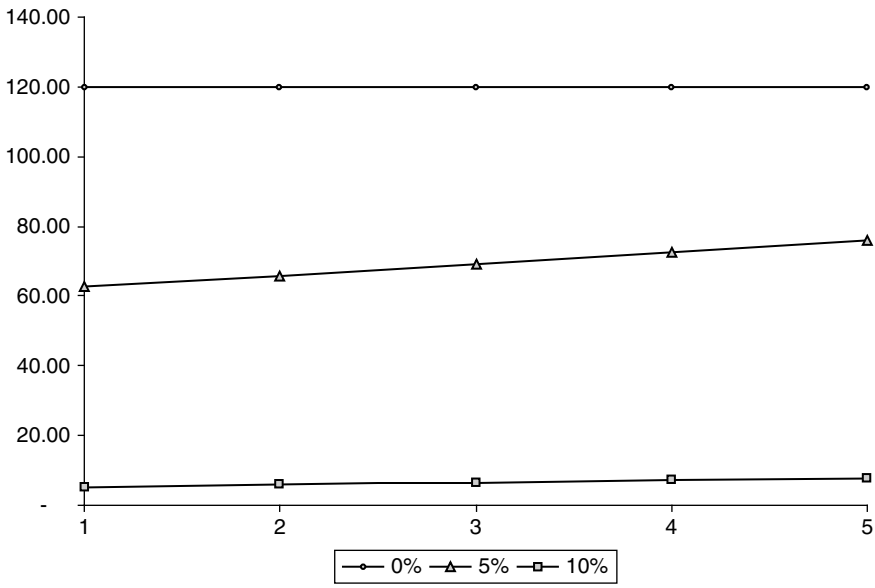

Figure 4.1 Free cash flow as a function of growth

debt/equity ratio and 14.6% for a 70% debt/equity ratio. ROIC has an inverse relationship with the sales growth rate, decreasing with the increase in the growth rate in sales. The increase in net income from the increase in growth in sales is offset by the increase in the average total assets in the ROIC denominator.

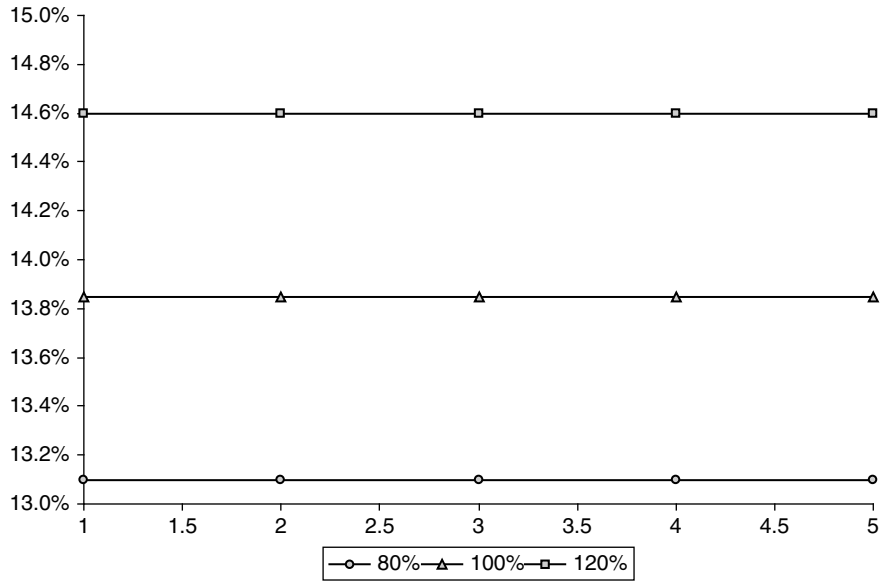

Figure 4.2 ROCE as a function of the change in the debt to equity ratio

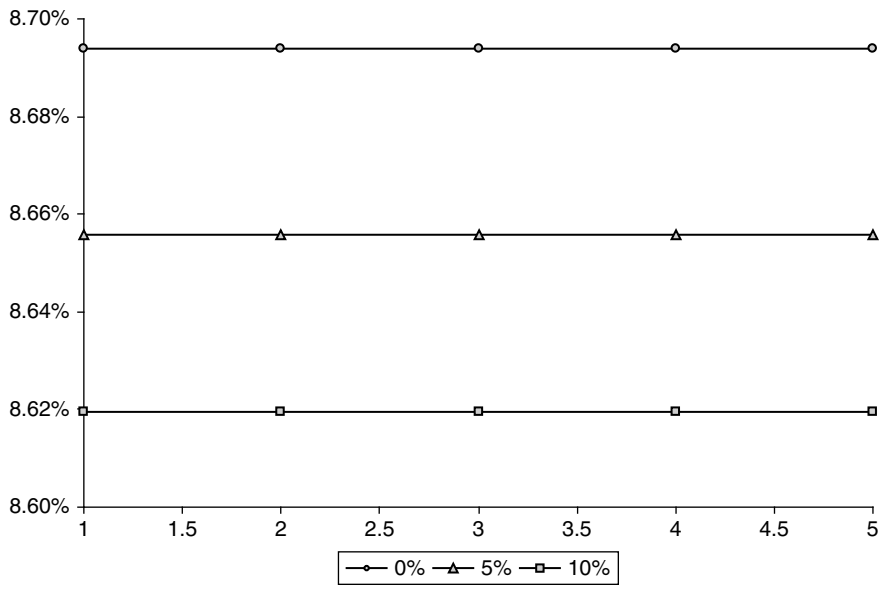

Figure 4.3 ROIC as a function of the change in growth

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5
The Analysis of Investments

Introduction

Six case studies illustrate the accounting, discounted cash flow (DCF), expected net present value (ENPV) and real options investment analysis methods:

- A corporate software IT project – which considers the asset DCF, and the option to defer, the equivalent to a call option.
- A power generator valuation – using the DCF method and switching options, represented as a series of call options on the plant, which can identify the value flowing into a firm's income statement.
- A pharmaceutical drug development – using DCF, ENPV and real options methods.
- A manufacturing firm – illustrates residual earnings and growth options and examines growth through innovation and the sustainability issues around climate change.
- The metamorphosis of a media firm – examines the abandonment option, with the exit from the firm's existing operations to align its business model with the transformation to an information economy.
- The sale of commercial real estate assets – which analyzes the put real option in the deferring of an office property sale.

The first, second, fourth and fifth case studies are hypothetical examples constructed to illustrate the industry issues and valuation methodologies. The third case study shows the various valuation methods used in the pharmaceutical and biotechnology industries, while the sixth case study appeared in the *Real Estate Finance Journal*.

The first, second and sixth case studies are considered from a management viewpoint, while the remaining are from an investor's perspective.

5.1 Software

5.1.1 IT investments and value

Investment in information technology (IT) has become a major component of the capital budget in many service and manufacturing organizations. Although IT investments can be highly risky, the corporate rewards can be enormous. Managing this expenditure in today's business environment raises a number of important issues for corporate decision makers, including how IT investments should be integrated with strategy, and the risk management implications of these investments. IT projects can be viewed as an activity where resources are allocated with the goal of maximizing shareholder value. Any software project is therefore managed with the goal of maximizing value, where value is defined in terms of the market value that is added to the firm. IT investments are not only costly but they are also often risky due to the uncertainty of the value of future payoffs.

The trend in placing IT on a cost recovery or profit center basis introduced the return on investment (ROI) concept into IT project analysis. In a conventional discounted cash flow valuation analysis, a forecast of the future cash flows is discounted at the risk-adjusted opportunity cost of capital to obtain the present value. Present values are derived for both costs and benefits. Taking the sum of the present value of the returns derives the net present value (NPV). If the resulting NPV is positive then the project is viable. The NPV of a feasible project corresponds to the change in value of a firm if it proceeds with the investment. If the NPV was positive the investment decision would be to proceed with the investment, as this would increase firm value by the NPV amount. Likewise if the NPV is negative the investment should not be made.

Valuing IT investments using cost/benefit or ROI analysis, however, has always been a problem in computation. It is typically a lot easier to calculate the costs/investment than it is to calculate the benefits/returns. However, there are concepts such as partitioning returns/benefit analysis into tangible and intangible benefits that can be used. The approach used in this case study is to ignore all intangible benefits and focus on tangible benefits, as most tangible benefits can be converted into measurable returns. The uncertainties associated with a firm's IT investments can also be defined as project and market related risks. Project related risks are associated with the planning, implementation and management of a firm's IT project, such as the technology not delivering, cost overruns and project setbacks. Market

related risks are the factors that can influence the demand for a firm's products and services, such as customer approval and the behavior of competitors. Even if a project meets management expectations, any capabilities created by the project may not be suitable for the existing market environment at the time of completion.

5.1.2 Software restructuring

The decision to restructure a software system is one regularly faced by many IT managers. Restructuring a system is often not only very costly but also risky, as the future payoffs are not only uncertain but also likely to be in numerous dimensions. If the focus is simply a payoff of reducing any costs that will be related to making future system alterations, for example, the future required changes might not materialize. Other uncertainties that can be associated with software restructuring projects include development costs, coding problems and subsequent operational failures, developments in future technology and standards, user acceptance and the possible costs associated with changes in processes.

IT managers cannot always predict how systems will need to be adapted to changing user requirements, market developments and developments in technology. The management objective, however, is still to design and implement IT investments that maximize firm value. Selecting a modular structure or architecture allows any future potential changes to be localized rather than system wide, and therefore can reduce any costs associated with software restructuring. The modular concept can be extended by considering the value of an information system as the sum of the values of each of the system's modules (Baldwin and Clark, 2000). The advantages of using this additive approach to value a system are its simplicity and the potential to provide a practical framework for managing systems that consist for the most part of independent components. Such an approach to managing software systems therefore would be consistent with maximizing value.

5.1.3 DCF analysis

A modular approach to software architecture has the potential to localize any required future software restructuring. Any payback from software modifications using a modular approach will therefore be in the form of reduced future costs. Under a DCF analysis based on using only tangible returns the IT manager would compare the present value of the future tangible benefits represented as a cash flow stream against

Table 5.1 IT software restructuring DCF analysis

Costs at t_0	=	(100,000)
Savings at t_1	=	132,000
Discount rate	=	10%
NPV	=	$-100,000 + \frac{132,000}{1.10}$
	=	20,000

the present value of the costs. The DCF's associated with the software restructuring appear in Table 5.1. The expected future tangible savings are $132,000 and associated costs are $100,000. A discount rate of 10% and a one-year time horizon (t) are used for illustration.

The NPV decision rule is to invest if the NPV is positive. As the static NPV of the investment is $20,000, which is positive, the decision under the NPV is to restructure immediately. The project would then be accepted immediately based on this analysis.

5.1.4 Value and flexibility

The way in which an organization's software is structured can have a significant influence on value. Any flexibility that an IT manager has in making software modifications over time is determined by a system's structure. As the business environment becomes increasingly dynamic and uncertain, flexibility as a capability can have a significant impact on value, by offering protection from the downside risks while maintaining an exposure to any upside opportunities. For example, the capability to abandon a project at an early stage as new unfavorable information becomes available provides downside protection, while the flexibility to adapt to an evolving market or select from a range of developing technologies provides upside potential (Sullivan et al., 1999). An organization can hedge against adverse outcomes by staging IT investments and making decisions contingent on project risks and market demand, while capturing the upside benefits if market conditions turn out to be positive. The capabilities to make management decisions such as these more effectively has the potential for substantial economic payoffs in terms of value.

The software restructuring project is now analyzed under the concept that there is value in the form of a real option. This option offers the flexibility to defer any software modifications until one-time step into the future, at which point new information will become available. The focus in this relatively simple case study is more on demonstrating the

concept of real options, rather than developing a market-based real option evaluation through arbitrage methods. The concepts, however, can still provide capabilities in software management and therefore add value to an organization.

5.1.5 Software real options

The DCF software restructuring analysis in Section 5.1.3 factored risk into the analysis by using a discount rate to discount the cash flows. Another way to analyze the software restructuring is to recognize two possible scenarios that can result from the uncertainties associated with future conditions. One uncertainty could be the future requirements for software modifications, which could be either frequent or occasional. Another future scenario is the possible success of replacement software that is under development, which would limit any requirements for modifications to the existing legacy system. To illustrate these future uncertainties two possible scenarios for the restructuring of the software are assumed: one where numerous modifications are required, which implies the potential for outlays on restructuring, and the alternative where no or only a relatively small number of modifications are needed, in which case there would be no major outlays on restructuring.

A one-step binomial tree is used to analyze the uncertainty associated with the restructuring decision. The payoff is now represented as three cash flows, with the restructuring costs at t_0 (the present) of \$100,000, and two possible payoffs at t_1 (one step into the future) of \$198,000 at one branch if the outcome is favorable, and \$66,000 at the other branch if the outcome is unfavorable. Arbitrary probabilities of 0.5 are assigned to each branch, and the same discount rate of 10% is used. These are simplified parameters for the purpose of illustration. In option modeling a continuously compounded interest rate and risk-neutral probabilities would typically be used.

If the decision is made to invest immediately, the benefits are the asset S, the expected value of the profit stream from restructuring at time t_0. Over the time period Δt from t_0 to t_1, the asset value S can either go up to uS (favorable) or down to dS (unfavorable), with values at t_1 defined in this case study as:

$$uS = 198,000$$

$$dS = 66,000$$

With probabilities $p = 0.5$, the expected asset value is therefore:

$$S_0 = 0.5^* \left(\frac{198,000}{1.10} \right) + 0.5^* \left(\frac{66,000}{1.10} \right)$$
$$= 120,000$$

With the inclusion of the outlay of 100,000, or the strike K, the payoff from exercising at t_0 is $S_0 - K$, which equals 20,000. Table 5.2 illustrates the cash flows for the decision to invest immediately. The NPV at t_0 is still \$20,000 as per the case in Table 5.1 of the DCF analysis, and again the restructuring project would then be accepted immediately based of this analysis. The same analysis appears below in Table 5.3 using a simple binomial tree.

The software restructuring project is now analyzed as an option to defer, or a call option on the restructuring project at t_1, with a strike of $K = 100,000$ (the restructuring costs of \$100,000 are assumed to be constant at t_0 and t_1). At t_0 the payoff for the call option on the restructuring project is:

$$c = Max(S_T - K, 0) \tag{5.1}$$

Table 5.2 Software restructuring cash flows: invest immediately

Costs at t_0	$= (100,000)$
Favorable savings at t_1	$= 198,000$
Unfavorable savings at t_1	$= 66,000$
NPV at t_0	$= 20,000$
NPV	$-100,000 + 0.5^* \left(\frac{198,000}{1.10} \right) + 0.5^* \left(\frac{66,000}{1.10} \right)$
	$= 20,000$

Table 5.3 Software restructuring binomial tree cash flows (1)

T	p	r	df	K	uS	dS
1	0.5	10.00%	0.9091	(100,000)	198,000	66,000
	t_0		t_1			
	Key:					
	CFt					
	NPV					
			198,000			
	(100,000)					
	20,000					
			66,000			

where c is the value of the call option, and T is equal to t_1. The payoffs for the option at the up and down nodes at t_1 are:

$$c_u = Max(uS - K, 0) \tag{5.2}$$

$$c_d = Max(dS - K, 0) \tag{5.3}$$

The expected value of the call option at t_0 is:

$$c = P(t,T)\left[0.5^{*}Max(uS - K, 0) + (1 - 0.5)^{*}Max\left(dS - K, 0\right)\right]$$

The expected cash flow payoff at t_0 is therefore:

$$\begin{aligned} c &= P(t,T)\left[0.5^{*}Max(198,000 - 100,000, 0)\right. \\ &\quad \left. + (1 - 0.5)^{*}Max(66,000 - 100,000, 0)\right] \\ &= 44,545 \end{aligned}$$

The same analysis appears in Table 5.4 using the simple binomial tree.

In this software-restructuring example the alternative strategies are either to exercise at t_0 or to wait until t_1. The IT manager has the right to invest immediately in the restructuring at t_0, and a call option on the restructuring with exercise at t_1. The DCF analysis implies that the project should proceed immediately as the discounted cash flows are positive. The decision to proceed with the restructuring at time t_0, however, gives up the right to exercise the call option at t_1. Therefore the value of the decision to invest immediately at t_0 is 20,000 (the value of investing immediately) minus 44,545 (the value of the call option, or the option to defer), which equals (24,545).

Although the initial perception is that the best alternative based on the NPV analysis is to invest at t_0, it is clearly not the optimal decision for adding value to the organization when the option to defer is also

Table 5.4 Software restructuring binomial tree cash flows (2)

T	*p*	*r*	*df*	*K*	*uS*	*dS*
1	0.5	10.00%	0.9091	(100,000)	198,000	66,000
	t_0		t_1			
	Key:					
	St *Call*		198,000 98,000			
	120,000 44,545					
			66,000 0			

considered. If the DCF analysis had given a negative NPV for the project at t_0, the right to defer the project may still have value due to the call option. Even though the project had a positive NPV at t_0, the organization may gain by delaying the project and proceeding with it in the future. In the DCF analysis this right is worthless and adds no value to the organization. When the right to delay the project is considered as a call option, however, this right does have value and should therefore be considered in the analysis.

5.2 Energy

5.2.1 The global energy markets

The energy market is the largest market in the world after currencies. Over the 20th century the global GDP 3% annual average growth rate was sustained by an annual growth rate of 2% in the energy supply, while energy consumption increased from an annual equivalent of 4 barrels of oil per person to 13 barrels. The factors that will influence energy use in the 21st century will be energy demand and consumption, energy efficiency, and the energy mix and infrastructure.

The two most significant drivers of energy demand are population and income growth. Since the start of the 20th century the world's population has more than quadrupled, with real income and primary energy consumption growing by factors of 25 and 22.5 respectively. Over the last two decades the world's energy demand has increased by 45% or an average annual rate of 1.9%. By 2008 the world was consuming 504.7 quadrillion British Thermal Units (quad Btu) of energy per year, the equivalent to 247 million barrels of oil per day.

Over the next 20 years the forecast for global energy demand is an increase of over 39% or an average annual rate of 1.7%. Growth in global energy consumption is therefore expected to continue, with industrialization in the developing world being the driver. Efficiency improvements, however, are also likely to accelerate.

The OECD forecast for energy consumption is a rate of growth of 6% by 2030 with an average growth rate of 0.3% per annum. OECD energy consumption per capita is expected to have a negative trend of -0.2% per annum from 2020. The forecast for growth in non-OECD energy consumption is 68% by 2030, with an annual average from 2010 of 2.6%, and driving 93% of total global energy growth. This illustrates the rising trend in non-OECD energy consumption, from 43% in 1990

to approximately 50% today to two-thirds by 2030, driven by new industries and power generation.

Energy efficiency, generally defined as the energy to GDP ratio or energy per unit of GDP, is forecast to accelerate and be a factor in faster income growth over the next 20 years, with more rapid efficiency gains in non-OECD economies. The impact of this efficiency acceleration will be the limiting effect on overall growth in primary energy. This trend is supported by the rise and decline of the industrial sector, with the structural shift away from industry to less energy intensive activities, occurring initially in rich economies followed by newly industrialized economies.

Figure 5.1 illustrates the trends in total world energy consumption, which is forecast to rise to 619 quad Btu by 2020 and 770 quad Btu by 2035. The forecast for OECD energy is a rise from 244.3 quad Btu in 2008 to 260.6 quad Btu in 2020 and 288.2 quad Btu in 2035. The non-OECD energy forecast rises from 260.5 quad Btu in 2008 to 358.9 quad Btu in 2020 and 481.6 quad Btu in 2035.

Figure 5.2 shows the forecast for the world energy consumption by fuel from 1990 to 2035. The composition of the energy mix in 2008 was 34% liquids, 23% natural gas, 28% coal, 5% nuclear and 10% renewables. The forecast for the energy mix is a decline of 4% in liquids

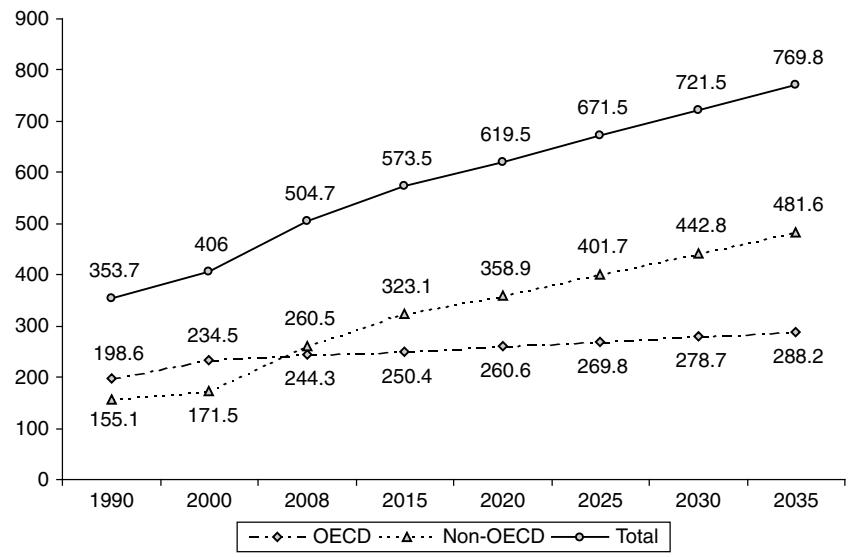

Figure 5.1 World energy consumption, 1990–2035 (Quadrillion Btu)
Source: U.S. Energy Information Administration, International Energy Outlook, 2011

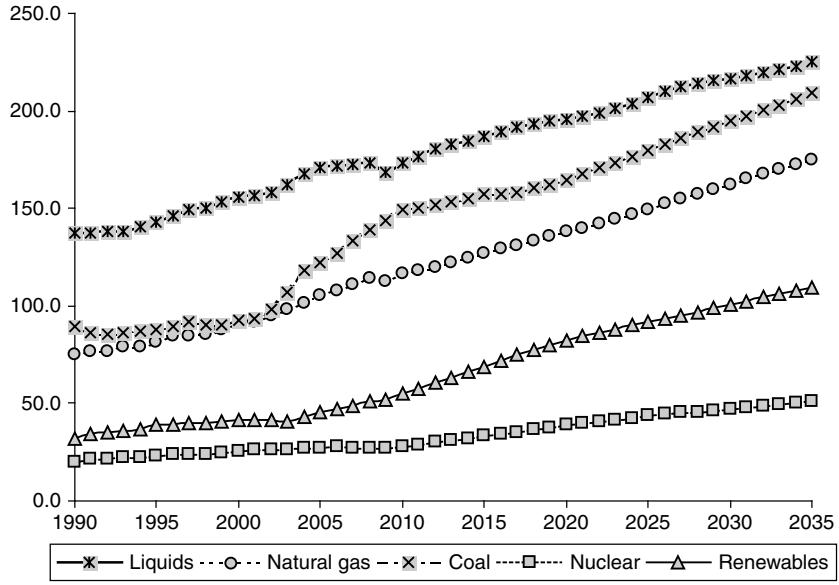

Figure 5.2 World energy consumption by fuel, 1990–2035 (Quadrillion Btu)
Source: U.S. Energy Information Administration, International Energy Outlook 2011

with a 3% increase in renewables over the next 25 years. The consequence of the long life of energy assets is that change in the energy mix is slow; however, gas and non-fossil fuels are expected to increase their share at the expense of oil and coal. Renewables, including biofuels, are forecast to have the fastest growth from 2010 to 2030 with 8.2% per year, with gas having the greatest growth among the fossil fuels with 2.1% per year.

The global energy supply infrastructure requires large-scale investment in the future. The IEA forecast under its 'New Policies Scenario' for this investment is $38 trillion from 2011 to 2035, or an annual average of $1.5 trillion, with two-thirds of this required in non-OECD countries.

The power sector requires almost $17 trillion of this total investment. Oil and gas together need almost $20 trillion, the increase a function of higher costs and additional upstream investment requirements, with coal and biofuels making up the remaining investment.

5.2.2 The gas markets

Natural gas production is forecast to be the fastest growing globally among the fossil fuels to 2030. BP makes a case in its latest Energy Outlook that gas could rival coal and oil as a primary source of energy

by 2030. The IEA in its 'World Energy Outlook 2011' comments that natural gas will have a greater share of the global energy mix in 2035 compared to today.

In 2009 global proved gas reserves were 6,621 trillion cubic feet (tcf), or the equivalent to 63 years of production at existing levels. Unconventionals such as shale gas and coal bed methane are yet to have a detailed global appraisal; however, they have the potential to provide an additional 30 years of supply.

In OECD markets a moderate annual growth in global gas consumption of 1% is expected. The 0.5% forecast for the industrial and residential sectors is due to low population growth and efficiency gains. Annual growth rates are expected to be the fastest in the power sector with 2.6% and the industry sector with 2%, which is consistent with past trends. Non-OECD countries make up 80% of the increase in global gas consumption, with an average annual growth forecast of 3% to 2030.

Although coal is currently the primary fuel for power generation, it is steadily being supplanted with natural gas and renewables. Gas is seeing the fastest growth globally among the fossil fuels used in power generation, with its share of fossil fuel use in generation increasing from the current 30% to 37%, and growth in the share of total electricity generation from 20.5% to 22%. This fuel substitution is also providing a solution for curbing greenhouse gas emissions, as natural gas used in power generation has approximately half the CO_2 emissions from those in coal power generation and almost zero sulfur dioxide emissions.

5.2.3 The power markets

For most of the 20th century power companies existed as natural monopolies and controlled the complex social, economic and technological structures that permitted customers to obtain increasing amounts of electricity at decreasing prices. State regulatory commissions were created to ensure that customers benefited from the monopoly positions of utilities. Regulation provided protection that allowed utilities to expand and build alliances, and the market power of power companies seemed to be permanently established. However, the end of technology improvements in generating equipment, combined with the consequences of the 1970's energy crisis changed everything. Utilities could no longer produce declining cost electricity, with the belief in uncontested growth challenged by an increasingly popular environmental movement. Power companies started to lose

control over both the utility system and the stakeholders who formerly supported the consensus.

By the 1990s utilities no longer enjoyed universal support from stakeholders. When conceived decades earlier the consensus was that the required market structure for utility companies required natural monopolies, with government oversight necessary to ensure that this structure provided benefits to society. However, by the 1990s it was evident that the motivation for public monopoly and regulation no longer appeared to be valid. As a result support for the consensus eroded among stakeholders who, along with large industrial customers, saw opportunities in a newly structured system based on deregulated markets.

As a result the competitive environment for power companies in the 21st century contrasts with the protected market structure that emerged in the early 20th century. The forces of deregulation, convergence through mergers and acquisitions, globalization and technology are driving fundamental changes in the global energy markets that are forcing power companies to rapidly evaluate their market structures and strategies. The global trend to open markets is accelerating as countries permit their power industries to separate and open up to competition in the traditional monopoly areas of generation, transmission and distribution.

Power utilities have responded to this new competitive environment by cutting costs, with mergers, and buying power companies in other countries. Another dominant trend in the energy industry is the convergence between the gas and power businesses. Units of energy are becoming interchangeable, and companies are now exploring energy areas such as gas transmission, gas distribution, gas trading, wholesaling power generation, electric utilities and electricity trading. At the same time small-scale power generating technologies are providing firms with the ability to produce electricity themselves, and therefore eliminating the need to purchase power from utilities.

In the 21st century, electricity demand should maintain its relationship with income while power generation migrates to lower carbon fuels. Income and electricity demand have historically had a high correlation, and this relationship should both continue and evolve with the drive toward energy efficiency. The BP forecast for the global electricity to GDP growth ratio is a decline from 0.9 in 1990 to 2010 to 0.7 from 2010 to 2030. The decline implies the expected rapid shift to less electricity intensive economies by industrializing non-OECD countries. Non-OECD power generation will exceed the OECD's by

2012 and growth is expected to continue to greater than three times the OECD rate. Electricity per capita consumption in the non-OECD economies, however, will stay considerably under OECD levels, with non-OECD per capita consumption as a percentage of the OECD level increasing from the current 20% to 30% by 2030.

5.2.4 Power generator case study

Energy Corporation (EC) is an energy generator with a portfolio of electricity plants. An evaluation of the potential value of the Sparkie Power Station (SPS), a gas-fired power plant within the energy portfolio, was required by EC. EC's strategy is to use SPS as a provider of high-peak power to maximize EC's gross margin, and also as a risk management tool to cover plant failure events at its coal fired power stations.

The industry standard for the valuation of power assets is the traditional dispatch model. This approach values plants by determining the marginal cost-based clearing price and calculating cash flows that are based on the intrinsic spread, the spark spread, between the electricity price and the cost of fuel for generation. The dispatch model calculates the margin received, or the spark spread, over the life of the plant, and discounts it to the present. The discount rate used was based on EC's weighted average cost of capital.

Although electricity cannot be easily stored, the fuels used to generate the electricity can be stored, and the link between the two implies that the forward curve for electricity should be related to the input fuels. An arbitrage pricing approach takes this into account by considering the conversion process. One of the key steps in the conversion process is the generation process itself, and this depends on the efficiency of generation expressed as the *heat rate* – the number of Btus required to generate one kWh of electricity.

A basic electricity forward curve can be obtained for the fuel forward curve via the following relationship:

$$Cost_{electricity} = Heat\ Rate \times Price_{fuel} \tag{5.4}$$

A constant value of the heat rate implies that the shape of the electricity forward curve should resemble the forward curve of the input fuel. The cost of electricity can be converted into a forward price after taking into account costs associated with fixed assets, transmission and tolling charges and others, such as fuel storage and fuel transportation. These costs obviously change through time. Figures 5.3 and 5.4 illustrate SPS's power and natural gas curves respectively. Forward energy curves can be created as composite curves that consist of market data such as

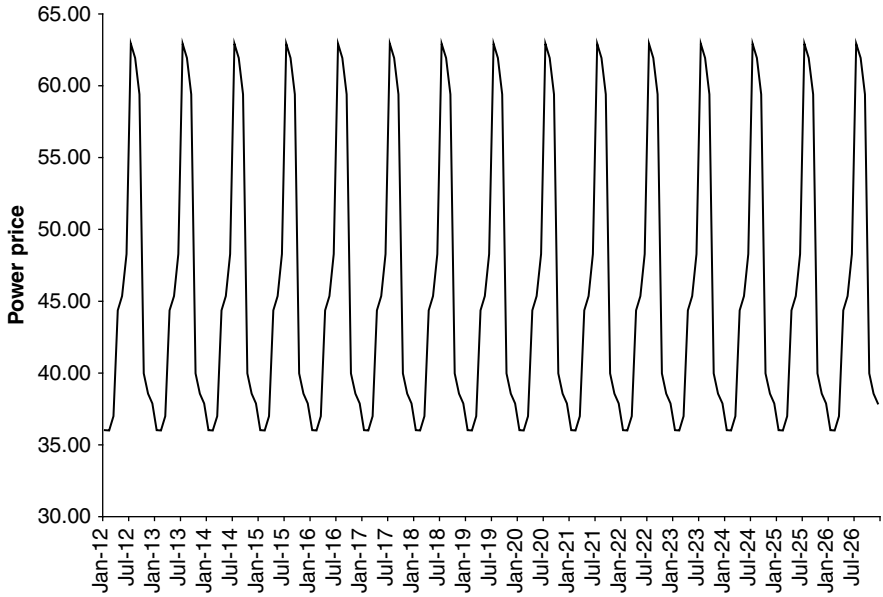

Figure 5.3 Power forward price curve

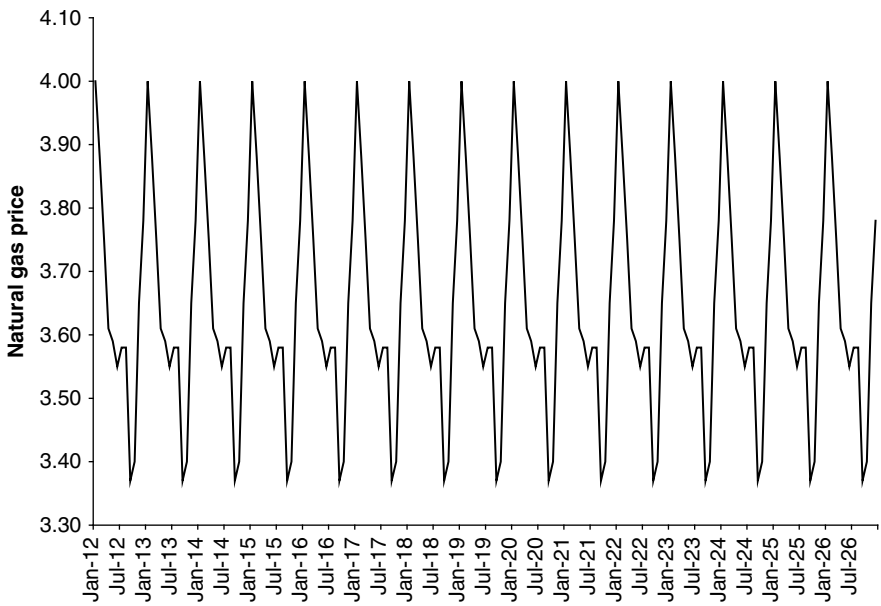

Figure 5.4 Natural gas forward price curve

futures, forward prices and curve modeling. One feature exhibited by energy prices is the high level of seasonality, a repetitive cyclical pattern in the price over time. Seasonality in the energy markets is driven typically by demand caused by weather factors such as hot summer months.

The assumptions for the DCF analysis shown in Table 5.5 are:

- The plant output is 300 MWh.
- It is assumed that SPS has a total remaining life of 15 years.
- The 15-year power and natural gas forward price curves each consist of a series of one-month forward prices that represent the hourly average over each month.
- The valuation cash flows are pre-tax.
- The heat rate is 10,000. To derive the spark spread the heat rate is divided by 1,000.
- The plant will run 16 hours per weekday, except in the summer months when it will run 24 hours per weekday.
  - The start-up cost is $5,000 per start-up. A MWh start-up cost was derived per month as the number of start-ups per month times $5,000, which is divided by the total operating hours per month times the number of MWs.
  - The operations and maintenance (O&M) costs are $1.50 per MWh.
  - The pretax discount rate is 6.50%. The maturity for each discount factor is the middle of each month.
  - The NPV of SPS is the sum of the present values of the net cash flows for each month.

5.2.5 Energy options

As the limitations of DCF techniques have become evident, the energy industries are adopting more sophisticated models that account for the optionality in strategic assets. The options in an energy company's electricity portfolio can exist in a range of assets, such as power plants, natural gas (commodity or pipeline capacity), oil (as a commodity and in storage) and emission credits (Challa, 2000). The new types of models are designed to capture the opportunity and risks associated with the volatility in the value of these assets and can be readily used for valuations, capital allocation decisions, operations and risk management.

Table 5.5 Discounted cash flow analysis (as on 31 December 2011)

Month	Jan. 12	Feb. 12	Mar. 12	Apr. 12	May 12	.....	Jul. 26	Aug. 26	Sep. 26	Oct. 26	Nov. 26	Dec. 26
Energy – MWh	300	300	300	300	300	.....	300	300	300	300	300	300
Power price	36.02	36.00	37.00	44.36	45.36	.....	62.93	61.93	59.40	39.98	38.57	37.88
Gas price	4.00	3.88	3.75	3.61	3.59	.....	3.58	3.58	3.37	3.40	3.65	3.78
Heat rate	10,000	10,000	10,000	10,000	10,000	.....	10,000	10,000	10,000	10,000	10,000	10,000
Spark spread – $/MWh	(3.98)	(2.80)	(0.50)	8.26	9.46	.....	27.13	26.13	25.70	5.98	2.07	0.08
Start-up costs	0.00	0.00	0.00	1.04	1.04	.....	0.16	0.15	0.12	1.04	1.04	1.04
Total operating hours	384	336	352	352	384	.....	528	552	552	352	368	368
Total revenue $	0	0	0	762,256	969,792	.....	4,272,392	4,302,128	4,235,920	521,488	113,528	0
O&M costs	1.50	1.50	1.50	1.50	1.50	.....	1.50	1.50	1.50	1.50	1.50	1.50
Total O & M costs $	172,800	151,200	158,400	158,400	172,800	.....	237,600	248,400	248,400	158,400	165,600	165,600
Net cash flows $	(172,800)	(151,200)	(158,400)	603,856	796,992	.....	4,034,792	4,053,728	3,987,520	363,088	(52,072)	(165,600)
Discount factor (6.5%)	0.9973	0.9923	0.9872	0.9820	0.9769	.....	0.4000	0.3979	0.3958	0.3937	0.3917	0.3896
Present value $	(172,339)	(150,031)	(156,377)	593,015	778,576	.....	1,613,998	1,612,923	1,578,253	142,955	(20,394)	(64,518)
NPV	= $136,874,152											

Electricity peaking plants can be valued as options on the spread between the fuel cost and the power price. The optionality in an individual peaking unit provides the owner, or option holder, with the right to operate the unit when electricity prices are higher than the cost of the fuel used to generate. A portfolio of peaking units can therefore increase marginal value significantly. The problem with the industry standard economic supply–demand dispatch models is that they take no account of volatility. Although the DCF model recognizes that a peaking plant has intrinsic value, that is, electricity prices can increase to a point where there is value in switching on the plant, it does not capture any value derived from the volatility in the spark spread.

The operating characteristics of the Sparkie Power Station can be defined as the equivalent to a power spread option. As SPS is a peaking plant, Energy Corporation can choose to run the power plant only when the power price exceeds the marginal fuel cost. The real option for EC is the ability to choose whether to generate or not at a given power price. While the peaking plant may have available capacity, there is no obligation to generate regardless of the electricity price. In deregulated power markets, however, a rational generator operator would choose to generate when power prices are above the fuel cost and any start-up costs. These types of real options are switching options, defined in this case study as a series of European call options on the spark spread between power and natural gas prices. Valuing the power plant as a real option illustrates the value in the flexibility to call the plant when the energy spread is positive, which can be used to optimize operations and therefore value.

5.2.6 Pricing energy derivatives

There are a number of practical problems associated with derivative modeling in energy markets. Some of the important issues associated with energy derivative pricing that were often overlooked in early modeling approaches are:

- Energy prices tend to be drawn to production costs. The GBM assumption permits price series to drift to unrealistic levels when applied to energy markets. In the short run, divergence from the cost of production can be possible under abnormal market conditions; however, in the long run, supply will adjust to the anomaly and prices will move to the level determined by the cost of production. This property is described as *mean reversion*.

- Energy prices display *seasonality*. Seasonality in energy prices and volatility may correspond to the time of year, such as winter or summer, and also can result from regular demand patterns due to factors such as the weather.
- Energy commodities cannot be treated solely as financial assets, as energy commodities are inputs to production processes and/or consumption goods. Models based on an automatic extension of those developed for financial markets may therefore break down when applied to energy markets.
- Another problem with applying the GBM assumption to energy prices is that their market price behavior is often not consistent with the assumption of price continuity over time. Commodity and energy prices often display *jump behavior*, determined in many cases by fluctuations in demand and supply. The frequency of these extreme values is often larger than the probability implied by GBM models.

In some markets such as energy, the concept of being able to perfectly replicate options by continuously trading the underlying asset can be unrealistic. Many energy derivatives, however, actually rely on futures prices rather than the spot price, and therefore futures can be used to replicate options positions and permit the application of the risk-neutral pricing approach.

5.2.7 Energy spread options

The payoff in a spread option is derived from the price differential between two underlying assets. These types of exotic options can be used either to take a position on, or to hedge the risk associated with, the relative performance of two underlying assets. The payoff of a European spread call option at maturity T is:

$$c = \max [S_{1T} - S_{2T} - K, 0] \tag{5.5}$$

where S_{1T} and S_{2T} are the spot prices of the two underlying assets, and K is the exercise price. Most option pricing models have the underlying assumption that the risk-neutral price distribution of the underlying asset is lognormal. A spread option is priced as the discounted double integral of the option payoffs over the risk-neutral distribution of the two underlying assets at maturity T (Pearson, 1997). Analytical Black–Scholes-type models for valuing spread call and put options that include a strike, however, are not known, and therefore numerical techniques have to be used.

If the futures contracts underlying the option are written on two separate energies, in this case natural gas and electricity, then the option is often referred to as a *spark spread option*. Organizations exposed to the price differences between two different energies often use options of this type. In this case of a natural gas-fired power generator, energy is an input into a process that produces another energy. If $F_a(t,T)$ represents the price of a T maturity futures contract on energy a, in this case power, $F_b(t,T)$ represents the price of a T maturity futures or forward contract on energy b, in this case natural gas times the heat rate, and K represents the start-up costs, then the payoff for a European call option with maturity T and strike K on the spread between the two forward contracts is:

$$c = Max(F_a(t,T) - F_b(t,T) - K, \mathrm{O}) \tag{5.6}$$

and therefore the value of the call option at time t can be written generally as:

$$= P(t,T)E_t[Max(F_a(t,T) - F_b(t,T) - K, 0] \tag{5.7}$$

where $P(t,T)$ is the continuously compounded discount factor.

Note: The following section has largely been adapted from Clewlow and Strickland (2000).

5.2.8 The Schwartz single factor model

Energies such as electricity and natural gas exhibit the property of mean reversion. Modeling these price series using Black–Scholes-type models can produce unrealistic spreads between the two related energy commodities. Mean reversion can be captured in a more realistic single factor model introduced by Schwartz (1997), which assumes that the spot price follows a mean reverting process:

$$ds = \alpha(\mu - \lambda - \ln S)Sdt + \sigma Sdz \tag{5.8}$$

where α is the mean reversion rate, which is the speed of adjustment of the spot price back toward its long-term level μ, σ is the spot price volatility and λ is the market price of energy risk. By defining $\mathrm{x} = \ln S$ and applying Itô's lemma to equation (5.8), the log price can be characterized by the Ornstein–Uhlenbeck process:

$$dx = \alpha(\hat{\mu} - x)dt + \sigma dz \tag{5.9}$$

where:

$$\hat{\mu} = \mu - \lambda - \frac{\sigma^2}{2\alpha}.$$

This process leads to the following differential equation for all contingent claims where the payoff depends on the level of the energy spot price and time:

$$\frac{1}{2}\sigma^2 S^2 C_{SS} + \alpha(\mu - \lambda - \ln S)SC_S + C_t - rC = 0 \tag{5.10}$$

where C is the contingent claim price, and r is instantaneous continuously compounded interest rate.

5.2.9 Forward curves

Capturing the significant features of the energy markets is important in applications of energy pricing models. Although a number of energy derivative models use forward curves for pricing, there are some associated problems. Energy forward curves are typically composed of discrete monthly futures contracts, and therefore are not continuous as assumed in the pricing model. Some energy markets can be in *backwardation* (where futures prices are lower than spot prices) while others might be in *contango* (where futures prices are higher than spot prices), which gives the spread its own forward curve. The spread can also become negative as a consequence of these properties. Another issue is that seasonality can also exist in the spreads. Figure 5.5 illustrates the forward curves used in the DCF and the real option example. The forward curves were derived for the case study, with annual seasonal patterns and negative spark spreads from January to March for each year.

5.2.10 Schwartz single factor futures and forward pricing

Futures and forward prices with maturity s in the Schwartz single factor model are equal with the appropriate boundary conditions and are given by:

$$F(t,s) = \exp\left[e^{-\alpha(s-t)}\ln S + (1-e^{-\alpha(s-t)})\left(\mu - \lambda - \frac{\sigma^2}{2\alpha}\right) + \frac{\sigma^2}{4\alpha}(1-e^{-2\alpha(s-t)})\right] \tag{5.11}$$

The mean reversion rate α determines how quickly forward prices even out to the long-term level. Figure 5.6 illustrates the sensitivity of the futures price defined in equation (5.11) to the mean reversion parameter, or the speed of mean reversion. The parameters used in the illustration are $S = 110$, $\sigma = 0.3$, $\lambda = 0$, $\mu = \ln(100)$ and $\alpha = 0.1$, 1 and

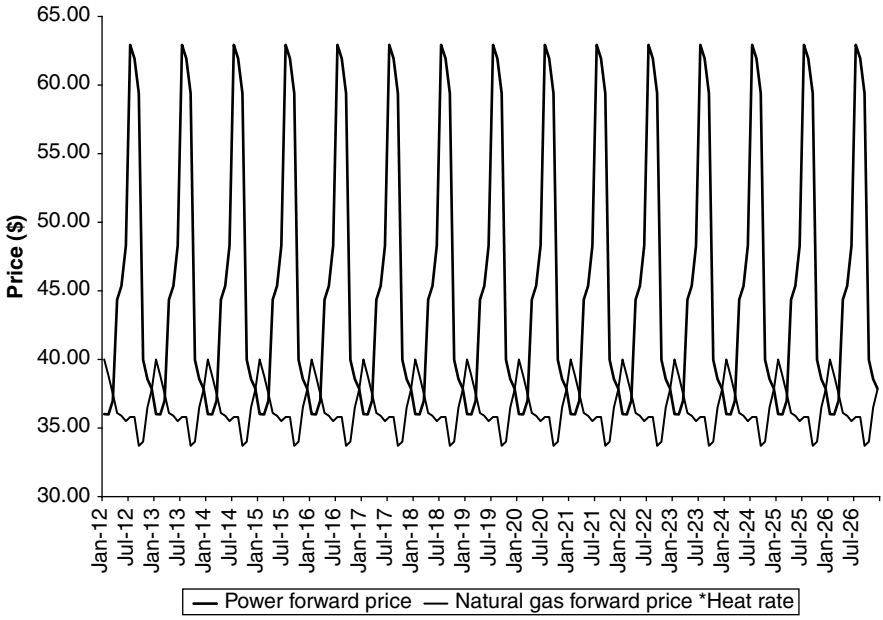

Figure 5.5 Spark spread forward curves

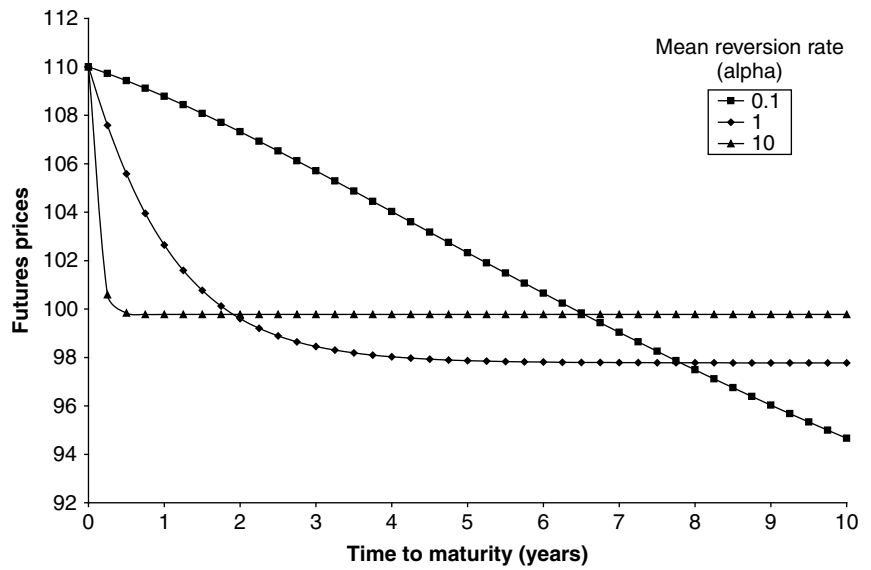

Figure 5.6 Schwartz single factor model futures prices
Source: Clewlow and Strickland (2000)

10. The long-term level of the futures curve does not equal $\exp(\mu)$, as it is adjusted by an amount that depends on the relative size of α and σ:

$$F(t,\infty) = \exp\left[\mu - \lambda - \frac{\sigma^2}{4\alpha}\right] \tag{5.12}$$

5.2.11 Volatility

The volatility measure used in energy pricing models should be defined and estimated in the context of the specific stochastic price process that captures the key features of the energy markets such as mean reversion. The constant volatility assumption used in the Black–Scholes model is not consistent with the empirical observation that long-dated energy forwards are less volatile then short-dated energy forwards. Figure 5.7 illustrates the shapes of the power and natural gas volatility term structures used in the generator real option case study.

Itô's lemma can be applied to equation (5.11) to provide the term structure of proportional futures volatilities in the single factor model:

$$\sigma_F(t,s) = \sigma e^{-\alpha(s-t)} \tag{5.13}$$

Figure 5.8 illustrates the effect of the speed of mean reversion, α in equation (5.13), on the term structure of volatility of futures prices.

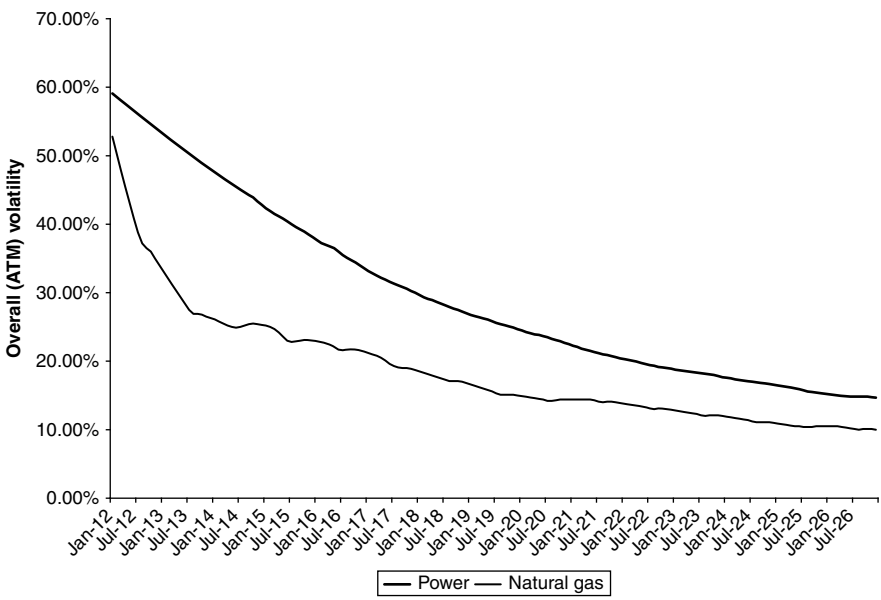

Figure 5.7 Power and natural gas volatility curves

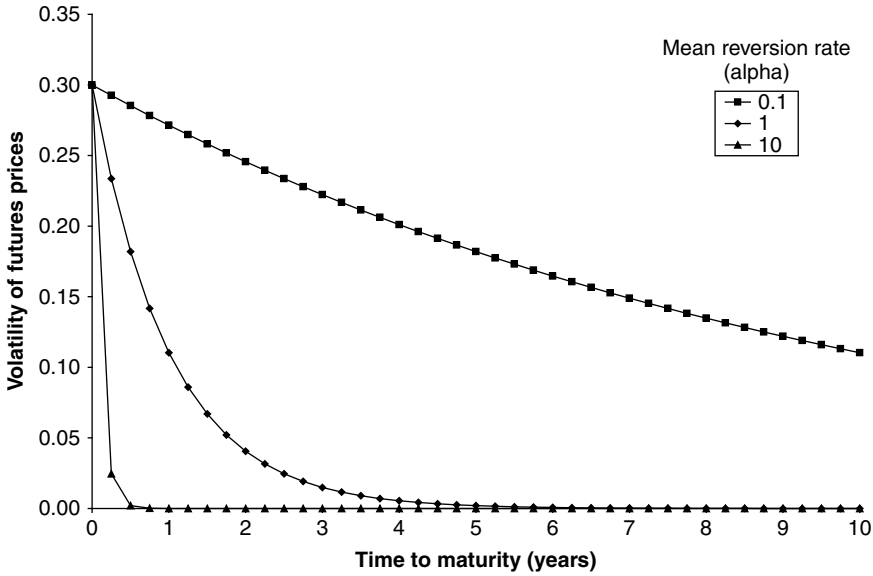

Figure 5.8 Volatility of futures prices in the Schwartz single factor model
Source: Clewlow and Strickland (2000)

Volatility parameters of 0.3 and $\alpha = 0.1$, 1 and 10 are used in the illustration. Increasing the speed of mean reversion, for example, increases the attenuation of the volatility curve. As the maturity of the forward contract increases, the volatility of the contract also tends to zero.

While the volatility term structure based on the Schwartz single factor model is a more accurate representation than the Black–Scholes model, its shape is still relatively simple. Even though a volatility function of this type describes the attenuation of typical market forward volatility term structures, the volatility parameters tend to zero for longer dated maturities. While market volatilities of forward energy prices do decrease as maturities increase, they typically do not approach zero and therefore the Schwartz model has a problem when pricing options on long maturity forward contracts.

5.2.12 Correlation

The volatility of a spread is less than the sum of the volatilities of the individual components, and should be considered in the pricing of spread options. Although there is typically a term structure of correlation similar to the term structures for forward prices and volatility, the correlation (or rho as it is typically called) between the volatilities is defined as a constant term in this case study. The correlation between

two assets is captured by:

$$\xi_{1,t} = \varepsilon_{1,t} \tag{5.14}$$

$$\xi_{2,t} = \rho\varepsilon_{1,t} + \varepsilon_{2,t}\sqrt{1-\rho^2} \tag{5.15}$$

where $\xi_{1,t}$ and $\xi_{2,t}$ are two independent random numbers from a standard normal distribution, and ρ is the correlation between the two assets.

5.2.13 Simulating mean reversion

A Monte Carlo simulation simulates possible future values of an underlying asset using a stochastic process based on assumptions of the behavior of the relevant market variables. The advantages of Monte Carlo simulation are that it can facilitate accuracy in the modeling of market price behavior by including factors such as jumps, seasonality, stochastic volatility and possible future structural changes in the market. The disadvantages are its relative complexity in implementation and the resources required for computation.

The mean reverting spot price model in equation (5.9) can be specified in terms of the natural logarithm of the spot price, $x = \ln(S)$:

$$dx = \left[\alpha\,(\mu - x) - \tfrac{1}{2}\sigma^2\right]dt + \sigma\,dz \tag{5.16}$$

which can be discretized as:

$$\Delta x_i = \left[\alpha\,(\mu - x_i) - \tfrac{1}{2}\sigma^2\right]\Delta t + \sigma\sqrt{\Delta t}\varepsilon_i \tag{5.17}$$

In contrast to the GBM model the discretization in this specification is only correct in the limit of the time step tending to zero, as the drift term is dependent on the variable x. Time steps that are relatively small to the speed of mean reversion should therefore be chosen. To simulate the path of the spot price, the parameters α, μ, σ and Δt are chosen or estimated, normally distributed random numbers ε_i are repeatedly generated and new values of Δx are calculated, from which a new spot price at each time step is then derived.

5.2.14 Estimating the mean reversion rates

Two methods can be used to estimate the mean reversion rate α, either through linear regression using spot price data or by fitting the single factor volatility function to the empirical volatility term structure. The simple mean reverting process for the natural logarithm of the energy spot price:

$$dx = \alpha\,(\bar{x} - x)\,dt + \sigma\,dz \tag{5.18}$$

is essentially the same as equation (5.16) but with the $-1/2\sigma^2$ included in $\bar{x}$. This can be discretized as:

$$\Delta x_t = \alpha_0 - \alpha_1 x_t + \sigma \varepsilon_t \tag{5.19}$$

where $\alpha_0 = \alpha \bar{x} \Delta t$ and $\alpha_1 = \alpha \Delta t$. Observations of the spot price through time imply the linear relationship between Δx_t and x_t with the noise term $\sigma \varepsilon_t$. Regressing observations of Δx_t against x_t obtains $\alpha_0 = \alpha \bar{x} \Delta t$ and $\alpha_1 = \alpha \Delta t$ as estimates of the intercept and slope of this linear relationship. As the time interval between observations Δt is known, estimates of α and $\bar{x}$ can therefore be obtained.

An alternative is to estimate α, the mean reversion rate, from the term structure of volatility. Figure 5.7 compares the volatility of short-term energy forward contracts versus long-term energy contracts, with short-term contracts being more volatile than long-term contracts, and the volatility declining as the maturity increases. Equation (5.20) represents this decline in the volatility as t gets large:

$$\sigma_1(t, T) = \sigma e^{-\alpha(T-t)} \tag{5.20}$$

where $n = 1$. The mean reversion rate of the spot energy price can be estimated through the relationship between the spot price process and single factor model described in Section 5.2.8. The negative exponential function in equation (5.20) can be fitted to the volatility curves illustrated in Figure 5.7. The volatility function $\sigma e^{-\alpha(T-t)}$ is set as equal to the observed volatility $\sigma(t, T)$ by minimizing the square root of the squared differences between the two curves and solving for α.

Table 5.6 illustrates the alpha parameters derived from the complete power and natural gas volatility term structures. The volatility term structures for the actual data and the volatility functions are compared in Figures 5.9 and 5.10. While the power volatility term structures compare favorably, the natural gas term structures do not. The initial steeper attenuation in the short dated natural gas volatility term structure has a relatively stronger implied mean reversion. Reducing the volatility term structure sample size to one year will give a higher estimate of α; however, the volatility for longer dated forwards in the single factor model converges to zero too quickly (see 'Volatility function 2' in Figure 5.10). This implies that the single factor model can underestimate the volatility of longer dated natural gas forward contracts and can therefore give a downward bias to options priced on these parts of the curve.

Table 5.6 Estimation of the power and natural gas alpha parameters

	Power			Natural gas			Natural gas: one year		
	Spot σ 60.00% α 0.1081 $\Sigma\varepsilon$ 0.1613			Spot σ 53.00% α 0.1712 $\Sigma\varepsilon$ 0.7723			Spot σ 53.00% α 0.5117 $\Sigma\varepsilon$ 0.0334		
	Power	Volatility function	Difference	NG	Volatility function	Difference	NG	Volatility function	Difference
Month	%	%	%	%	%	%	%	%	%
Jan. 12	59.08	59.73	−0.65	52.80	52.62	0.18	52.80	51.86	0.94
Feb. 12	58.58	59.21	−0.63	50.30	51.89	−1.59	50.30	49.76	0.54
Mar. 12	58.08	58.69	−0.61	47.90	51.18	−3.28	47.90	47.74	0.16
Apr. 12	57.58	58.16	−0.58	45.50	50.45	−4.95	45.50	45.75	−0.25
May 12	57.08	57.64	−0.56	43.20	49.74	−6.54	43.20	43.83	−0.63
Jun. 12	56.59	57.12	−0.53	40.90	49.03	−8.13	40.90	42.00	−1.10
Jul. 12	56.09	56.61	−0.52	38.80	48.33	−9.53	38.80	40.24	−1.44
Aug. 12	55.59	56.09	−0.50	37.20	47.63	−10.43	37.20	38.53	−1.33
Sep. 12	55.10	55.59	−0.49	36.50	46.96	−10.46	36.50	36.91	−0.41
Oct. 12	54.61	55.09	−0.48	36.00	46.29	−10.29	36.00	35.37	0.63
Nov. 12	54.12	54.59	−0.47	35.00	45.63	−10.63	35.00	33.89	1.11
Dec. 12	53.63	54.10	−0.47	34.10	44.98	−10.88	34.10	32.47	1.63
Jan. 13	53.14	53.61	−0.47	33.10	44.33	−11.23			
Feb. 13	52.66	53.14	−0.48	32.10	43.73	−11.63			
.....	.....	.....	.....	.....	.....	.....			
Dec. 26	14.67	11.90	2.77	10.00	4.08	5.92			

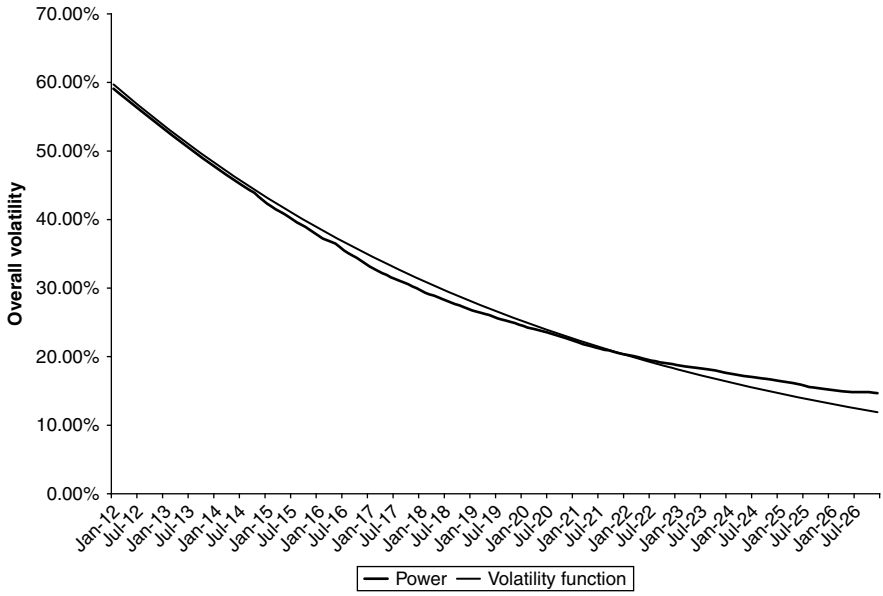

Figure 5.9 Power volatility and volatility function term structures

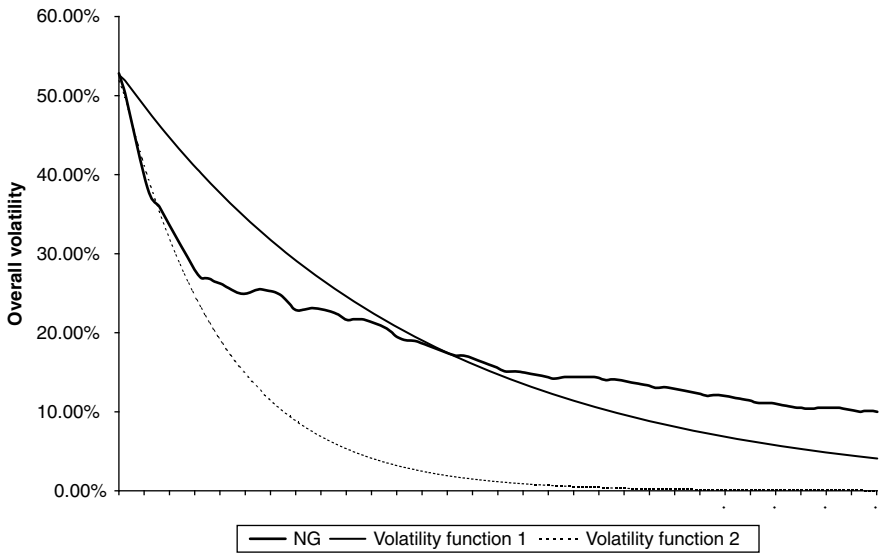

Figure 5.10 Natural gas and volatility function term structures

5.2.15 The half-life of a mean reverting process

A key property of a mean reverting process is the half-life. This is the time taken for the price to revert half way back to its long-term level from its current level if no more random shocks arrive. Ignoring the randomness allows a focus on the mean reverting behavior alone. The half-life, denoted by $t_{1/2}$, can be derived as:

$$t_{1/2}=\ln(2)/\alpha \tag{5.21}$$

The half-lives of power and natural gas are:

- *Power*: The value of 0.1081 for α_{power} implies a half-life for price shocks of 6.4 years.
- *Natural gas*: The value of 0.1712 for $\alpha_{n\ gas}$ implies a half-life for price shocks of 4 years.

These half-lives are averages over a long time period, representing the time that shocks to the spot price take to decay to half their deviation from the long-term level. Table 5.7 illustrates the range of half-lives for various values of alpha.

5.2.16 Pricing the energy spread option

A sample of the results of the Monte Carlo simulation for the call spread options is illustrated in Table 5.8. The switching real options on SPS are priced as a series of European call spread options with payoffs as specified in equation (5.6). The pricing data consisted of the power and natural gas monthly forward and volatility curves, and the start-up costs as the strike K for each month. The power and natural gas forward prices for each month were used for the mean parameter μ, and the α parameters were derived in Section 5.2.14. The 10% correlation between the two assets, defined as rho, was estimated from spot price returns.

Table 5.7 Mean reversion rates and the corresponding half-lives

a	$t_{1/2}$
1	8 months
10	25 days
100	2.53 days
1000	6 hours

Source: Clewlow and Strickland (2000).

Table 5.8 Monte Carlo simulation of the two-asset energy spread option (as on 31 December 2011)

Month	Jan. 12	Feb. 12	Mar. 12	Apr. 12	May 12	.....	Aug. 26	Sep. 26	Oct. 26	Nov. 26	Dec. 26
Power curve	36.02	36.00	37.00	44.36	45.36	.....	61.93	59.40	39.98	38.57	37.88
NG*Heat rate	40.00	38.80	37.50	36.10	35.90	.....	35.80	33.70	34.00	36.50	37.80
Power σ	59.08%	58.58%	58.08%	57.58%	57.08%	.....	14.83%	14.83%	14.83%	14.75%	14.67%
NG σ	52.80%	50.30%	47.90%	45.50%	43.20%	.....	10.00%	10.10%	10.10%	10.10%	10.00%
Correlation ρ	10%	10%	10%	10%	10%	.....	10%	10%	10%	10%	10%
Time to maturity (T)	0.04	0.12	0.20	0.29	0.37	.....	14.63	14.72	14.80	14.88	14.97
Start-up costs	1.04	1.04	1.04	1.04	1.04	.....	0.15	0.12	1.04	1.04	1.04
Strike (K)	1.04	1.04	1.04	1.04	1.04	.....	0.15	0.12	1.04	1.04	1.04
Alpha (α) power	0.1081	0.1081	0.1081	0.1081	0.1081	.....	0.1081	0.1081	0.1081	0.1081	0.1081
Mean (μ) power	3.58	3.58	3.61	3.79	3.81	.....	4.13	4.08	3.69	3.65	3.63
Alpha (α) gas	0.1712	0.1712	0.1712	0.1712	0.1712	.....	0.1712	0.1712	0.1712	0.1712	0.1712
Mean (μ) gas	3.69	3.66	3.62	3.59	3.58	.....	3.58	3.52	3.53	3.60	3.63
Interest rate (r)	1.8419%	1.9251%	1.9052%	1.9318%	1.9521%	.....	6.3681%	6.3724%	6.3767%	6.3809%	6.3850%
dt	0.0001	0.0002	0.0003	0.0005	0.0006	.....	0.0244	0.0245	0.0247	0.0248	0.0249
Number of time steps	600	600	600	600	600	.....	600	600	600	600	600
Number of simulations	10,000	10,000	10,000	10,000	10,000	.....	10,000	10,000	10,000	10,000	10,000
MR spread option price	0.66	2.30	4.21	10.95	13.04	.....	11.41	11.01	3.52	2.50	2.04
Energy – MWh	300	300	300	300	300	.....	300	300	300	300	300
Total hours	384	336	352	352	384	.....	552	552	352	368	368
Total option cash flows	76,513	232,082	444,185	1,156,524	1,502,223	.....	1,889,564	1,823,780	371,295	275,497	224,802
O & M costs	1.50	1.50	1.50	1.50	1.50	.....	1.50	1.50	1.50	1.50	1.50
Total O & M costs	172,800	151,200	158,400	158,400	172,800	.....	248,400	248,400	158,400	165,600	165,600
df	0.9992	0.9976	0.9961	0.9945	0.9928	.....	0.3938	0.3915	0.3891	0.3868	0.3845
PV O & M costs	172,665	150,842	157,785	157,522	171,552	.....	97,819	97,238	61,638	64,058	63,678
Net present value	–96,152	81,240	286,399	999,002	1,330,671	.....	1,791,745	1,726,542	309,657	211,440	161,124
Total value	=	$266,636,868									

It was assumed that the generator would run continuously during the weekdays for the summer months of July, August and September, and be started up each weekday for the remaining months of the year. This is reflected in the per MWh start-up costs for each month. The middle of each month is used as the maturity or expiry date for each spread option. The interest rate used for each month was derived as a term structure of zero coupon rates from USD LIBOR, Eurodollar futures and interest rate swaps. Although in academic derivative valuations a risk-free interest rate such as a Treasury Bill rate is typically used in option pricing, most organizations borrow at interest rates that are much closer to LIBOR than Treasury Bill rates.

The price paths for the two assets, power and natural gas, were simulated from t_0 to T, the maturity or expiry for each European call spread option (in this case the middle of each month). Ten thousand simulations were used for each of the 180 European spread options. The payoff for the spread option at T, as defined in equation (5.6) is then derived for each simulation and added to an incremental sum of the payoffs. The value of each call spread option is the expected value of the total payoffs simulated for each T; that is, the sum of the payoffs simulated for each month divided by the number of simulations.

The single factor model used in this case study is a relatively simple model for the forward curve. While the volatility structure under the Schwartz single factor model is more realistic than the Black–Scholes model, it still has a relatively simple shape, and the volatilities tend to zero for longer maturities. The single factor model in Section 5.2.11 can be generalized and modified, as illustrated in Section 5.2.14, to include multiple sources of uncertainty in the forward curves. Clewlow and Strickland (2000) value energy options in a general multi-factor model for the forward curve, which can capture multiple sources of uncertainty. As spread options depend simultaneously on forwards related to separate energies, Clewlow and Strickland extend the multi-factor model to a specification that can simultaneously model a number of different energy forward curves, and therefore capture the multiple dynamics of the forward curves in the valuation of spread options.

5.2.17 Implications for energy analysis and valuation

The DCF valuation of SPS is \$136,874,152, while the spread option valuation approach is \$266,636,686 using the NG alpha of 0.1712. While the DCF method does capture the intrinsic value, it does not account for the value in the volatility in the spark spread. Figure 5.11

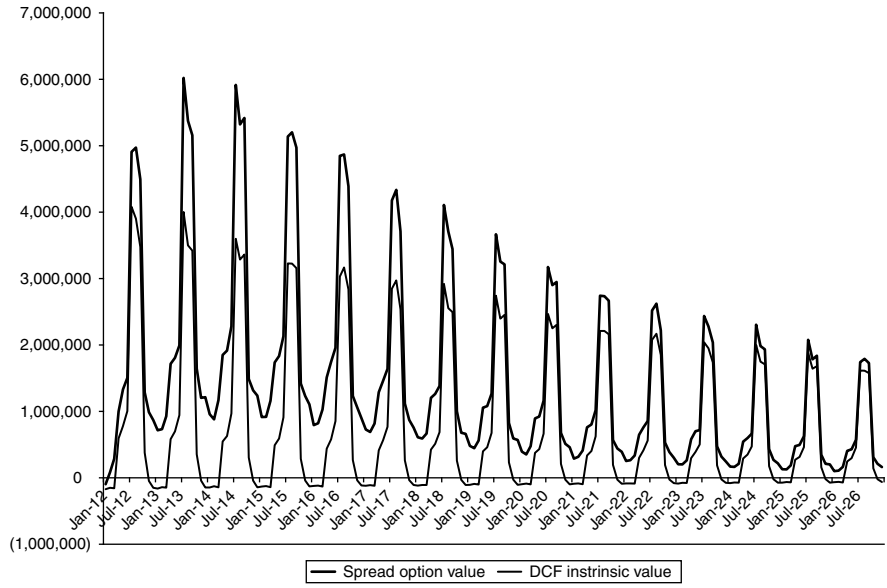

Figure 5.11 Spread option and DCF intrinsic values by month

compares the spread option values and the DCF intrinsic values by month.

SPS is essentially an out-of-the-money option for at least part of the year. Although the spark spread can be negative, as is the case from January to March, the relatively large volatility associated with the energy markets implies that there is time value in the option, as there is some probability that the spark spread can be positive in these months. Consequently the DCF valuation of SPS is likely to understate the true long-term value that SPS will offer to EC.

EC can also maximize value by considering the natural gas power generator as an asset that can be traded through its option value. A number of factors can have an influence on the value of natural gas power generator. The 15-year life used for the power plant in this case study is arbitrary, and can feasibly be extended to value a new power plant. A benchmark for the cost of building a natural gas power plant is USD $500,000 per MW. For the 300 MW used for the generator in this case study the cost to build would be USD $150,000,000 million. The value captured by including the volatility in the valuation will therefore have a significant impact on management decisions such as whether to build, divest, or shut down a generator. Another driver of value that will influence decisions is the heat rate, the efficiency at

which natural gas is converted into electricity. New natural gas generators will typically have lower heat rates than older plants, which will produce a relatively wider spark spread, and therefore have a competitive advantage over older generators.

5.3 The pharmaceutical industry

5.3.1 Overview

The pharmaceutical (pharma) industry dominates the health care sector with a market capitalization of over $1.5T, while the biotechnology (biotech) industry is a significant component of the sector with a market capitalization of nearly $200B. Both industries focus on the discovery, development, manufacturing and sale of prescription drugs and have drivers that are both similar and unique to the industries. These include a focus on innovation and patents, drug licensing and a significant regulatory and political environment.

There are, however, some significant differences between the two industries. Pharmaceutical drugs are generally based on chemicals defined as small molecules, while biotech drugs are derived from living organisms such as proteins and are defined as large molecules. The biotech industry also typically focuses on diseases that have no known cures. While both industries are involved in many types of innovation, the discovery and development of new chemical and biotech drugs is generally the most significant.

The drug industry is research and development (R&D) intensive, as it is essential for firms to have a pipeline of new drugs in development due to the revenue constraint imposed by the life of a drug's patent. A drug patent typically has a duration of 20 years, during which a drug firm has exclusive rights on the patent. With an average of ten years in development, drug firms therefore have around ten years to recover a drug investment and make a profit. Once the patent expires other firms can sell the drug, described as a generic, with off-patent drugs potentially losing up to 80% or more in revenues.

The drug value chain follows a discovery, development and commercialization process, with all healthcare products regulated to some extent in their manufacture, testing and use. Alliances have become fundamental to pharmaceutical and biotechnology business models to minimize the risks associated with bringing drugs to market. Firms now rely on these partnerships for multiple stages in their value chains. For large pharmaceutical firms these partnerships provide a source of innovation and the ability to outsource R&D, while providing access

to capital, technical expertise and global reach for biotech companies. Managing a portfolio of strategic alliances is therefore a critical component of the industry innovation processes and value strategies.

A drug has two life cycles: a development life cycle before the drug's market launch, and the product life cycle once the drug is released for commercial sale. The development life cycle can last up to 10 to 15 years and is divided into a number of stages that a drug has to follow before entering the market. The commercialization process starts with the product approval, with marketing expenses, typically the largest component of a drug's commercialization costs, spread over the life of the drug's patent.

5.3.2 New drug development

The drug development process follows a number of stages over which drug firms organize evidence to present to regulators that a drug can be safely, effectively and reliably manufactured for the intended medical condition. Drug firms also have to make decisions as to whether to abandon or to continue a drug's development using the technical and market information available at the start of each stage. In general drugs go through the following stages in the United States before reaching the market:

1. ***Discovery:*** significant resources are applied to the development of new molecular entities (NME), with many abandoned at this stage.
2. ***Pre-clinical:*** NMEs are screened for activity and toxicity. An Investigational New Drug application (IND) is then filed with the Food and Drug Administration (FDA) by the drug firm if the NME has the potential for further development. Once the Investigational New Drug application is approved the drug firm can continue development through the testing of the drug in clinical trials.
3. ***Clinical trials:*** generally have three consecutive phases:
   - ***Phase I*** – tests are performed on a small number of volunteers to gather information on the drug's toxicity and to establish safe dosages. Data on the compound's absorption, distribution, metabolic effects, toxicity and excretion is also compiled.
   - ***Phase II*** – trials are performed on subjects with the disease or condition for which the drug is intended and are designed to obtain evidence and data on safety and efficacy.
   - ***Phase III*** – large-scale trials designed to further establish effectiveness are conducted on patients. The large sample size of these trials is designed to approximate the drug's intended use and uncover any potential side effects.

4. ***FDA filing and review:*** Once the clinical development phases are finalized and sufficient evidence has been compiled for approval, the drug firm submits either a New Drug Application (NDA) or a Biological License Application (BLA) to the FDA for review. Marketing can start for approved uses once the notification is received from the FDA.
5. ***Post-approval:*** The drug firm performs additional research in support of marketing and product extensions as it collects revenues from sales of the new drug.

5.3.3 Valuation

The pharma and biotech industries' unique value drivers present a range of issues in regards to valuation. The three most common valuation approaches used in drug valuations are the discounted cash flow, expected net present value and real options methods, and all require assumptions in regards to revenues, development costs, probabilities of success, development phase durations, the cost of capital and other cash flow parameters.

The trends in these factors over the last 20 years include the increasing uncertainty in revenues, the increasing development costs and the decrease in the success probabilities for drug development. DiMasi et al. (2003) observed that average clinical phase costs have increased by a factor of five in real terms since the authors' previous study (1993). These trends are having an influence on the cost of capital for the pharma and biotech industries, and on investments in R&D generally.

The following data is drawn from various sources to illustrate the valuation methods.

5.3.3.1 The revenues

Myers and Howe (1997) defined five categories for the quality of drugs that reached the marketing stage, with probabilities for each drug quality of 10% with the exception of 60% for an average quality. Myers and Howe also found the revenues for the quality categories to be highly skewed.

Table 5.9 illustrates the five drug quality categories, the annual revenue assumptions for each category and the quality probabilities. The Myers and Howe revenues ramp up after launch, with assumed annual peak revenues for breakthrough drugs of $1.3 billion a year, which compares to $7.4 million for below average drugs and $6.6 million for dogs.

The Myers and Howe (1997) revenues are in 1994 dollars, and were inflated to 2010 for the valuation illustrations using GDP data.

Table 5.9 Revenues by quality category (USD $000)

Drug quality	Launch 1	Launch 2	Launch 3	Launch 4	Launch 5	Probability(%)
Dog	110	3,310	6,620	6,620	6,620	10
Below average	100	3,720	7,440	7,440	7,440	10
Average	1,100	33,100	66,200	66,200	66,200	60
Above average	44,130	209,620	413,720	661,960	661,960	10
Breakthrough	44,130	275,820	772,290	1,323,920	1,323,920	10

Source: Myers and Howe (1997).

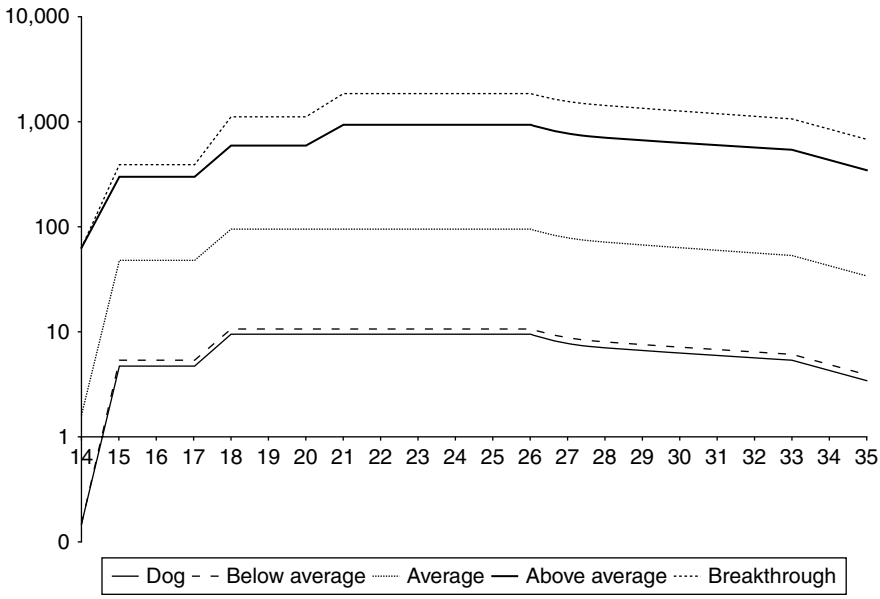

Figure 5.12 New drug revenue streams by quality category
Note: USD M, inflated to 2010, log scale
Sources: First 13 years: Myers and Howe (1997); remaining years: U.S. Congress, Office of Technology Assessment (1993), GDP inflation index.

Figure 5.12 shows the timeline for new drug revenues, with Myers and Howe (1997) data for the first 13 years and the following years sourced from the Office of Technology Assessment 1993 report (U.S. Congress), with both adjusted for inflation.

A drug's product life cycle typically peaks just before the expiry of its patent. Generic versions of the drug can be marketed once the patent expires, with revenues for the off-patent drug generally falling.

5.3.3.2 *The research and development costs*

New drug discovery and development is a long and expensive process. Information on the costs of drug innovation is therefore essential for the valuation of drug investments. As with any investment analysis, both the amounts and timing of expenditures need to be identified, as R&D outlays have both an opportunity and a direct cost. The probabilities of a drug's success are factors that account for the risk associated with each development stage. These success probabilities are used to scale the cash flow estimates for each stage.

Table 5.10 shows for each drug development and commercialization stage:

- the pre-tax cost assumptions,
- the duration of each stage, and
- the probability of success for the completion of each stage conditional on completion of the previous stages.

Total costs are out-of-pocket and full time employee combined. The cost for each stage is equally weighted to each year when a stage has a duration longer than a year, and weighted within the relevant year for the half-year durations.

Table 5.11 shows the additional cash flow assumptions.

5.3.3.3 *The cost of capital*

Most of the weight in the pharma industry's cost of capital consists of equity, with debt typically making up less than 10% of market valuations.

Table 5.10 R&D stage (pre-tax) costs, durations and conditional success probabilities

Stage	Cost ($000)	Duration (yrs)	Probability(%)
Discovery	13,500	4.5	51
Pre-clinical	5,000	1	69
Clinical:			
Phase I	15,000	1.5	54
Phase II	40,000	2.5	34
Phase III	150,000	2.5	70
FDA filing	40,000	1.5	91
Launch	44,275	9	100

Sources: Paul, S., Mytelka, D., Dunwiddie, C., Persinger, C., Munos, B., Lindborg, S., and Schacht, A. (2010); Launch costs: Myers and Howe (1997) inflated to 2010.

Table 5.11 Additional cash flow parameters

Parameter	% revenue assumption	Source
Cost of sales	20	Industry estimate*
Marketing expense:	100	Myers and Howe
year 1 post launch	50	
year 2 post launch	25	
year 3–4 post launch	20	
year 5–13 post launch		
General and admin expenses	11.1	U.S. Congress
Working capital	17	U.S. Congress
Tax rate (% operating profit)	35	Myers and Howe
Revenue Inflation adjustment	–	–

* from public financial reports.

DiMasi et al. (2003) found an average real rate of 11.1% and an average nominal rate of 15.1% for the pharmaceutical industry's cost of capital from 1985 to 2000. Myers and Shyam-Sunder (1996) analyzed the cost of capital for smaller biotech firms. These firms typically have fewer commercialized products and more early-stage R&D projects than large pharma firms, which was reflected in the study results, with an average cost of capital nominal rate of 19% and a real rate of 14%. DiMasi et al. (2007) found a downward trend in the cost of capital for biopharmaceutical firms, with real and nominal costs of capital from 12.5% and 17% in 1994 to 10% and 13% by 2004.

Drug valuation can also be framed as a compound option, where a firm has a series of call options during drug development with the exercise price equivalent to the future R&D costs. Myers and Howe (1997) reduced this valuation problem to two discount rates, with a higher discount rate for the net revenues and a lower discount rate for future costs. The two real discount rates were specified as 6.0% and 9.0% for R&D costs and revenues respectively. Adding a five-year GDP inflation average estimate of 1.9% to the real discount rates yields nominal discount rates of $r_d = 7.9\%$ for the R&D stage, and $r_c = 10.9\%$ for the commercialization or revenues stage.

Large pharma firms typically bundle their R&D projects into portfolios of later stage marketed products. This implies that the cost of capital and therefore the hurdle rate or required return on R&D investments should be actually higher. An alternative source for the market's cost of capital expectations for individual R&D investments are smaller biotech firms or the rates of return used by venture capitalists. Stewart et al. (2001) argue that a 20% discount rate should be for biotechnology

firms, as this is the general benchmark hurdle rate used by venture capital and pharmaceutical firms, the main sources of biotech capital.

5.3.4 DCF valuation

The discounted cash flows method is a standard valuation technique used in drug valuations. The DCF method nets the present value of revenues and costs, and if the value is positive then the drug is profitable and adds value. One issue with pharma and biotech valuations is that the revenue and cost cash flows are not the same in terms of timing or likelihood. In a DCF analysis all risk is reflected in the discount rate. In the past a number of researchers observed that the net present value of new drug development investment was approximately zero.

Table 5.12 illustrates a DCF valuation of a NME drug in the discovery stage using the data in Tables 5.9, 5.10 and 5.11.

The cash flow assumptions include:

- a cost of capital of 11%, which reflects all risk in the example,
- the present value of the R&D costs, which assume a 100% probability for each development stage, and
- the NPV for the launch stage, which is derived from:
  - the revenues for each drug quality from year 14 minus taxes, marketing, general and administration costs and other expenses, and

Table 5.12 NPV of a drug at the discovery stage ($000)

Drug phase		R&D NPV	
	Discovery	(10,494)	
	Pre-clinical	(13,386)	
	Phase I	(21,005)	
	Phase II	(37,525)	
	Phase III	(85,247)	
	FDA Filing	(95,557)	
Quality of drug		Quality prob (%)	Revenue NPV
	Dog	10	4,168
	Below average	10	4,687
	Average	60	37,148
	Above average	10	344,353
	Breakthrough	10	664,169
	NPV:		124,026

– the sum of the product of the net revenue for each drug quality scaled by the probability for that drug quality.

The NPV of the drug is therefore the sum of the present value of the (negative) R&D costs and the NPV of the launch net revenues:

$$(95,557,000) + 124,026,000 = 28,469,000.$$

5.3.5 The ENPV method

The expected net present value (ENPV) or risk-adjusted net present value (rNPV) method is used extensively in the pharma and biotech industries for drug valuations. The method includes risk as a probability in the valuation of future cash flows. Multiplying the discounted cash flows with their success probability estimates derives the expected values.

ENPV can be specified for drug valuations as:

$$ENPV = \sum_{i=1}^{7} \rho_i \sum_{t=1}^{T} \frac{DCF_{it}}{(1+r)^t} + \rho_7 \sum_{j=1}^{5} q_j \sum_{t=1}^{T} \frac{CCF_{jt}}{(1+r)^t} \tag{5.22}$$

where:

- $i = 1, \ldots..$n is the index for each drug stage (discovery to launch),
- p_i is the probability for each drug end stage i,
- DCF_{it} is the expected development stage cash flow at t,
- $j = 1, \ldots.5$ is the index for the drug quality,
- q_i is the probability for drug quality j,
- CCF_{jt} is the expected commercialization cash flow at t for drug quality j,
- r is the discount rate for the development and commercialization cash flows,
- T is the maturity for all future cash flows.

Table 5.13 illustrates the ENPV results for a discovery phase NME drug using a cost of capital of 11%.

The calculations are:

1. ρ_i represents:
   – the probability at the R&D phase, derived as one minus the probability of success, or probability of failure, times the product of the success probabilities for the previous stages, and
   – for the approval stage the product of the probabilities of success from Table 5.10.

Table 5.13 ENPV of a NME drug in the discovery phase ($000)

Phase:	*i*	*j*	1 ρ_i (%)	2 q_j (%)	3	4	5
Discovery	1		49.0		(10,494)		(5,142)
Pre-Clinical	2		15.8		(13,386)		(2,116)
Clinical Phase I	3		16.2		(21,005)		(3,400)
Clinical Phase II	4		12.5		(37,525)		(4,706)
Clinical Phase III	5		1.9		(85,247)		(1,652)
NDA submission	6		0.4		(95,557)		(389)
Launch:	7						
Dog		1	4.12	10	(95,557)	4,168	(376)
Below average		2	4.12	10	(95,557)	4,687	(374)
Average		3	4.12	60	(95,557)	37,148	(1,442)
Above average		4	4.12	10	(95,557)	344,353	1,024
Breakthrough		5	4.12	10	(95,557)	664,169	2,340
ENPV:							(16,235)

2. q_j is the probability for each of the drug qualities.
3. is the cumulative sum of the present value of the development costs at each stage.
4. is the commercialization phase NPV, or revenues net of cost of sales, general and administration costs, marketing expenses and taxes for each drug quality revenue stream.
5. is the sum of columns 3 and 4 multiplied by column 1 and for revenues columns 1 and 2, the total of which derives the ENPV of ($16,235,000).

5.3.6 The real options method

Biotech firms often have a significant premium over book value, or high discounted cash flow valuation well before a drug finally reaches the market. This premium can be defined as a growth option, where a biotech firm's R&D expenditure is an asset that although has no current cash flows does have the probability of growth.

The market value of a firm can also be framed as having two components: the assets-in-place and the growth options. A firm's value is derived from both the expected profitability from current products and the growth potential from drugs in development.

The concept of growth options can be applied to the optimal capital structure for pharma firms. Well over half of the value of a large pharma firm is derived from growth options, with the remainder consisting of the current products or the assets-in-place. As R&D is the driver of value or a substantial source of expected future cash flows, a

pharma firm needs either sufficient equity or access to equity capital to maintain its R&D programs. Major pharmaceutical firms maintain low debt levels as a result, with biotech firms carrying almost no debt, as R&D expenditure is the principal driver of value.

The value of a NME drug project is illustrated using a real options approach. Kellogg and Charnes (2000) specified a binomial tree to derive a biotech firm's growth option. The value of the growth option was derived by adding a second binomial tree representing a research phase NME, with the second option value added to the end branch of the initial NME binomial tree.

The variables used in the binomial tree are:

- the asset value A at t_0,
- the asset's standard deviation σ,
- the exercise price amount and timing,
- the probability of moving to the next development phase, and
- the risk free rate r.

The binomial tree's asset value A is derived as the expected commercialization cash flow values discounted at a 11% cost of capital at t_0:

$$A = \sum_{j=1}^{5} q_i \sum_{i=1}^{T} \frac{CCF_{jt}}{(1+r_{coc})^t} \tag{5.23}$$

The asset volatility is specified as the standard deviation $\sigma = \ln\left(h/A\right)^{1/l}$, with h representing the maximum value at node (i,j) for the value of the asset, where $j =$ asset level and $i = l = T$.

$$h = \max_j \left\{ \sum_{t=1}^{T} \frac{CCF_{jt}}{(1+r_{coc})^t} (1+r_{COC})^l \right\} \tag{5.24}$$

The underlying asset A follows a binomial process, and at any time can only change in either one of two possible values. For a time period Δt the asset A can move to up to uA or down to dA, with u and d determining the volatility and average behavior of the asset. The parameters u and d are derived as:

$$u = e^{\sigma\sqrt{\Delta t}} \quad \text{and} \quad d = \frac{1}{u} \tag{5.25}$$

The payoffs for each node within the binomial tree are:

$$P_k = Max\left[E_k(\theta_t) - DCF_t, 0\right] \tag{5.26}$$

where θ_t is the probability at t of continuing to the following t, and DCF_t represents the R&D cost at t. The binomial risk neutral probabilities are derived as:

$$p = \frac{e^{r\Delta t} - d}{u - d} \tag{5.27}$$

where r is the risk free rate.

The value $V_{t,k}$ represents the option value for each t and k within the tree, with each payoff value adjusted by the probability of success θ_t at each development phase, and DCF_t the equivalent to the exercise price for each Δt.

$$V_{t,k} = \max\left\{\left[V_{t+1,k}\rho + V_{t+1,k+1}(1-\rho)\right]e^{-r\sqrt{\Delta t}}\theta_t - DCF_t, 0\right\} \tag{5.28}$$

Two scenarios for the cash flow assumptions in the valuation are illustrated:

- 100% probabilities of success in the development stage cash flows for the R&D pre-commercialization costs, and
- the actual probabilities of success from Table 5.10.

Table 5.14 shows the binomial tree and parameters for the commercialization cash flow asset. Table 5.15 shows the NME drug call option payoffs with the success probabilities equal to one, and Table 5.16 the NME drug call option payoffs with the probabilities of success.

For the 100% probabilities of success in the R&D stages, the value of the option on the NME drug is $30,652,000. If the probabilities of success are included, the option on the NME drug has a zero value, or is out-of-the-money. The tree is most sensitive at the phase II probability of 34%.

5.4 A growth firm

5.4.1 Overview

One approach often used by investors is to develop a top-down framework to arrive at the decision to invest in a firm. The framework builds on a general outlook for the economy and capital markets, identifies industries expected to prosper within the framework, and then focuses on specific firms operating within those industries. Industry sectors are generally defined through the products they create or the services on offer. Industries are also identified by their response to economic and business cycles, typically defined as growth, defensive or cyclical. The

Table 5.14 The 14 step Binomial Tree for the commercialization cash flow asset ('000)

A at t_0	h	T	σ	r	df	dt	u	d	p	1−p
188,281	3,482,109	9	32%	1.89%	0.9813	1	1.383	0.723	0.449	0.551
Year	0	1	2	3	4	5	6	7	8	9
R&D costs		5,000	10,000	13,000	16,000	16,000	60,000	60,000	43,333	26,667
Asset tree	188,281	260,368	360,056	497,911	688,547	952,171	1,316,731	1,820,869	2,518,028	3,482,109
		136,152	188,281	260,368	360,056	497,911	688,547	952,171	1,316,731	1,820,869
			98,456	136,152	188,281	260,368	360,056	497,911	688,547	952,171
				71,197	98,456	136,152	188,281	260,368	360,056	497,911
					51,485	71,197	98,456	136,152	188,281	260,368
						37,230	51,485	71,197	98,456	136,152
							26,922	37,230	51,485	71,197
								19,469	26,922	37,230
									14,078	19,469
										10,181

Table 5.15 The Binomial Tree NME drug call option payoffs with success probabilities equal to one ('000)

Probabilities	1	1	1	1	1	1	1	1	1	1
Option Tree	0	1	2	3	4	5	6	7	8	9
	30,652	67,161	144,353	278,246	477,939	753,851	1,130,931	1,692,670	2,448,527	3,455,442
		2,012	15,929	58,906	149,448	299,590	502,747	823,972	1,247,230	1,794,202
			–	–	11,312	62,048	174,256	369,711	619,046	925,505
				–	–	–	2,482	132,169	290,555	471,244
					–	–	–	7,953	118,780	233,702
						–	–	–	28,955	109,485
							–	–	–	44,530
								–	–	10,564
									–	–
										–

Table 5.16 The Binomial Tree NME drug call option payoffs with the probabilities of success ('000)

Probabilities	1	0.69	1	0.54	1	0.34	1	1	0.7	0.91
Option Tree	0	1	2	3	4	5	6	7	8	9
	–	–	–	1,041	59,071	130,754	660,517	1,039,397	1,542,333	3,142,052
		–	–	–	–	32,370	260,364	486,037	777,107	1,630,324
			–	–	–	–	51,115	196,673	376,954	839,809
				–	–	–	–	45,358	167,705	426,432
					–	–	–	–	58,284	210,268
						–	–	–	1,066	97,232
							–	–	–	38,122
								–	–	7,213
									–	–
										–

industry life cycle considers an industry's viability over time, with the four stages of pioneer, growth, mature and decline indicating a phase in an industry's evolution.

The term 'growth' as used in investment analysis has a range of interpretations. Growth is applied typically to sales, earnings and assets. Generally, however, growth describes the capability to create value. A growth firm is able to grow sales and earnings regardless of its stage in the business cycle. A growth industry is identified typically with new technologies and products. Growth firms can have annual growth rates that exceed 12% to 15%, and while earnings will be typically steady or growing, these firms will generally consume cash, with investments exceeding cash generated internally.

Growth fundamentals are not the same for all firms. Three attributes can be identified that differentiate growth firms. The classic growth firm typically has innovative products or technologies in markets where demand is yet to be determined. The market share growth firm is located within a mature industry where growth is derived from increasing market share. A consolidating firm grows through acquisitions, typically in mature and fragmented industries, where cost synergies and valuations are the focus.

5.4.2 The valuation of growth

The value of a firm is equal to the sum of the value of its debt and equity, or the value to all claimants on the firm. Summing the claims on the firm therefore represents the firm's value. The valuation of equity can be based on earnings, cash flow or assets. Earnings, or the income statement's net income, is the fundamental bottom-line metric for

shareholder value. Growth is typically framed as a firm's capacity to grow earnings. The issue with growth in earnings for valuation, however, is that a firm can create growth in earnings though investment and accounting techniques that do not add value.

The valuation of equity based on the present value of future free cash flows focuses on the cash flow from operations with capital expenditure deducted. Cash flow from operations is the total cash flow derived from operations. Free cash flows will generally fluctuate over the life cycle of a product or firm and are analyzed in three life cycle phases. During the growth phase, cash flow from operations is usually down while new products are being established and investments consume cash. The maturity phase will have positive free cash flow if the new venture is successful and investment requirements are reduced. Finally the decline stage is reached if product demand or cash flow from operations diminishes. Free cash flow at this point should continue, however, while investment decreases.

The cash flow life cycle illustrates why free cash flow can be an imperfect metric for valuing a firm. Free cash flow does not measure the value added from operations over a period in time. Profitable firms can potentially have negative cash flows, while those with significant free cash flow can be barely profitable. A negative cash flow from investing more cash into operations than being received will give a negative NPV. This investment, however, could produce a return from cash flow from operations at some later stage. The three life cycle phases are also not consistent for all firms. Some firms can maintain growth consistently for extended periods, while others are unsuccessful at the initial phase. Firms have also been able to react to the risk of decline and continue in the mature phase.

A more appropriate metric for measuring growth is the residual earnings model. A firm's net assets quantify the book value of equity, which represents the total shareholder investment in the firm. The net assets are used in the firm's operations to generate shareholder value. The residual earnings measure captures the value in excess to book value over a cost of capital. Residual income models distinguish the excess earnings for a time period over an investor's required rate of return on equity. Residual earnings therefore represent the differential between earnings and investors' expected return on book value:

$$\text{residual earnings}_t (RE_t) = \text{earnings}_t - [(p_E - 1) \times \text{common shareholders equity}_{t-1}]$$

where t represents any year and $p_E - 1$ is the required return on equity. The added firm value to shareholders can therefore be defined in terms of the opportunity cost to investors.

5.4.3 A growth case study

Wave Nouveau Materials Inc. (Wave Nouveau) was founded in 1985 for the manufacturing of industrial materials. The firm focused on using science, engineering and chemistry to conceive, develop and commercialize new industrial products. Wave Nouveau also developed proprietary innovative processes for the manufacture of materials, equipment and various components. In addition the firm created an intensive R&D program and partnered with commercial firms and government for the development of new technologies.

Over time Wave Nouveau developed markets worldwide, creating a reputation for performance and innovation with its products. The firm framed its growth strategy as leveraging its materials and manufacturing technologies to compete in the growing environmental and alternative energy markets. To take advantage of these trends the firm expanded its operations by adding a production facility for the development and production of fuel cells.

A fuel cell is an electrochemical conversion device that combines a fuel and an oxidant for the creation of electricity. The fuel is typically hydrogen and the oxidant is oxygen, while the by-products are heat and water. Fuel cells are modular, with sizes varying from a couple of watts up to around 250W and have numerous power applications, including stationary and portable electricity generation, and transportation. The advantage of a fuel cell is that, while often compared to a battery, it does not lose power or need recharging. A fuel cell will continue to function as long as fuel is provided. The transformation of fuel into energy is also efficient, clean and quiet as no actual combustion process takes place.

The climate change and energy security issues that are driving alternative energy technologies have created a growth market for fuel cells. A fuel cell is actually a member of a group of technologies in various stages of development, with five classes defined by their electrolytes. Proton exchange membrane (PEMFC) are typically used in transportation, while alkaline (AFC) has its origins in the space program of the 1960s and is currently used for smaller applications. Phosphoric acid (PAFC) and molten carbonate (MCFC) are applied to larger applications, while solid oxide (SO) fuel cells are suited to stationary small-scale power systems.

Wave Nouveau's strategy is to leverage its existing manufacturing and customer base and use its new facility for the manufacturing of SOFC types. Focusing on an existing commercialized product allows Wave Nouveau to cap research and development costs and facilitate access to capital. SOFCs are used widely in applications ranging from vehicles to stationary power generation, and although they currently operate at high temperatures the residual gases can be used as a secondary energy source. The materials used in manufacturing SOFCs, which include nickel and nickel oxide, are also available in large quantities.

The condensed financial statements for Wave Nouveau are illustrated in Table 5.17.

The residual earnings with the required return on equity of 12% are shown in Table 5.18.

Wave Nouveau grew fixed assets by investing in plant and equipment for the manufacturing of fuel cells and financed this expansion through debt in 2010. The firm also leveraged sales through its existing customer base, and therefore maintained the trend in sales and marketing costs. As a result expenses remained constant at 60% of revenues. As there were no dividends, the total earnings for each year flowed into shareholders' equity. The growth in residual earnings therefore can be attributed to the increase in revenues from fuel cell sales and maintaining the ratio of expenses to revenues.

Table 5.17 Condensed financial statements for Wave Nouveau ($000)

Year	2008	2009	2010	2011
Balance sheet:				
Assets	400,000	432,000	488,000	528,000
Liabilities	200,000	200,000	220,000	220,000
Shareholders' equity	200,000	232,000	268,000	308,000
Income Statement:				
Revenues	80,000	90,000	100,000	120,000
Expenses	48,000	54,000	60,000	72,000
Net income	32,000	36,000	40,000	48,000

Table 5.18 Residual earning trend for Wave Nouveau ($000)

Year	2008	2009	2010	2011
Earnings	32,000	36,000	40,000	48,000
Shareholders' equity	200,000	232,000	268,000	308,000
Cost of equity	24,000	27,840	32,160	36,960
Residual earnings	–	12,000	12,160	15,840

5.4.4 Industry evolution

Industry structures are dynamic and becoming increasingly so, driven by external factors such as demand, innovation and technology and internal factors such as competition and firm strategies. The result of these dynamics historically has been some firms adapting and thriving, while others decline and ultimately cease operations.

The fundamental capability for responding to external change is flexibility. Industry life cycles are not always predictable and are progressively shortening over time. The ability to recognize and adapt to external change is a source of competitive advantage and a critical success factor. The dynamics that establish a firm's competitive advantage can also be internal. Innovation generates internal change and can create a competitive advantage for a firm within an industry. While innovation is often defined in terms of new products or processes, it also includes new business models, management systems, organizations, value chains, processes, contractual relationships and investment approaches.

The ability to adapt to change implies that firms must compete concurrently within two time horizons. Firm value is a function of managing operations in the short term while investing for the long term. An effective strategy maximizes value in the current environment through the productive use of existing resources and capabilities, while developing the resources and capabilities to adapt and compete in the future. These resources and capabilities are developed through investments in resource growth within or through acquisitions. Investments such as acquisitions have option like attributes, where downside losses can be limited to an initial outlay while creating an upside exposure. Internal investment in innovation such as research and development, new capacity and the development of technologies can also be structured as options on further investments.

The adaption option is a firm's capability to avoid adverse outcomes and is a function of how a firm is structured and its ability to adapt, liquidate technologies and reinvent its business model. A growth option is a firm's ability to adapt to positive outcomes. Adaption options limit a firm's downside risk, while growth options create potential upside opportunities for a firm. The growth option is the equivalent to the ability to place assets, or to grow net operating assets, and take advantage of new opportunities.

5.4.5 Industry evolution and climate change

Industrialization has had a significant influence on economic growth over the last 200 years. A residual effect of the technologies and innovations that drove this growth has been the impact on climate. The same drivers of innovation also have the potential, however, to address the factors that contributed to climate change over the last 200 years.

Schumpeter emphasized five industrial waves as innovations. The factory was an innovation that introduced scale, efficiency and standardization in production and increased the output of many products. This increase in output intensified pressure on transportation infrastructure. Innovations in the steam engine produced the locomotive and steam-driven ship, which along with the expansion of railways transformed the transportation of people and freight. The demand generated by railways resulted in the expansion of iron and then steel production. This created a surge in coal mining to supply the fuel for iron smelting and the developments in steam engines. Nineteenth-century railways also dramatically increased immigration, integrated markets and spurred other industries. This further created an enormous increase in the use of coal, iron, steel and petroleum based products.

Car manufacturing combined numerous innovations, including the internal combustion engine and new steel manufacturing methods. The mass production that followed in the early 20th century led to lower prices and product access for the masses. Industry and agriculture also began using gasoline and diesel powered transportation and machinery.

The advent of electricity saw the development of long-distance power transmission and the expansion of electricity utilities and grids. Electrical power became available for street lighting, residential use, public transport and industrial uses such as heat for the refining and manufacturing of copper and aluminum. Coal became the fuel source for electrical power with the development of coal fired electrical generating plants toward the end of the 19th century.

While industrialization has produced tremendous economic benefits, it has also generated significant burdens. Accompanying the Industrial Revolution was a massive growth in energy consumption, largely through the burning of coal, a fossil fuel. Since the onset of the Industrial Revolution societies have increased their use and dependence on fossil fuels such as oil, coal and gas, primarily to generate electricity and power transportation and industrial processes.

Fossil fuels when burned emit carbon dioxide (CO_2) and other gases. Many of these sources include direct emissions such as fossil fuel combustion and industrial process emissions, as well as indirect emissions such as electricity consumption. Since the start of the Industrial Revolution approximately 337 billion tons of carbon have been released to the atmosphere as a result of human activities. Annual emissions have increased by 82% since the mid-1970s. Figure 5.13 illustrates the trend in global carbon emissions from fossil fuel burning from 1751 to 2009.

Greenhouse gases (GHG) are atmospheric gases that are vital in moderating the Earth's temperature. CO_2 is the second most abundant greenhouse gas after water vapor. One influence of a gas on the greenhouse effect is its abundance. Carbon dioxide atmospheric concentrations have risen steeply since the start of the Industrial Revolution, with the largest increases coming after 1945. Figure 5.14 illustrates the rise in CO_2 concentrations, which has increased from

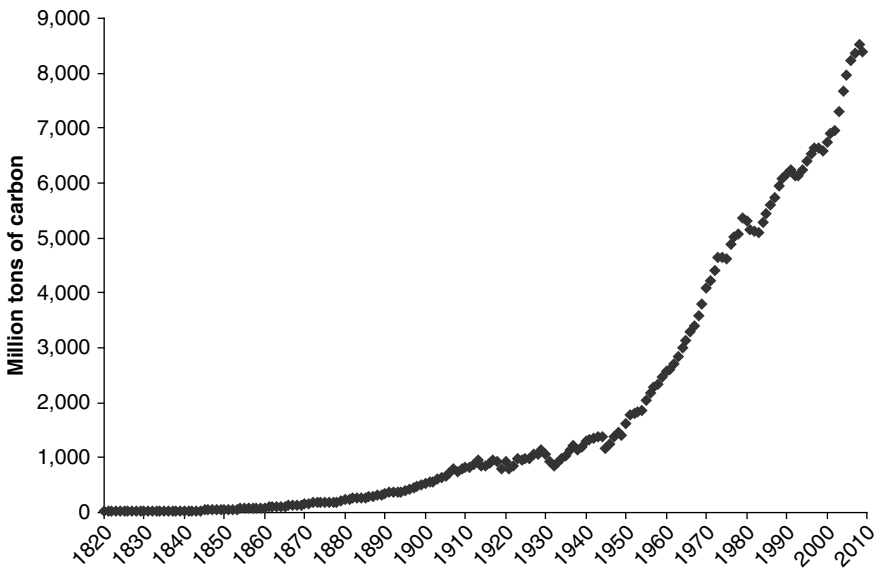

Figure 5.13 Global carbon emissions from fossil fuel burning, 1751–2009
Sources: G. Marland, T.A. Boden and R.J. Andres, 'Global, Regional, and National CO2 Emissions', *Trends: A Compendium of Data on Global Change* (Oak Ridge, TN: Carbon Dioxide Information Analysis Center, 2010); 2008 and 2009 emissions calculated by Earth Policy Institute from energy consumption in BP, Statistical Review of World Energy (London: 2010), and cement production in U.S. Geological Survey (USGS), Mineral Commodity Summaries 2010 (Washington, DC: 2010), p. 39; USGS, *Mineral Commodity Summaries 2009* (Washington, DC: 2009), p. 41.

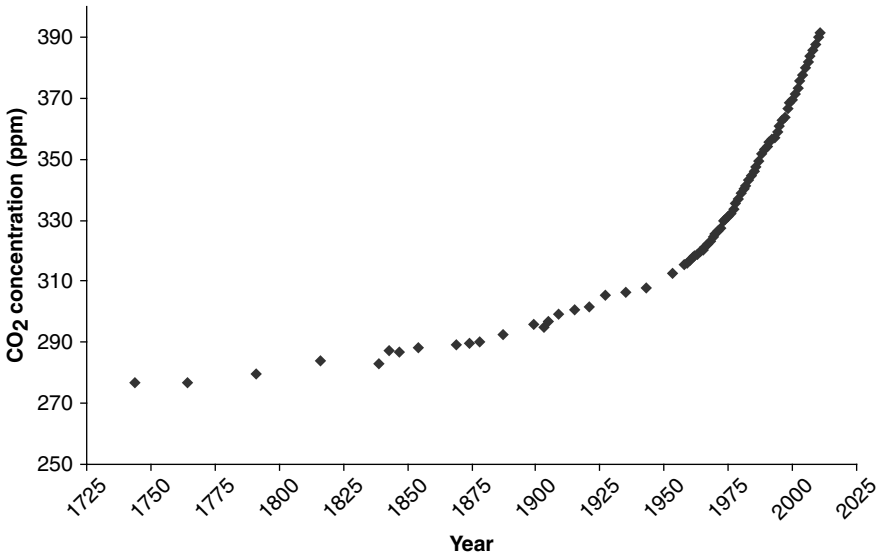

Figure 5.14 The rise in atmospheric carbon dioxide concentration, 1744–2011
Source: 1744–1953, Historical CO2 record from the Siple Station ice core, 1958–2011, Mauna Station.

277 parts per million (ppm) to 392 ppm since the start of the Industrial Revolution. Approximately 20% of this increase occurred from the start of the Industrial Revolution to 1975, with an 18% increase from 1975 to 2011. Other greenhouse gases include methane, which has increased 145% since the beginning of the Industrial Revolution, nitrous oxide, which has increased 15% over this period, and the man-made gases such as CFCs, PFCs and HCFCs, which did not exist in the atmosphere until the 20th century.

Figure 5.15 illustrates a breakdown of the trends in global fossil fuel carbon dioxide emissions from human activity. Total CO_2 emissions in 2008 from fossil fuels were 8,749 million metric tons (mmt) of carbon, with petroleum, natural gas and coal combined accounting for 94.7% of emissions. Petroleum accounted for 1,616 mmt of carbon or 18.5% of total emissions, natural gas 3,095 mmt or 35.4% and coal 3,578 mmt or 40.9% of total emissions. Emissions from cement production, at 386 mmt of carbon, have risen by nearly a factor of four since the mid-1970s, and now represent 4.4% of global CO_2 releases. Finally gas flaring makes up the remaining 0.8% of total emissions.

The largest contributors to global emissions at the sector level are electricity and heat with a total of 24.6%, forestry and change in land

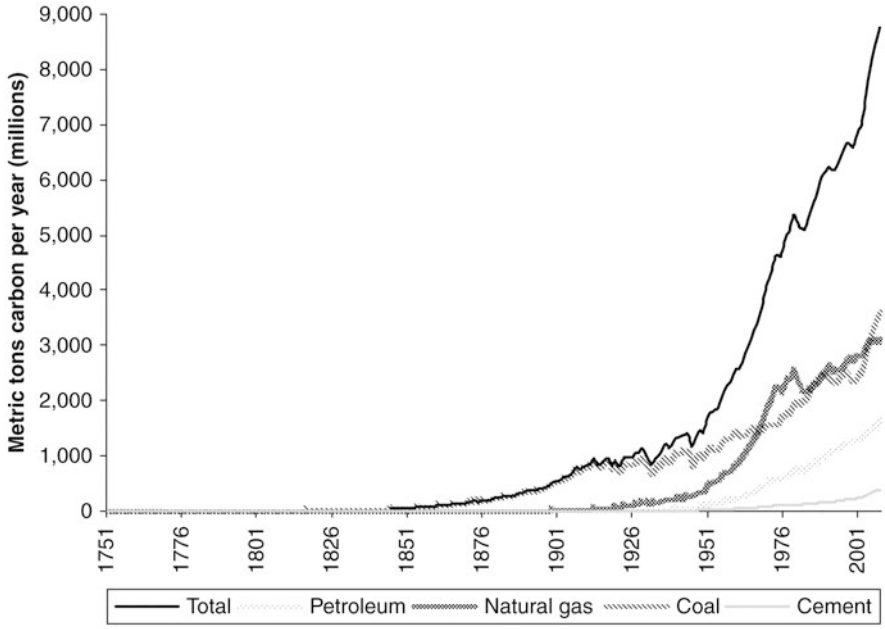

Figure 5.15 Trends in global fossil fuel carbon dioxide emissions from human activity, 1751–2008
Source: Boden, T., Marland, G. and Andres, R. *Carbon Dioxide Information Analysis Center*, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A. (2011).

use with 18.2%, transport with 13.5% and agriculture with 13.5%. The largest emissions through activity or end use are from road transport with 9.9%, residential buildings with 9.9%, oil and gas production with 6.3%, agricultural soils with 6.0%, commercial buildings with 5.4%, and chemicals and petrochemicals with 4.8%.

The influence of this change in atmospheric greenhouse gas concentrations is being reflected in the climate globally. Climate change refers to global warming, or the increase in average temperature in the contemporary climate. The consensus is that most of the increase in temperature since the middle of the 20th century is associated with the rise in greenhouse gas concentrations from human activity. The impact of global warming is enormous, with its influences being felt on weather patterns, water resources, agriculture, disease rates, financial systems and national security. Projections based on current trends on average forecast that GHG emissions are expected to continue to increase by another 50% through to 2025.

5.4.6 Climate change and adaption

One of the great challenges of climate change today is that greenhouse gas emissions result from almost every major function in society, including electricity production, transportation, agriculture and industry. Energy related emissions account for about 60% of the world's total emissions. Fossil fuel combustion and transport are the major sources of the greenhouse effect and account for about half of global warming. Chemical products account for about 20%, which has been decreasing in recent years with regulation and the decline of halocarbons. Collectively the industry related sectors spanning iron and steel and other industry comprise about 21% of global emissions.

Climate change and its associated issues generate systematic risks throughout the economy and will have an influence on agriculture, energy, health, national income, regulation and reputations at the sector, industry and organizational levels. Sectors such as agriculture, fisheries, forestry, health care, insurance, real estate, tourism and the energy infrastructure will disproportionately feel the effects of climate change. The consequence is that climate change is changing the competitive environment, with particular sectors, industries and organizations at risk more than others.

As there are uncertainties in regards to how climate change will impact future states of the world, any number of risk factors will have an impact on a firm. These include exposures to financial, commodity, legal, operational, strategic, technology, product, political and reputational risks. Climate change could include some or all of these risk factors depending on the nature of an organization's activities. Two specific risk categories can, however, be defined. Sector specific risk, the risk exposure to firms within a sector or industry, includes regulatory and physical risks, such as severe weather episodes directly affecting economic sectors such as insurance, agriculture, health care, real estate, water and tourism. Firm specific risk includes competitive, litigation and reputational risks, where a firm's operations could result in repercussions with consumers, shareholders and stakeholders.

Climate related events represent risks to all firms at some level. These can occur as events at regular frequencies and regionally, such as disruptions to agricultural or energy production, supply chains or infrastructure. Most firms have strategies and processes to manage the regular changes in climate. Firms in the future, however, cannot depend on climate conditions being consistent with those over the last century. Climate trends are anticipated to undermine the notion of

continuity, with deviations both in general conditions and the number and severity of extreme weather events. Firms will therefore need to consider changes in the climate regime and factor them into their strategies and business models.

The Pew Center on Global Climate Change survey consensus is that the climate change issue is driving a major transition that will both alter existing markets and create new ones. As in any such transition there are risks and opportunities, with both winners and losers. A growing number of firms in the Pew survey believe that inaction is no longer a viable option, with all firms affected in varying degrees and with some obligation to assess their business exposure and decide whether action is required. Some of the themes from the survey include strategic timing and the creation of business opportunities. There is consensus among the surveyed firms that changes in the level of external awareness of climate risks, stronger government policy and consumer demand for cleaner and more efficient products make it essential to address the issue. Timing is therefore a critical issue for a firm in both responding to eventual regulation and identifying the options that provide the required flexibility. Firms that integrate climate change into their strategies and business models will be in the best position to take advantage of emerging opportunities and gain a competitive advantage in the changing market environment.

The climate change issue is persuading firms to take advantage of the opportunities that exist in providing the products, services and technologies needed to create a sustainable society. As a result firms are changing the way they design products and develop business models to reduce their exposure to environmental constraints and risks and maintain long-term competitiveness.

5.4.7 Growth options

Defining a firm's future growth investments as call options on real assets provides a framework for approximating the value of the firm's growth options. A firm's value (V) can be broken down into the current earnings stream, or the value of assets-in-place (VAIP), and the value within the firm's potential future investment choices, or the value of growth opportunities (VGO):

$$V = VAIP + VGO \tag{5.29}$$

The value of growth options VGO is a function of the value that is ultimately derived from a firm's investment choices, while the assets-in-place VAIP represents assets whose value is independent of

these investments. This relationship can be extended by quantifying the firm's growth option value as the differential between its market value and capitalized current earnings stream. The capitalized current earnings stream symbolizes the firm's VAIP with no growth factored into value. The percentage of a firm's value that can be sourced to growth options, the growth option value (GOV), is therefore represented by:

$$\text{GOV} = \text{VGO/V} = [V - \text{current earnings/discount rate}]/\text{V} \tag{5.30}$$

This relationship can be extended using the economic profit concept, which considers the firm's equity cost of capital. Earnings only take into account the cost of debt capital, whereas economic profit considers a firm's earnings or profit net of all capital costs, including the cost of equity:

$$\text{EP} = \text{NOPAT} - [\text{CI}^*\text{WACC}] \tag{5.31}$$

where:

CI = capital invested

EP = economic profit

NOPAT = net operating profits after tax

WACC = the weighted average cost of capital

The firm value (V) includes the book value of all equity, debt and other capital invested (CI) plus a residual factor over CI, the market value added (MVA):

$$\text{V} = \text{CI} + \text{MVA} \tag{5.32}$$

The firm's MVA represents the total NPV of all investments, which is the equivalent to the present value (PV) of the expected economic profit:

$$\text{MVA} = \text{PV of expected EP} \tag{5.33}$$

Expected EP therefore is comprised of a current EP with no growth plus a future residual factor that represents EP growth, which can be either positive or negative due to declining operations or unsuccessful investment outcomes.

$$\text{PV of expected EP} = \text{PV of current-level EP} + \text{PV of EP growth} \tag{5.34}$$

The firm's value (V) can be redefined using the above equations:

$$V = CI + PV \text{ of current-level EP} + PV \text{ of EP growth} \tag{5.35}$$

Combining the first two terms CI and PV of current-level EP is the equivalent to the firm's value of assets-in-place VAIP in equation (5.29), while the firm's value of growth options is established through the PV of EP growth or VGO in equation (5.29). The firm's growth option value (GOV) is derived by solving equation (5.35) and then dividing the result with the firm value (V):

$$GOV = [V - CI - PV \text{ of current-level EP}]/V \tag{5.36}$$

where:

$$\begin{aligned} V &= \text{the firm's market value} \\ GOV &= \text{the firm's growth option value as \%} \\ CI &= \text{capital invested, the total book value of debt and equity} \\ PV \text{ of current-level EP} &= \text{EP perpetuity discounted by the firm's WACC} \end{aligned}$$

5.4.8 A growth option case study

Wave Nouveau operates in an industry and in markets where the climate change issue will have a significant influence. Government policy responses and consumer demand for more energy efficient products are creating an environment where new products and operational flexibility will define the winners and losers. Wave Nouveau's growth strategy is to develop products and expand into the environmental and alternative energy markets. The percentage of Wave Nouveau's value that can be sourced to growth options is examined using equation (5.36).

The market value of the firm (V) is derived using Geske's compound option model. The Geske model is specified as a call option on a stock which itself is an option on the firm's assets. The functional representation of this relationship is:

$$C = f(S,t) = f\big(g(V,t),t\big) \tag{5.37}$$

where C is the value of a call option, S is the firm's stock and V is the value of the firm. Transformations in the call option value are therefore defined as a function of transformations in firm value and time. The Geske model transforms the option's underlying state variable from the

firm's stock to the firm's market value (V), or the total market value of the firm's equity and debt. The Geske specification therefore provides a measure of firm value when applied to listed options.

The Geske model is specified as:

$$C = VN_2\left(h_1 + \sigma_V\sqrt{T_1 - t}, h_2 + \sigma_V\sqrt{T_2 - t}; p\right) - Me^{-r_{F_2}(T_2-t)}N_2\left(h_1, h_2; p\right) - Ke^{-r_{F_1}(T_1-t)}N_1\left(h_1\right) \tag{5.38}$$

where:

$$h_1 = \frac{\ln\left(V/V^*\right) + \left(r_{F_1} - \frac{1}{2}\sigma_V^2\right)(T_1 - t)}{\sigma_V\sqrt{T_1 - t}}$$

$$h_2 = \frac{\ln\left(V/M\right) + \left(r_{F_2} - \frac{1}{2}\sigma_V^2\right)(T_2 - t)}{\sigma_V\sqrt{T_2 - t}}$$

$$p = \sqrt{\frac{T_1 - t}{T_2 - t}}$$

V* represents the firm's critical total market value where the firm's stock level S_{T1} is equal to the option strike K. S_{T1} is derived using Merton's definition of the Black–Scholes model where a firm's stock is the equivalent to an option:

$$S = VN_1\left(h_2 + \sigma_V\sqrt{T_2 - t}\right) - Me^{-r_{F_2}(T_2-t)}N_1\left(h_2\right) \tag{5.39}$$

therefore, at $t = T_1$ when $S_{T1} = K$

$$S_{T1} = V_{T1}^* N_1\left(h_2 + \sigma_V\sqrt{T_2 - T_1}\right) - Me^{-r_{F_2}(T_2-t)}N_1\left(h_2\right) = K \tag{5.40}$$

where h_2 is defined above. The variable M is the face value of a firm's debt, while T_2 represents the debt's duration. The addition of the M term to the Black–Scholes model reflects the effects of leverage, where leverage changes the firm's equity volatility. The Black–Scholes model assumes that a firm's equity volatility is not a function of the level of equity. The Geske model, however, considers that a firm's equity volatility has an inverse relationship with a firm's stock level. As a firm's stock level increases, the firm's leverage and stock volatility will fall, and the inverse of this relationship also holds. The Geske model also implies the volatility of a firm's total market value, conforms to Miller and Modigliani, and is the equivalent to the Black–Scholes model when the firm has no debt.

A summary of the Geske model variables follows:

C = current market value of a firm's stock call option

S = current market value of the a firm's stock

V = current market value of the firm's securities (debt + equity)

V^* = the critical total firm market value where $V >= V^*$ which implies $S >= K$

M = face value of market debt (debt outstanding for the firm)

K = strike price of the option

r_{Ft} = the risk-free rate of interest to date t

σ_V = the instantaneous volatility of the firm market value return

σ_s = the instantaneous volatility of the equity return

t = current time

T_1 = expiration date of the option

T_2 = duration of the market debt

$N_1(.)$ = univariate cumulative normal distribution function

$N_2(\ldots)$ = bivariate cumulative normal distribution function

ρ = the correlation between the two option exercise opportunities at T_1 and T_2

Refer to Geske and Zhou (2007a) for further details of the application of the Geske model to firm value. Geske and Zhou also provide details on calculating M, the firm notional debt.

The firm value (V) is found by solving the three equations (5.38), (5.39) and (5.40) simultaneously for three variables, the total firm market value (V), the total instantaneous volatility of V, σ_V, and V^*, the value of (V) at a specific time in the future (T_1) where S_{T1} is equal to the strike price K of an option expiring at t_1. The option price C represents a quoted bid/ask average, near term at-the-money option price. At-the-money options are usually the deepest and most liquid.

The value for the firm's market value (V) was solved using the following variables for Wave Nouveau:

$S = 400$ million, the total market capitalization

$M = 220$ million, weighted duration of total debt

$K = S_T$

$t_1 =$ option expiry (1 month)

$T_2 =$ debt duration (5 years)

$S = \$80.00$

$K = \$80.33$

$r = 5\%$

$\sigma_s = 15\%$

$C = \$1.38$

Wave Nouveau has five million shares outstanding, and as the firm's current stock price (S) per share is \$80, the total market capitalization is \$400 million. The firm's market value (V) was derived using equations (5.38), (5.39) and (5.40) as \$571 million. The capital invested (CI) for Wave Nouveau is equal to the sum of the book value of debt (\$220 million) and the book value of equity (\$308 million), which equals \$528 million. Table 5.19 summarizes the compound variables.

The total value of a firm is equivalent to the sum of the original investment, or the book value of debt and equity, and the MVA, or the NPV of the economic profit cash flows discounted at the weighted cost of capital. This is the equivalent to the total value of the firm as the sum of the original investment and the NPV of the sum of the residual earnings discounted at the cost of equity.

Table 5.19 Wave Nouveau's compound option variables for firm market value (V) (in \$millions)

Compound option model variable	Description	Variable
Asset price (S)	Total market capitalization	400
Strike underlying option (X_1)	Face value of debt (M)	220
Strike option on option (X_2)	ATM option price x total equity	402
Time to maturity – option on option (t_1)	Option maturity	0.08
Time to maturity – underlying option (T_2)	Duration of M	5.00
Discount rate (r)	Interest rate	5.00%
Volatility (σ_V)	Volatility	10.50%

The residual earnings number in Section 5.4.3 is substituted for the economic profit parameter to arrive at Wave Nouveau's growth option value. A WACC of 5% is used for illustration. The perpetuity for the PV of current-level EP is derived as the 2011 residual earnings of $15,840 divided by the WACC of 5%, which equals $316,800.

Wave Nouveau's growth option value, or the firm's growth option value as a percentage of firm value, is therefore:

$$\begin{aligned} \text{GOV} &= [571 - 528 - 0.317]/571 \\ &= 7.48\% \end{aligned}$$

5.5 Firm abandonment

5.5.1 Overview

Many industries follow life cycles that are defined by convention as pioneer, growth, mature and decline. An industry in decline either has negative growth or is not expanding at the general economic growth rate. These industries are typically identified by extreme price competition, excess capacity, a lack of innovation, a dwindling number of competitors and buyouts of departing firms.

Firms within a declining industry can undergo transition from the mature to the decline stage as a consequence of foreign competition, shifts in consumer behavior and changes in technology and demographics. Declining revenues, margins, operating cash flows and earnings are all features of the final phase of a firm's existence. Other factors identified with declining firms include commoditized products, diminishing resources or substitutes appearing due to innovation.

Industry decline and falling market demand lead to uncertainty around the sustainability of product demand, which could either stabilize at some significantly lower level or, in the worst case, fade to where operations are no longer justified. Declining demand leads to industry-wide pressure to reduce capacity, as excess capacity diminishes profitability. Reducing capacity has significant costs, as both fixed and sunk costs can be a comparatively large percentage of an industry's total costs. These large sunk costs also create high barriers to exit and prolonged excess capacity in the industry, which can lead to lengthy periods of industry downsizing. Firms in a declining industry are also motivated to reduce and stop investments in products when decreasing sale volumes reduce profitability. This leads to a fall in product quality and ultimately firms exiting the industry.

5.5.2 Strategies in declining industries

The conventional strategies in declining industries are either to maximize cash flows from existing investments with no further investment or to divest. These strategies can be extended to dominating the market through increased investment, staying at current investment levels, reducing investments, milking the cash cow or finally divesting.

Continuing to invest in the industry through research and development or marketing programs has significant risks and requires forecasts of declining product demand. In some cases a firm can be successful in a turnaround and return to the maturity phase, or reposition itself to take advantage of new market trends. Many firms in a declining industry will, however, ultimately face liquidation. If the future for a firm appears bleak then the best management alternative may be divesting the business and selling assets before the industry decline gains momentum.

The market for a declining industry's assets is dynamic and can rapidly diminish. A firm would focus on resale asset values to establish potential realized proceeds, and try to maintain the flexibility to sell before asset values significantly decline. The firm also has value if the assets have the flexibility to switch to operations for other products. Both the industry and a firm's exit barriers are also factors that will influence a firm's decision on the timing of an exit.

5.5.3 The newspaper industry

The newspaper publishing industry in the United States is a $59 billion industry that employs an estimated 356,000 people. Circulation is the underlying driver of value in the newspaper industry and makes up 15 to 20% of earnings for a typical newspaper and 85 to 90% of the advertising rate variance. The average newspaper with a circulation of 100,000 has an annualized 15.6% pre-tax profit margin.

The newspaper industry is inundated with problems. The peak of the industry was in the early 1920s, when the average household daily read 1.3 newspapers, and newspapers were highly profitable due to the (near) monopoly over retail customer access. By 2001, however, nearly one out of two households were not reading a newspaper. Today four in ten Americans read a newspaper daily whereas ten years ago the ratio was one in two Americans. Consumers are switching to other media such as cable television, Internet news sites and blogs for news. Revenues from classifieds have also declined due to online classified sites. This has led to uncertainty in the industry's growth and future profit margins, with declines of 15 to 20% in the level of earnings.

Many newspapers are shutting down operations and reducing staff, with approximately 2,800 permanent jobs disappearing as a result.

Attempts at increasing revenue through newspaper price increases have a significant negative influence on circulation, and therefore the advertising charge rates that flow into revenue. There are growth areas in the newspaper industry however, which include the ethnic press, especially the Spanish language press in the United States, diversifying into niche newspaper distribution and investments in online media.

Newspapers are now offsetting losses from print editions with online editions. A critical issue in this migration is the offset on the loss on revenue from traditional print media with the gains in revenue when a consumer switches to the newspaper's online content. While newspaper online revenues are growing at more than 30% annually, expectations are that it will take until 2017–2018 before newspaper revenues return to previous levels, which assumes advertising rates stay constant and online media will continue to grow at 30%.

5.5.4 A case study

Founded in 1857, *The Sunset Examiner* is a morning newspaper based in a provincial city with a daily circulation of 180,000 on weekdays and 225,000 for a weekend edition. The newspaper has won awards over the years, and it is published from an editorial operations center and printing plant in the provincial city. The publisher of *The Sunset Examiner*, Sunset Inc., is a single business newspaper firm. The circulation area covers the provincial city and surrounding counties. The firm has 1,500 employees, over 1,000 independent newspaper carriers, and operates on a 15% pre-tax profit margin.

The newspaper had enjoyed a monopoly on local news content for decades, with growth in circulation flowing into profit margins. In the late 20th century, however, alternative sources of news became available, initially with cable news and then with Internet news sites. The newspaper's circulation started to decline as a result. While print advertising revenue had grown through to the end of the 20th century, advertisers were aware of the declining circulation numbers and growth in advertising and classifieds revenue slowed considerably. By the start of the 21st century the newspaper's advertising revenues from the print edition were declining year-on-year.

Offsetting the decline in revenue was difficult as most of the firm's costs were fixed costs. In an attempt to reverse the declining circulation Sunset Inc. invested in marketing and redesigns to retain readers. These measures proved to be unsuccessful in reversing the decline in print

circulation. Sunset Inc. was successful, however, in establishing an online edition strategy to offset the decline in print revenues.

A firm as a going-concern assumes that it will continue operations indefinitely, and firm value is based on this assumption. Managers and investors can, however, consider other values. A firm's liquidation also has value if the firm ceases operations and the assets are sold off. The firm as a going-concern is therefore one strategy while selling off the assets is another. Firm value is then either the maximum of the value as a going concern or value in liquidation.

Sunset Inc.'s management and shareholders examined the value of the newspaper in liquidation while there was still a market for the newspaper's physical assets. The printing plant assets have the potential to be switched into alternative print media such as direct marketing and niche media markets.

A liquidation analysis involves valuing each asset in a sell off. Percentages for assets in liquidation founded on comparable firms are established. The sum of these asset values is netted against the liability redemptions and associated liquidation costs. A positive result provides a maximum value from which the investors' required return is deducted.

Table 5.20 illustrates Sunset Inc.'s liquidation analysis using balance sheet data. Percentages of asset value in liquidation were determined and the net liquidation value calculated. The investors' required rate of return would consider the range in the percentage estimates for the assets in liquidation, the rate at which the firm is consuming cash, and the probability of other firms also analyzing the value in an acquisition.

The discount-to-book value of $29.4 million in liquidation value to the equity of $100 million reflects the value of the firm as a going-concern. The book value per share is $33, while the value to investors is $9.81 per share. If the assets take six months to liquidate then the present value at a 15% internal rate of return is $9.13.

5.5.5 The firm abandonment option

Economies are continually responding to the dynamics of competition, comparative prices and innovations in technology. Structural change results from shifts in the relative significance of the various technologies, economic factors and production processes that create economic output. Economic structural change inevitably creates successes and failures as certain industries grow while others decline.

Table 5.20 Sunset Inc. liquidation analysis ($000)

Assets		**Liquidation (%)**	**Values**
Cash	50,000	100%	50,000
Accounts receivable	22,000	72%	15,840
Inventory	2,000	55%	1,100
	74,000		66,940
Plant & equipment	125,000	54%	67,500
Goodwill	(1,000)	0%	–
	198,000		134,440
Liabilities & shareholder equity			
Short-term debt	50,000	100%	(50,000)
Other liabilities	50,000	100%	(50,000)
	100,000		(100,000)
Shareholder equity	100,000	Cost of shutdown	(5,000)
	200,000		(105,000)
		Net liquidation value	29,440
		Shares outstanding	3,000,000
		Value per share	9.81

The economic waves in Schumpeter's analysis are distinctive and determined by totally dissimilar industry clusters. Creative destruction is a function of market dynamics, where capital markets eliminate firms if their operations are not competitive or they operate within a discontinuous or declining industry. Discontinuities are the limits to durable firm operations that result from the inevitable transformations within an economy, and result from changes in the competitive environment, technology, consumer behavior or government policy.

The waves that result from the dynamics of creative destruction will probably continue with increasingly shorter economic cycles, creating an external environment to which firms will increasingly need to adapt. A firm's assets will provide value if the going concern value is greater than the firm's liquidation value. The continuity of organizations, however, over the 20th century has changed considerably, with the firm life average in the S&P 90 Index declining from 65 to 10 years. Liquidation becomes the final alternative in the event where a firm is ultimately no longer competitive and is the ultimate breakup of a going concern.

If the capital markets believe that a firm's management is performing in the shareholders' interest, the firm's market value should represent fair value. In the case where a firm is not performing well and the firm's equity does not reflect fair value, then the firm's investors may

campaign for the breakup of the firm and the realized value returned to investors.

5.5.6 Investor valuation of the abandonment option

The value to investors in a firm's liquidation can be defined as an option to abandon the firm for its exit value. This option can be valued as an American put on a dividend paying stock, where the stock price is the equivalent to a firm's cash flows, and the strike is an uncertain exit value. The value of this option increases along with the firm's exit value. Structural change within an industry may therefore persuade investors to value and even exercise this option. The data in a firm's balance sheet can be used to value the option to abandon the firm for the exit value of its assets.

Berger, Ofck and Swary (BOS) (1996) present a method for assessing the value of the abandonment option. The following equation defines the relationship between firm value and those attributes that determine the value of the abandonment option:

$$\text{VALUE} = \text{PVCF} + \text{P(PVCF, EXIT, SDEV)} \tag{5.41}$$

where:

$$\begin{aligned}
\text{VALUE} &= \text{the firm's market value, or market capitalization} \\
\text{PVCF} &= \text{the firm's present value of expected operating cash flows} \\
\text{P} &= \text{American put option} \\
\text{EXIT} &= \text{the firm's assets exit value} \\
\text{SDEV} &= \text{standard deviation of the PVCF/EXIT ratio}
\end{aligned}$$

The investors' decision to sell the firm is illustrated by equation (5.41), where firm market value is equal to the total of the value of the expected operating cash flows and the abandonment option value. Equation (5.41) can be redefined as a function of the option's parameters, where the value of the abandonment option is expressed as the percentage by which firm value exceeds the PVCF:

$$(\text{VALUE/PVCF} - 1) = \text{P}(1, \text{EXIT/PVCF, SDEV}) \tag{5.42}$$

The value of the abandonment option is now the percentage by which the value of equity is greater than the after-interest cash flows for a firm as a going concern. There is no closed form solution available for the abandonment option; however, the relationships in equation (5.41) can be used to determine the option payoff. This

option value is a function of the EXIT/PVCF ratio, which is defined as the excess exit value. The excess exit value in equation (5.42) is a put option's stochastic strike with the underlying stock value normalized to one.

The abandonment option value is at-the-money when the excess exit value is equal to one, in which case a firm's exit value is equal to its expected cash flows. The option moves to in-the-money with an increase in the exit value, and out-of-the-money with an increase in the value of the expected cash flows. There is therefore a positive relationship between a firm's excess value and the value of the abandonment option.

Observable exit values for the assets of firms as going-concerns are typically unavailable. The focus, however, is on the relationship between balance sheet data and the value of the abandonment option. BOS derive estimates for the relationships between the book value of assets and the exit value and find on average exit values of \$0.72 on the dollar for receivables, \$0.55 for inventory and \$0.54 for fixed assets.

BOS derive the present value of cash flow (PVCF) proxy through analysts' earnings forecasts. The use of earnings forecasts instead of cash flows has advantages and disadvantages. Earnings are measured for firms as going-concerns, and therefore a PVCF proxy based on earnings forecasts does not include the value of the abandonment option. Forecasts of distributed cash flows would include the expected cash flows from occurrences outside the going-concern assumption such as a firm's exit.

The disadvantage, however, is that earnings are not the same as cash flows, and therefore the present value of earnings from a going-concern should be modified to arrive at the PVCF as a going-concern. These adjustments are required as capital expenditures may not match depreciation and working capital growth is not deducted from earnings. No adjustments are made for changes in the capital structure as these are unknown.

The specification of the PVCF proxy is:

$$PVCF = \sum_{t=1}^{n} \frac{EARN_t}{(1+r)^t} + \sum_{t=n+1}^{10} \frac{EARN_2 * (1+gr)^{t-2}}{(1+r)^t} + \frac{EARN_2 * (1+gr)^9}{(r-tg)} * \frac{1}{(1+r)^{10}} - CAPEX_ADJ - WC_ADJ \tag{5.43}$$

where:

$PVCF$ = present value of analysts' forecasted going-concern cash flows

$EARN_t$ = the forecast at year t of the analyst's after-interest earnings

r = the expected CAPM return

gr = five year earnings growth consensus forecast

tg = the terminal growth rate for earnings

n = number of years for the earnings forecast

t = year index

$CAPEX\ ADJUST$ = present value of analysts' earnings forecasts adjustment down for the capital expenditures and depreciation difference

$WC\ ADJUST$ = present value of analysts' earnings forecast adjustment down for working capital growth

The *CAPEX ADJUST* is specified as:

$$CAPEX\ ADJUST = \frac{(CAPEX_0 - DEPN_0)/(r-g)}{EQUITY_0}$$

$CAPEX_0$ = the year 0 capital expenditures

$DEPN_0$ = the year 0 depreciation expense

$EQUITY_0$ = the year 0 market value of equity

g = the growth rate of excess capital expenditures

The *WC ADJUST* is specified as:

$$WC\ ADUST = \frac{([0.5\,(gr) + 0.5\,(tg)] * 0.5\,[NETWC_0])/r}{EQUITY_0}$$

5.5.7 An abandonment option case study

The estimates in Section 5.5.4 provided the Sunset Inc.'s exit value. The BOS dollar book exit value estimates for receivables, inventory and fixed assets were used for each book value component and the book values of debt and payables were deducted. A ratio of one was used for cash and short-term marketable securities in non-inventory

current assets. The exit value is therefore equal to the sum of $29.44 million.

The BOS PVCF equation as specified in equation (5.43) has five components. The first is the sum of the analysts' discounted expected earnings forecasts up to two years. The second term represents the sum of the discounted earnings forecasts from three to ten years based on analysts' long-term, five-year earnings growth projections. The third variable is the present value of a perpetuity for earnings greater than ten years, with the assumption of a constant nominal terminal growth rate (tg).

The fourth component deducts an adjustment for the net present value of future capital expenditure excesses after subtracting future depreciation. Earnings forecasts are not cash flows that can be distributed, and growth in earnings usually requires capital investments that are greater than depreciation. BOS arrive at a value of 12% for the capital expenditure adjustment. The fifth item, the working capital adjustment, is a similar adjustment representing the present value of the growth in working capital. BOS derive a value of 5.5% for the working capital adjustment.

Table 5.21 illustrates Sunset Inc.'s condensed income statements. The decline in circulation has created a downward trend in net income, while advertising was stable due to Sunset Inc.'s online venture.

Table 5.22 illustrates the calculation of the first two terms in equation (5.43) using an earnings forecast of $9 million, which is based on a decline in circulation revenues from $30 million to $29 million for 2012. The earnings forecast to ten years and perpetuity for earnings from year 11 assume a constant 2% nominal terminal growth rate. The present value of future cash flows is then derived by adjusting the present value of future earnings with the deduction of the present value of future capital expenditures minus future depreciation and working capital growth. A CAPM discount rate of 5% is used for illustration.

Table 5.21 Condensed income statements for Sunset Inc. ($000)

	2008	2009	2010	2011
Revenues:				
Advertising	120,000	120,000	120,000	120,000
Circulation	35,000	33,000	32,000	30,000
Total revenue	155,000	153,000	152,000	150,000
Total operating costs	140,000	140,000	140,000	140,000
Net income	15,000	13,000	12,000	10,000

Table 5.22 PVCF earnings projections

Year	1st term	df	2nd term	gr
2012	8,571,429	0.9524	–	1.0200
2013	8,163,265	0.9070	–	1.0404
2014	–	0.8638	11,056,328	1.0612
2015	–	0.8227	11,841,328	1.0824
2016	–	0.7835	12,682,062	1.1041
2017	–	0.7462	13,582,488	1.1262
2018	–	0.7107	14,546,845	1.1487
2019	–	0.6768	15,579,671	1.1717
2020	–	0.6446	16,685,827	1.1951
2021	–	0.6139	17,870,521	1.2190
2022	–	0.5847	–	1.2434

Note: The 3rd term in equation (5.43) is the perpetuity which is derived as $17,520,119.

The total of the sum for each of the first two terms, $16.7 million and $113.9 million, and the third-term perpetuity of $17.5 million result in the unadjusted PVCF of $148.1 million. Deducting the capital expenditure adjustment of $17.8 million and the working capital adjustment of $8.2 million provides an adjusted PVCF of $122.2 million.

BOS's research provides results for the variables in the valuation of the abandonment option. The median sample value of the abandonment option is 11.5% with an excess exit value of −0.761. Using the Sunset Inc. example, the market capitalization value of the firm is $136.2 million and the excess exit value is −0.759. As the exit value of $29.4 million is less than the PVCF of $122.2 million, the value of the abandonment option is out-of-the-money for investors.

The factors that can influence the value of the abandonment option include the degree of specialization in a firm's assets. The option has greater value when the assets are less specialized. Current assets are less specialized than fixed assets and therefore provide greater option value, while land is less specialized than other fixed assets and also provides greater option value.

The model in equation (5.43) was stressed to identify the sensitivity of the model variables. The at-the-money value of the abandonment option was derived by adjusting the advertising revenue forecast, the discount rate and growth rate forecast. The earnings forecast for 2012 is adjusted down to $2.2 million based on a decline in 2012 advertising revenues of approximately 5.7%. The discount rate was increased to 8% and the growth forecast lowered to minus 1%. Table 5.23 illustrates the calculation of the stressed first two terms in equation (5.43) using an

Table 5.23 At-the-money abandonment option PVCF earnings projections

Year	1st term	df	2nd term	gr
1	2,027,778	0.9259	–	0.9900
2	1,877,572	0.8573	–	0.9801
3	–	0.7938	2,676,831	0.9703
4	–	0.7350	2,862,068	0.9606
5	–	0.6806	3,060,123	0.9510
6	–	0.6302	3,271,883	0.9415
7	–	0.5835	3,498,298	0.9321
8	–	0.5403	3,740,380	0.9227
9	–	0.5002	3,999,214	0.9135
10	–	0.4632	4,275,960	0.9044
11	–	0.4289	–	0.8953

Note: The 3rd-term perpetuity value from equation (5.43) is $4,319,151.

earnings forecast of $2.2 million, the 8% discount rate and growth forecast of minus 1%.

The sum of the first two terms, $3.9 million and $27.4 million, and the third-term perpetuity of $4.3 million resulted in an unadjusted PVCF of $35.6 million. Subtracting the $4.3 million capital expenditure adjustment and $2 million working capital adjustment resulted in an adjusted PVCF of $29.4 million. As the exit value is $29.4 million the stressed abandonment option is therefore at-the-money. The PVCF was found to be most sensitive to declines in advertising revenue and therefore had a significant influence on the value of the abandonment option.

5.6 The sale of corporate real estate assets

5.6.1 Overview

In this article, the authors analyze a downtown corporate office property that the corporate owner considered for a sale. They extend the conventional discounted cash flow analysis by valuing the embedded real put option held by the owner of the property to defer the sale until some optimal time in the future.

The use of such options, while increasingly commonplace in some industries, has yet to be widely adopted by commercial real estate investors and owners. Interestingly, embedded optionality – either explicit in the form of contractual rights or implicit in the ability of an owner or lessor to exercise their ownership rights – is a feature common to many familiar real estate asset management decisions. The deferral option in this example is shown to depend upon both the

future market value of the property, as well as the intrinsic value of the building to the corporate owner as an asset that contributes to production. The gap between these two values may differ significantly, however, since the implied discounted cash flows from the building treated as a market asset are not identical to those when the building is valued as a productive asset. The effects of this difference are clearly reflected in the options analysis; by contrast, the conventional DCF approach does not make use of this gap and, as a result, may lead to erroneous decisions. The analysis values both the deferral option and, via the calculation of the option's early exercise boundary, identifies the conditions under which a sale is optimally triggered.

5.6.2 Real options analysis

Real options analysis has made significant inroads into the resource allocation decisions of many capital-intensive industries, such as energy and power generation, high technology, pharmaceuticals, mining, and telecommunications. Interestingly, the real estate industry, especially commercial real estate, has been a notable exception to this trend. (In the discussion that follows, the authors refer to the decisions of the owners or renters of the property asset itself, and not the owners of a derivative security.) Though a handful of academic papers have applied real options in the analysis of real estate problems, such as Schwartz and Torous (2003), Bulan, Mayer, and Sommerville (2002), Quigg (1993), Williams (1991), and Titman (1985), the commercial real estate industry has to date been somewhat resistant to adopting formal options methodologies. This is somewhat surprising for several reasons.

First, modern real estate capital markets routinely trade financial instruments which are characterized by significant optionality. For instance, commercial mortgage-backed securities are priced with respect to the probability of loan default, which can be modeled as an exercise of an embedded default option by the borrower, for example Merton (1974), Fabozzi, and Jacob (1996), Childs, Ott, and Riddiough (2003), and L'Heureux and Coleman (2003a). In a similar fashion, residential mortgage-backed securities are valued with respect to borrower prepayments which again are typically represented as a rational option by the borrower to pay down the mortgage debt at a rate faster than the contractual amortization schedule.

Second, property investors are already quite familiar with contractual real estate option rights, such as lease extensions, redevelopment

rights, future repurchases and so on, and attempt to value such rights as part of their ongoing investment activities.

Third, as several authors have noted, for example Trigeorgis (1996), commercial real estate provides an excellent backdrop for real options analysis. Many property investment and leasing decisions are characterized by high fixed costs, long decision cycles and are exposed to significant demand, supply, and price uncertainty over time. As a result, option premia should be quite large with respect to the underlying project NPV.

Finally, it is relatively straightforward to show that many of the most common commercial real estate asset decisions – purchases, sales, leasing, relocation, development and redevelopment, sale-leasebacks, and so on – are indeed characterized in a fundamental way by embedded optionality. Following methods outlined in the seminal work by Dixit and Pindyck (1994), this optionality can be effectively modeled and the authors argue, has both significant economic value to the decision maker and offers insights into the capital investment decision that may be far less obvious if only the traditional 'static' net present value rule is used.

This article presents a real-world example of modeling an extremely common real estate decision – a sale – as a deferral option. Specifically the authors explore the recent decision by a large U.S. telecommunications firm to sell a corporate headquarters property in downtown San Francisco as part of the ongoing consolidation of its national real estate portfolio. The company conducted a conventional analysis using standard net present value techniques and determined that the sale of the property to a third party at prevailing market prices met its financial objectives. Using the same underlying assumptions and data, the authors extend their analysis to consider the optimal timing of the sale, modeling the decision as an American put option. This deferral option is shown to depend upon the future market value of the property, as well as the intrinsic value (or 'value in use') of the building to the corporate owner as an asset that contributes to production or earnings.

The gap between these two values may differ significantly, however, since the implied discounted cash flows from the building treated as a market asset are not identical to those when the building is valued as a productive asset. The effects of this difference are clearly reflected in the options analysis; by contrast, the conventional DCF approach used by the company does not fully reflect the strategic value of this asset. Once the put option is modeled, the authors conduct a sensitivity

analysis to show how the option value varies with real estate market valuations.

The authors also calculate the early exercise boundary, which the authors then map onto a forecast of future market values. This allows the authors to identify the market conditions under which a sale is optimally triggered and when such conditions might occur given a prediction of future property values.

In practice, the authors generalize this approach as a set of 'exchange options' from the current form of ownership to various alternatives (sell for cash, structured sale leasebacks, 1031 and other like kind exchanges, and synthetic leases with forward sale of the residual equity position).

While the authors are firm believers in the 'law of one price', the real estate ownership and rental markets are highly segmented and have a microstructure which suggests that the 'best owner' and 'highest and best use' of an asset will change from time to time. This is particularly true during times when the direction of heavy capital flows is weakly correlated with rental market fundamentals. The result is that transactions may often occur at prices which appear at odds with the NPVs implied from discounting current building cash flows. Under such conditions, real options provide a useful framework to help an investor decide if it is best to sell now or wait.

5.6.3 The conventional decision to sell

Acquisitions and dispositions are among the most common commercial real estate decisions. The conventional discounted cash flow analysis of these transactions has been extensively researched and is now the fundamental method used for property valuation, see, for example, Brueggeman and Fisher (1996) for a detailed discussion of the method in the context of commercial real estate analysis. For the present case, the authors consider the prospective sale of an office property owned by a large, publicly traded U.S. telecommunications company. The company recently conducted an extensive review of its corporate real estate holdings across the United States, with an eye toward disposing of underutilized or obsolete facilities and reducing leasing and building maintenance expenses. As a result of this analysis, several properties, including the one presented here, were identified as likely candidates for sale. Once identified, a more extensive financial analysis was conducted, including a discounted cash flow analysis of a prospective sale to a third party at a price consistent with prevailing office market conditions in San Francisco.

Table 5.24 Preliminary sales analysis ($000)

Decision	Cost/proceeds	PV/NPV
Keep property		$6,932
Sell and relocate:		
Operating expenses	$1,485	
Expense to vacate	$3,334	
Capital to vacate	$3,854	
Sales price:	$53,000	
Less commissions	(1,690)	
Less 50% gain on land	($8,927)	
Net sale proceeds	$42,383	$21,981
Difference		$15,049

The subject property is a 350,000 square foot (sf) building located in downtown San Francisco. The property currently houses several hundred employees, who would be relocated to other company-owned or leased facilities in the event of a sale. The building, constructed in the 1920s, was flagged for sale in part because it had become increasingly functionally obsolete and expensive to maintain to current standards. Occupancy costs, including capital improvements, were rising sharply. The building is wholly owned by the company and unencumbered by debt. The company has owned and occupied the property for several decades, and it has been fully depreciated. A recent appraisal put the value of the property (and the surrounding parcel of land) at $53 million, a figure consistent with the company's internal analysis.

Based upon the current and projected costs of maintaining the property at its current level of occupancy and intensity of use, the company determined that the present value of keeping the property was $6.932 million. To determine the effects of a sale, the company assumed the property would sell for its appraised value and employees would be relocated to another company-owned facility. After factoring in operating, relocation and capital equipment expenses, brokerage fees, and taxes (note: under California state law, utilities are required to return 50% of any gain on land sales to ratepayers), the NPV was calculated to be $21.981 million. Note that these calculations were performed assuming a ten-year horizon. The authors summarize the results in Table 5.24. Based upon these results, the decision was made to sell the subject property.

5.6.4 Real options model of deferred sale

As is well known, the real options approach offers two strong advantages compared to traditional NPV. First, it correctly recognizes the

inherent uncertainty and flexibility of many capital investment decisions. Second, it compels the analyst to establish a more rigorous link between the strategic or business value of an asset as a factor of production and its value in the market to a third-party buyer. This latter requirement is particularly interesting in the case of commercial real estate since most firms tend to view their property holdings as static expenses, rather than as productive assets that can be optimally managed to contribute to earnings. Corporate real estate tends to be managed in a cost-minimizing fashion; that is, firms work to keep operating and maintenance costs at a minimum, regardless of the impact such actions may have on the ability of real estate to contribute to earnings when augmenting other factors, such as labor. By contrast, many other types of assets, such as capital equipment, research and development expenditures, intellectual property, inventories, and so on, are increasingly perceived and managed in a more dynamic fashion with an eye toward increasing earnings, and not simply 'cutting costs'.

As noted above, many common commercial real estate decision problems can be modeled as options. In actual practice, a building owner would identify a number of competing strategies for the asset, for example outright sale, subletting vacant space, sale-leaseback, or some combination of these, and so on. Which of these alternatives are ultimately feasible depends on many factors – strategic business considerations, legal and tax restrictions, operational uses, market conditions, and company-specific financial requirements. The specific option models that must be evaluated will reflect this feasible set. For the subject property, the company considered several competing alternatives before opting on an outright sale. To keep the exposition simple, the authors will present the real options modeling of the sale alternative only. This has the added benefit of being one of the simpler options technically to model, interpret, and solve. Part of the motivation for selling the subject property has been the perceived imbalance recently between prices in the San Francisco office market and rental conditions.

Figure 5.16 depicts the path of office rents in the subject property's submarket. The unprecedented run-up in rents during 1999–2000, at the peak of the 'dot.com' boom, stands out. Since 2000, however, office rents have declined 53% from their peak, as a combination of the bursting Internet stock bubble, the retrenchment of the high-tech sector, and the broader decline in the national economy have caused a precipitous decline in the demand for office space. At the same time,

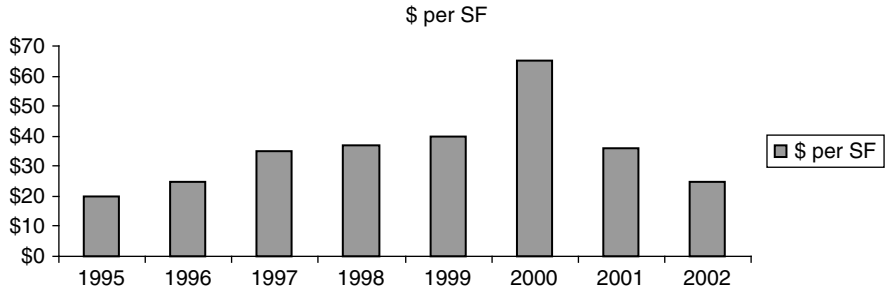

Figure 5.16 Asking rents in San Francisco office market

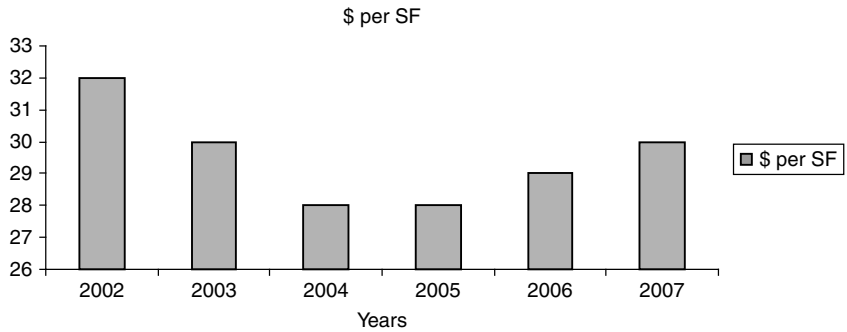

Figure 5.17 San Francisco office market – rent forecast

office vacancy rates, which stood at a scant 3.3% in 2003, are now over 18%. As a result, occupancy-adjusted cash flows from office properties have declined significantly. Interestingly, however, the prices investors will pay for real estate have for the most part remained firm. Much of this has to do with the amount of capital that institutional investors have allocated toward real estate in the past. Due to diminished equity returns, many large investors have increased their capital allocations to commercial property. As a result, capitalization rates (the discount factor that real estate investors apply to building cash flows for valuation purposes) have not risen nearly as sharply as the deterioration in rental rates and occupancies would have implied. Under these circumstances, many corporate property owners have recognized that they can sell property at favorable prices and simultaneously relocate to far cheaper leased space.

Given the dramatic softening of the office market in the past three years, and the sizable gap between the demand and supply for space, the office outlook not unexpectedly calls only for a very modest recovery in the next several years (see Figure 5.17). Rents are projected to



Figure 5.18 San Francisco office market – vacancy forecast

stabilize in 2004, and then rise slowly thereafter. Vacancy rates, which generally follow rental changes with a short lag, should peak within two years, before moving downward again. The downward correction in property prices should gain momentum, as investors move back toward equity markets, and as the unfavorable rental market conditions further depress building cash flows.

The authors extend the company's preliminary analysis by formally introducing the idea that the decision to sell can be modeled as a deferral put option. That is, rather than simply sell today, as the NPV analysis implies, the company can choose the optimal point to sell any time within some future interval by putting the subject property to a buyer at the market price which prevails at the time the option is exercised. Since the buyer can choose to exercise this option at any time, this option is treated as an American put. In general, however, even a simple cash sale real options model introduces some complications.

First, many properties are income producing, thus it would be reasonable to liken them to (perhaps stochastic) dividend paying stocks. In addition, the put option is not exercised at a fixed, pre-determined strike price; instead the sale occurs at an unknown stochastic future price. At a minimum some sort of one-factor model should be used to reflect the distribution of future building values. Further, equilibrium real estate prices are typically represented as the present discounted value of future rents, which as the authors note above, are imperfectly correlated with prices.

As a result, a multifactor model should be used to capture the interaction between prices and rents. The authors recognize the importance of these requirements in developing a rigorous real options model for real estate. For the sake of expository clarity, however, the authors make a number of simplifying assumptions and use a standard American put option with no dividends (note: as many corporate-owned buildings

are fully owner-occupied and hence not earning rental income, the assumption of no dividend payments is not untenable).

One of the challenges in using real options models centers on the difficulties of developing the necessary model input parameters. The deferral option formulation uses two distinct prices. The first is the market value of the property, that is the sales price the building would command in a pure, arms-length transaction. The second is an estimate of the 'value-in-use', or the marginal revenue (or earnings) value of the property to the current corporate owner. This latter price reflects in some sense the value of the building as a factor of production, which has a certain productivity or marginal revenue product. Given these prices, the put option is in-the-money when the market value of the property is greater than the marginal revenue product of the building as an operating asset. As the value-in-use of the property is closely tied to its operational functionality, this helps to underscore the link between capital investment and business strategies that real options emphasize.

To estimate this pair of prices, the authors begin by specifying a way to tie building value to market rents and capitalization rates (the main drivers of discounted cash flow pricing). For this, the authors adopt a relatively common 'mark-to-market' approach that capitalizes a market-based estimate of building rents, then makes an allowance for market vacancy rates. The basic idea is to identify an appropriate sub-market or peer group of buildings, and then use the average rents and occupancy rates of this sample to create an estimate of net operating income (NOI), which in turn is used to value the property. This is very similar to the procedure that debt-rating agencies use to underwrite pools of commercial mortgages when rating real estate securities and is the approach that many prospective buyers would take in valuing a property. The NOI calculation is detailed in Table 5.25.

To calculate the market value, the per square foot NOI is divided by a capitalization rate (or cap rate for short). This yields, on a per square foot basis, the discounted value of the building's net income stream, which when multiplied by the total size of the property produces an estimate of market value **(see** Table 5.26**)**. Note that the market value estimate also includes the land value associated with the subject property.

Next, the authors needed an estimate of the price of the subject property as a factor of production, which the authors denote value-in-use. The estimation of value-in-use ties closely to the nature and intensity of the business activities which the property supports. In many instances,

Table 5.25 Estimated property NOI

Factor	Value (psf)	Notes and sources
Asking rent	$25.00	Historical figures, quoted rents
Effective rent	$20.00	Historical figures, asking rents less free rent, concession, TI's
(–) Operating expenses	$4.11	Ongoing maintenance, insurance
(–) Capital expenses	$3.33	Company data; costs of maintaining building quality
Net rent	$12.55	Rents after expenses
Vacancy	18.0%	Historical figures, sub market vacancy rate
NOI	$10.30	Net rent* (1-Vacancy)

Table 5.26 Value calculations

	Market value	Value-in-use	Notes
Price	$53,080,144	$63,000,000	GLA × price (psf)
Gross leasable area (sf)	350,000	350,000	Building size
Price (psf)	$123.09	$180.00	NOI/discount factor
NOI (psf)	$10.29	$45.00	Estimated by authors
Discount factors			
Cap rate	8.36%		Source: Real Capital Analytics
Return on equity		25.0%	ROE target provided by company
Land value	$10,000,000		

Notes: Market value includes land. The cap rate is based on past 12 months of transactions in the sub-market, adjusted by authors.

establishing the 'earnings' generated by a specific property may be relatively straightforward. Retail properties are easily tied to the sales they support. The value of a warehouse building can be related to the dollar volume of goods shipped through the facility. Manufacturing plants can be linked to the value of the goods produced, while hotels have easily observed revenue streams. Office properties, however, are more problematic, since office space tends to be largely an augmenting factor, facilitating the productivity of labor, and there is no 'natural' way to directly assign a revenue value to a square foot of office space.

Moreover, regardless of the apparent ease of value-in-use estimation for any given property, there is the more complicating need to assess the potential strategic value of an asset. For instance, a retail property has value not just from supporting sales but also from preempting competition, generating branding for a company, or providing a platform for additional growth in the local trade area. These strategic factors are more difficult to estimate and often require very specific knowledge of a company, its competitors, the nature of its end markets, and so on.

For the example, the authors worked with company analysts to develop an estimate of value-in-use for the subject property. As a general rule, the authors have found that a large part of value-in-use is subjective. As this is a key component of the option's moniness, sensitivity analysis should be performed across the value-in-use parameters when pricing this form of deferral option. As shown in Table 5.26, a point estimate of the value-in-use of the subject property was calculated to be $63,000,000, or about $10,000,000 more than the estimated market value.

The final step before solving the deferral option model is to specify the remaining model inputs (Table 5.27). The authors assume a five-year expiration for the put option, and use a 4% risk-free rate. As the option value depends on both the market value and value-in-use, the authors estimate a compound volatility that reflects the (imperfect) correlation between the volatility of capitalized company earnings and office real estate values.

5.6.5 The results

The authors utilize a standard binomial tree-based American option model to price the deferral. Using the baseline parameters in Table 5.27, the value to the company to put the subject property at the current strike price over the next five years is $17.71 per square foot, or $6.2 million in total. This represents 11.7% of the current appraised value, a substantial amount in the context of a commercial real estate transaction. The authors next conduct a sensitivity analysis with respect to current cap rates. The results are summarized in Table 5.28. The cap rate was allowed to vary from 6 to 12%, a range that is reflective of the historical volatility of San Francisco office market transaction prices. Table 5.28 indicates the resulting put option value and the put value's share of the corresponding market value of the property. Even for very high cap rates, the put value remains a significant share of the market value, implying that the flexibility associated with the ability to defer a

Table 5.27 Benchmark option model inputs (per square foot basis)

Input	Value	Notes
Value-in-use	$180.00	Capitalized income to company from property
Strike price	$151.66	Current market value of asset (includes land)
Risk-free rate	4%	5-year treasuries
Annualized volatility	30%	Correlation of capitalized earnings and office values
Expiration (years)	5	Exercise time

Table 5.28 Sensitivity analysis-capitalization rates

Cap rate	6%	7%	8%	9%	10%	11%	12%
Market value ($)	70,042,222	61,464,762	55,031,667	46,025,333	42,750,303	42,750,303	40,021,111
Put value:							
Per square foot ($)	37.51	26.68	19.64	14.87	11.53	9.12	7.35
Total put ($mil.)	13,128,500	9,338,000	6,874,000	5,204,500	4,035,500	3,192,000	2,572,500
% of value	18.7%	15.2%	12.5%	10.4%	8.8%	7.5%	6.4%
% w/o land	14.6%	11.0%	8.4%	6.4%	5.0%	3.9%	3.1%

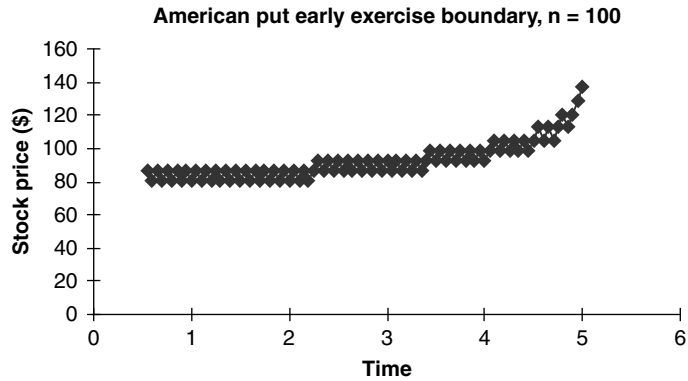

Figure 5.19 Early exercise boundary

sale is valuable. Even if the value of the surrounding land is factored out (the authors held this value constant in the analysis), the put retains a value sufficiently large to warrant the attention of management.

As noted above, a powerful dimension of real options methodology is the ability to show under what conditions the option may be exercised. For this, the authors calculated the early exercise boundary of the deferral put, using the benchmark parameters shown in Table 5.27. The result is shown in Figure 5.19. The boundary shows the minimum market price at which the put owner should optimally exercise, given the estimated value-in-use of the property. For this specific example, it would take historically low cap rates – under 5% – to trigger an optimal exercise.

5.6.6 Summary

There are two fundamental conclusions from the example: there is value in waiting to execute asset sale strategies and what a company

does has a great impact on this value. Given a reasonable characterization of conditions and uncertainties in the real estate markets and corporate business environment, the real options approach provides a way to determine when and under what conditions (price being one) it is optimal to sell. This is a critical step for companies seeking to coordinate their real estate policies with the optimal investment decisions for the firm. What a company does in its commercial space and the optimal way it contracts to use that space are largely determined by the business opportunities and tax considerations of the corporation. As discussed in L'Heureux and Coleman (2003b), the revenue potential business opportunities of a company determine 'the size of the pie' while the competitive dynamics of the rental market (relative to other factor markets) determine the size of the slice paid as rent. As a result, the value-in-use of a real estate asset (or any fixed asset) for a corporate user is determined by the profitability considerations of their business.

As the corporate tenant can either decline to lease space (the option to lease) or sub-lease currently held space at market rates, the value will be greater than or equal to the rental rate for the space or else the firm will sell. The authors are currently extending this approach in several directions. The conceptual framework above can be used to measure the impact of 'hidden assets' in commercial properties, for example L'Heureux and Coleman (2003c). These assets typically produce non-traditional real estate revenue streams. Examples include the ability to develop and lease a carrier hotel or central office in the basement of an office building, or construct and rent an 'antenna farm' on the roof. While these assets (or options to develop these assets) may or may not be reflected in the market value of the property, certain types of hidden assets provide non-transferable rights or facilities-specific services to the owners/users. In the telecommunications industry, such options could entail the right to expand or upgrade critical links in the carrier's network. These rights to develop future business could explain why it may be optimal for the carrier to retain an empty building. As a result, the real options approach to formulating corporate real estate policies aligns the interests and efforts of a company's real estate department with the business objectives of the Treasury and operational units.

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Part III

Quantitative Analytics and Methods

6
Data Analysis

6.1 Data and information

One fundamental change in today's business environment is the gradual replacement of the industrial society with the information society. Information has become one of the most powerful commodities in the world today. Information systems management is increasingly becoming integrated into corporate and business strategy, with data integrity and availability improving as a result. This process is providing a rich source of financial and business data, much of which is proprietary to an organization, which managers and investors can utilize for the analysis of strategic decisions. Statistical analysis can provide inferences about the properties of the behavior of economic, financial and business data. These properties can include price processes, trends, seasonality, and distributions, which are important considerations in the modeling and analysis of data.

6.2 Time series analysis

The econometric analysis of economic, financial and business time series has become an integral part in the research and application of quantitative descriptions of the real world. A time series typically consists of a set of observations of some observational unit or variable, y, which is taken at equally spaced intervals over time (Harvey, 1993). A time series can be considered from two aspects: analysis and modeling. The objective of a time series analysis is to identify and summarize its properties and describe its prominent characteristics. The analysis can be framed in either the time domain or the frequency domain. In the time domain the focus is on the relationship between observations at various points in time, whereas in the frequency domain the analysis focuses on the cyclical movements of a series.

Economic, business and financial time series will have at least one of the following key features:

- *Trends:* is one of the main features of many time series. Trends can have any number of attributes, such as upward or downward with relatively different slopes, and linear, exponential or other functional forms.
- *Seasonality:* time series can often display a seasonal pattern. Seasonality is a cyclical pattern that occurs on a regular calendar basis.
- *Irregular observations:* there can be periods or samples within a time series that are inconsistent with other periods, and therefore the series is subject to regime changes.
- *Conditional heteroskedasticity:* is a time series condition where there is variation (as opposed to constancy) in the variance or volatility, where patterns emerge in clusters, that is, high volatility is followed by high volatility, and low volatility is followed by low volatility.
- *Non-linearity:* generally a time series can be described as non-linear when the impact of a shock to the series depends if it is positive or negative and is not proportional to its size.

A stochastic process generates a stochastic time series; that is, each value of y in a series is a random draw from a probability distribution. Inferences can be made about the probabilities of possible future values of the series by describing the characteristics of the series randomness. Much of the research in time series has focused on investigating the hypothesis as to whether a series is a random walk or reverts to a trend after a shock. The simplest random walk process assumes that each successive change in y_t is drawn from a probability distribution with zero mean:

$$y_t = y_{t-1} + \varepsilon_t \tag{6.1}$$

where ε_t is an error term which has a zero mean and whose values are independent of each other. The price change $\Delta \mathrm{y}_t = \mathrm{y}_t - \mathrm{y}_{t-1}$ is therefore the error ε_t and is independent of price changes.

The question of whether economic variables follow random walks or tend to revert to a long-run trend after a shock is an important issue for modeling. Most financial models of futures, options and other instruments tied to an underlying asset are based on the assumption that the spot price follows a random walk. In some markets, however, the prices of such assets as energies and commodities are tied in the

long run to their marginal production cost. Although the price of an energy or commodity may be subject to sharp short-run fluctuations, it typically tends to return to a mean level based on cost.

A number of methods exist to test hypotheses about the properties of a time series. One technique is to examine its *autocorrelation* properties. Time series can be characterized by a set of autocorrelations, which can provide insights into possible models to describe the time series. A *correlogram* displays the autocorrelation and partial autocorrelation functions up to the specified order of lags. These functions characterize the pattern of temporal dependence in time series data. Another method for testing the hypothesis that the process is a random walk against the alternative that it is stationary – that is, the stochastic process in fixed time – is the unit root test introduced by Dickey and Fuller. Formally stated, the simplest model tested is:

$$y_t = \phi y_{t-1} + \varepsilon_t \quad t = 2, \ldots\ldots T \tag{6.2}$$

where the null hypothesis is that $\phi = 1$, and the alternative hypothesis is $\phi < 1$. The generalization of the test for a unit root is known as the augmented Dickey–Fuller (ADF) test (1979, 1981).

Most statistical tools are designed to model the conditional mean of a random variable. Autoregressive conditional heteroskedasticity (ARCH) models are specifically designed to model and forecast *conditional variances*. ARCH models were introduced by Engle (1982) and generalized as GARCH (generalized ARCH) by Bollerslev (1986). These models are widely used in econometrics, especially in financial time series analysis. The modeling of variance or volatility can be used, for example, in the analysis of the risk of holding an asset or in the valuation of an option. In a GARCH model there are two separate specifications: one for the conditional mean and one for the conditional variance. The standard GARCH(1,1) specification is:

$$y_t = \alpha_0 + \sigma_t \varepsilon_t \tag{6.3}$$

$$\sigma_t^2 = \varpi + \alpha_1 \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 \tag{6.4}$$

where y_t is the log return of a series, and the mean equation in (6.3) is written as a function of exogenous variables with an error term. As σ_t^2 is the one-period ahead forecast variance based on past information, it is called the conditional variance. The conditional variance equation specified in (6.4) is a function of three terms: the mean, news about volatility from the previous period, measured as the lag of the squared

residual from the mean equation (the ARCH term), and last period's forecast variance (the GARCH term).

6.3 Volatility

Volatility, defined as the annualized standard deviation of price returns, is one of the critical concepts in option pricing and risk management. A percentage is derived as:

$$r_t = \frac{S_t}{S_{t-1}} - 1 \tag{6.5}$$

where S_t is the spot price at the time t. Price returns are typically calculated by taking the natural logarithms of the price ratios:

$$r_t = \ln\left(\frac{S_t}{S_{t-1}}\right) \tag{6.6}$$

which is an approximation of the percentage change. Log returns are usually used to calculate volatility, as the natural log of S_t/S_{t-1} is equivalent to the natural log of $1 + r$, which is approximately equal to r. Another advantage is the log of a product is equal to the sum of the logs, and therefore a log return over a time period can be calculated as the sum of log returns for the sub-periods. Figure 6.1 illustrates the

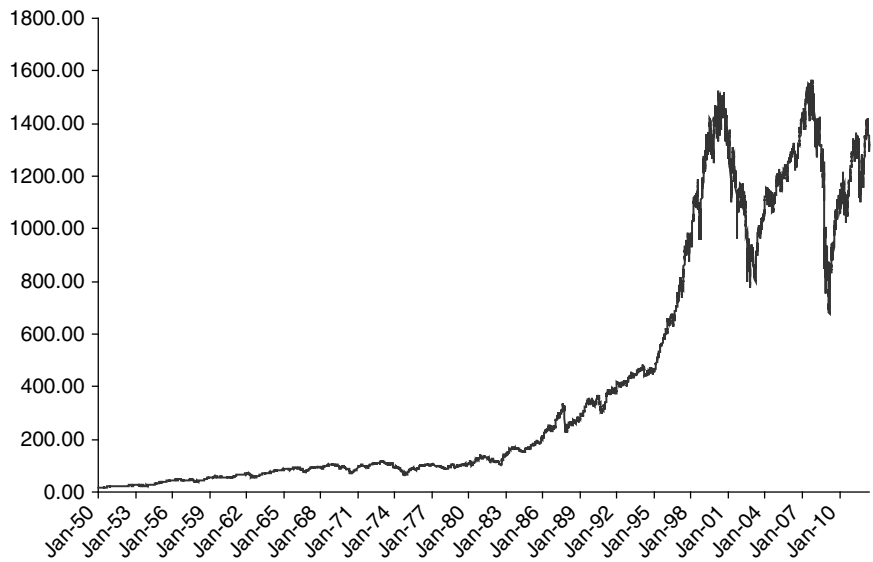

Figure 6.1 S&P 500 – 4 January 1950 to 31 May 2012

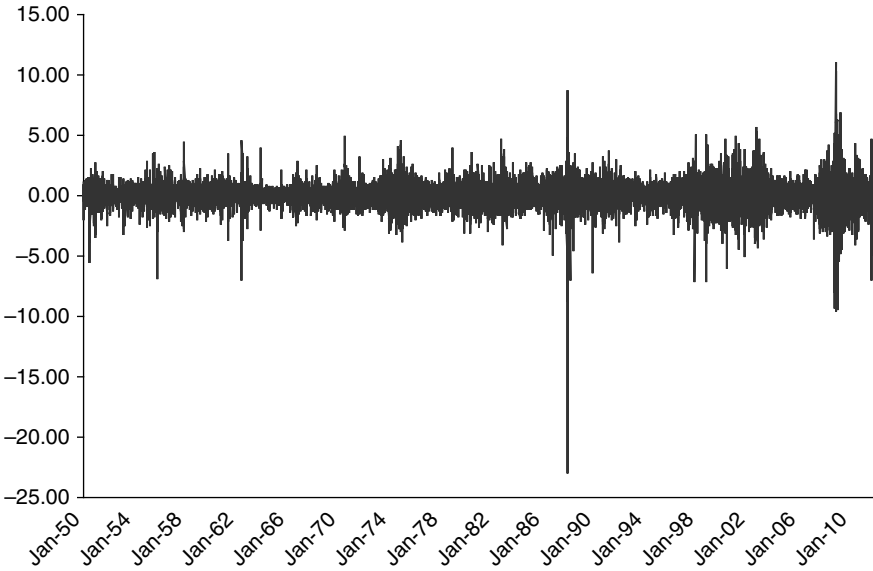

Figure 6.2 S&P 500 returns (×100) – 4 January 1950 to 31 May 2012

S&P index during the second half of the 20th century, and Figure 6.2 the S&P returns for the same period.

Volatility, rather than standard deviations or variances, is used as a measure of uncertainty so that any comparisons of distributions are equivalent. Normalizing a price return's standard deviation into a volatility measure creates a consistent measure of magnitude of random behavior, and therefore facilitates the comparison of various markets and models. The volatility of a price process also measures the annualized distribution of price returns, whereas standard deviations can measure the width of any distribution. The probability of exceeding an option's exercise price increases as a result of the volatility of the underlying asset, which is why volatility increases the value of options. Typically the greater the volatility associated with an underlying asset the greater the value of an option on that asset.

Volatility can be estimated from historical data or implied from option market prices. If there is a reasonably liquid market for traded options, then the implied volatility can be derived through an iteration process using an analytical pricing formula, such as the Black–Scholes model, the option price, and the known variables such as the interest rate, time to maturity and exercise price. The result is a forecast of the volatility implied in the quoted price of the option, with the forecast

horizon being the maturity or expiry of the option. Volatility can also be derived from historical data by annualizing the standard deviation of the log returns through a scaling factor defined as the square root of time. The annualization factor depends on the price data frequency. If the data is monthly, the factor is $\sqrt{12}$, for weekly data, $\sqrt{52}$, and for the daily data for each calendar day, it is $\sqrt{365}$. If the data is available for trading days only, the relevant number may vary from $\sqrt{250}$ to $\sqrt{260}$, according to public holidays.

While volatility provides a comparative risk parameter, other test statistics can provide insights as to how well the assumptions capture the behavior of a time series. The properties of a time series can be depicted by its descriptive statistics. The mean and standard deviation are descriptive measures of the properties of a time series. Other descriptive measures can be illustrated using a histogram, which displays the frequency distribution of a series. A histogram divides the range between the maximum and minimum values of a series into a number of equal length intervals or bins and exhibits the number of observations within each bin. Figure 6.3 illustrates the histogram of the S&P 500 index log returns from January 1997 to December 2001.

The descriptive statistics of the S&P returns sample are:

- The *mean* is the average value of the series sample, derived by adding up the series sample and dividing by the number of observations.
- The *median* is a measure of central tendency, or the middle value (or average of the two middle values) of a series sample sequenced from

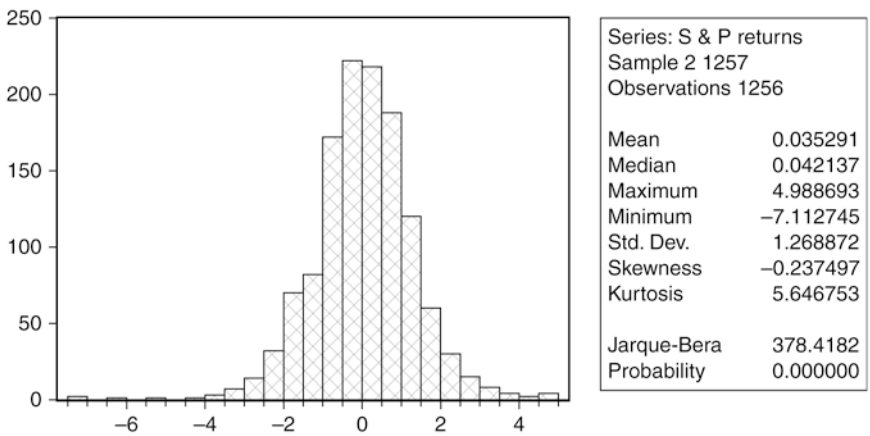

Figure 6.3 Histogram of the S&P 500 returns (×100) – 3 January 1997 to 31 December 2001

the smallest to the largest. The median is a more robust measure of the center of the distribution than the mean, as it is less sensitive to outliers.

- The *maximum* and *minimum* values of the series sample.
- The *standard deviation* is a measure of dispersion or spread in the series.
- *Skewness* is a measure of the asymmetry of a series distribution around its mean. The skewness of the normal distribution, which is symmetric, is zero. Positive skewness implies that a distribution has a long right tail, while negative skewness indicates a long left tail.
- *Kurtosis* measures the peakness or flatness in the distribution of a series. A normal distribution has a kurtosis of three. If the kurtosis exceeds three, the distribution is leptokurtic or relatively peaked to the normal distribution, while if the kurtosis is less than three, the distribution is platykurtic or relatively flat to the normal distribution.
- *Jarque-Bera* is a test statistic for testing whether the series approximates the normal distribution. The test statistic measures the differences of the skewness and kurtosis of the series with those from the normal distribution. The null hypothesis is that a series has a normal distribution.

The annualized volatility for the S&P 500 index sample period is 20.06%, which is 1.268872, the standard deviation, times $\sqrt{250}$. The histogram in Figure 6.3 also illustrates the presence of fat tails in the distribution of the S&P 500 index returns. Fat tails refers to the probability of extreme outcomes in an observed series exceeding the assumed theoretical probability distribution. Distributions displaying fat tails are described as leptokurtic and are measured by kurtosis, which in this case is 5.646753 and therefore greater than three. The skewness, which is zero in a normal distribution, is negative in this case and is typical of many financial assets such as stock prices.

6.4 The lognormal distribution

A variable has a *lognormal distribution* if the natural logarithm of the variable is normally distributed. Figures 6.4 and 6.5 illustrate the distributions of a simulated series and its natural log equivalent respectively. A lognormal variable can have any value between zero and infinity. As a result the lognormal distribution has a positive skew and so is unlike the normal distribution, as indicated by the skewness and kurtosis

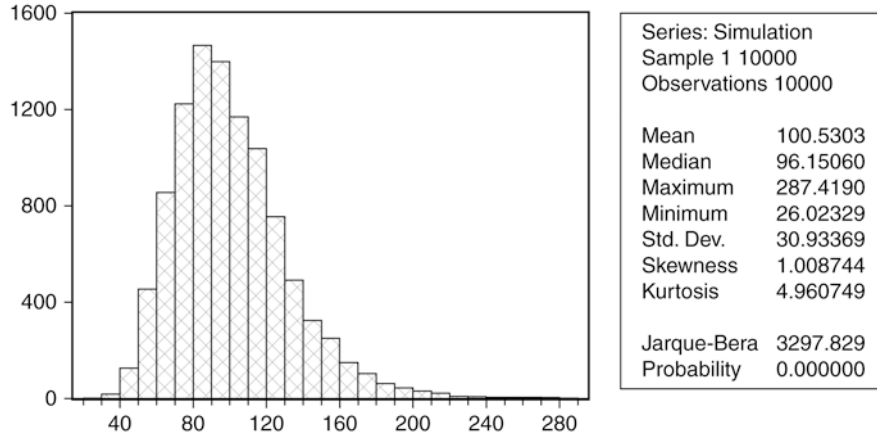

Figure 6.4 The simulated series

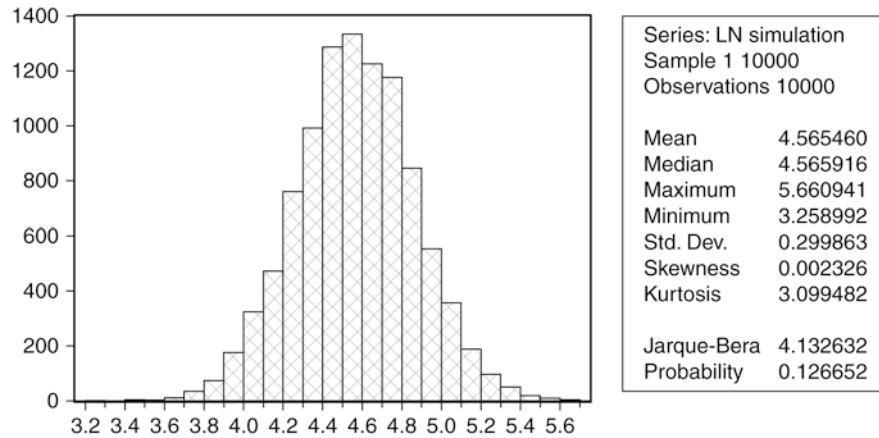

Figure 6.5 The natural log of the simulated series

statistics. The log series, however, has a skewness close to zero and a kurtosis that is approximately three, and therefore can be described as being normally distributed.

The use of the log of financial variables is popular in derivative modeling as the price can never become negative, and the return is the relative change in the level of the log price. Figure 6.6 illustrates the distribution of the log returns of the simulated series. The returns can also be described as being normally distributed. The lognormal property of asset prices also can be used to describe a price process and its probability distribution. If an asset price follows a geometric Brownian

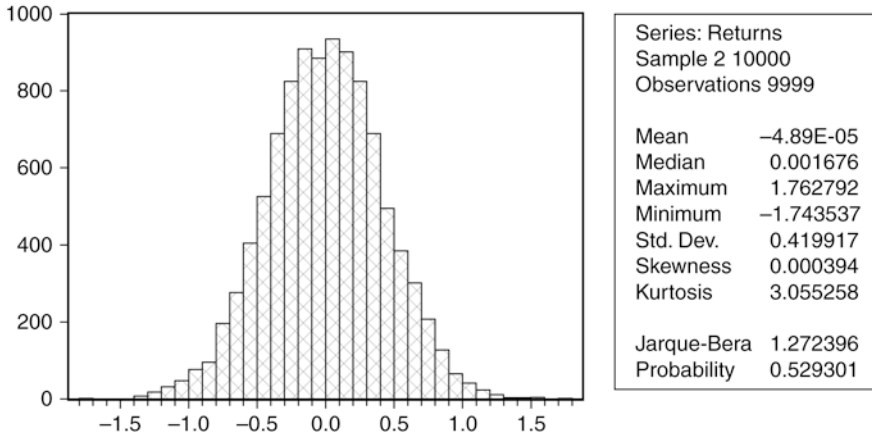

Figure 6.6 The simulated log returns

motion, then the natural log of an asset price follows a process called a generalized Weiner process. This implies that given an asset's price today the price at T is lognormally distributed. The standard deviation of the logarithm of an asset is $\sigma\sqrt{T}$; that is, it is proportional to the square root of the length of time into the future. This stochastic process is the basis for the Black–Scholes option pricing model.

6.5 Which volatility?

The volatility of a project, asset or firm is not necessarily the same as the volatility of one of its components. One example is the difference between the volatility of a firm's market value and the volatility of its equity. A firm's capital structure is the mixture of debt, equity and other liabilities that the firm uses to finance its assets. Merton (1974) defined the value of a firm's equity as a call option on the assets of the firm, where the strike is the book value of the firm's liabilities, and the underlying asset is the total value of the firm's assets. Merton's approach illustrated the link between the market value of the firm's assets and the market value of its equity, and provided a framework for determining the value of a firm's equity by reference to the underlying market value of the firm.

The analysis can be reversed to estimate a firm's value and volatility from the market value of its equity, the volatility of its equity, and the book value of its liabilities. KMV (now a division of Moody's Analytics) extended Merton's approach to estimate probabilities of default for credit analysis. If the market price of equity is available,

the market value and volatility of assets can be determined directly using an options pricing based approach, which recognizes equity as a call option on the underlying assets of the firm. The limited liability of equity provides equity holders with the right but not the obligation to pay off the debt holders and acquire a firm's remaining assets. A call option on the underlying assets has the same properties. The holder of a call option on a firm's assets has a claim on those assets after fulfilling the option's strike value, which in this case is equal to the book value of the firm's liabilities. If the value of the assets is not sufficient to meet the firm's liabilities, the shareholders, the holders of the call option, will not exercise the option and will abandon the firm to its creditors. KMV utilize the optional nature of equity to derive the market value and volatility of a firm's underlying assets implied by its equity market value by solving backwards for the implied asset value and asset volatility.

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7
Derivatives

7.1 Futures, forwards and options

A derivative is a financial instrument whose payoff depends on the values of other more basic variables. The variables underlying derivatives are often the prices of traded securities. Derivatives separate market and credit risks from the underlying assets and liabilities, and offer the ability to reduce a risk exposure through its transfer to a party that is prepared to take on and manage those risks. Derivative securities are also known as contingent claims and can be contingent on almost any variable, from the price of a commodity to weather outcomes. There are two basic types of derivatives: futures/forwards and options.

Forward and futures contracts are agreements to buy or sell an underlying asset at a predetermined time in the future for a specified price. Futures are exchange standardized contracts, whereas forward contracts are direct agreements between two parties. The cash flows of the two contracts also occur at different times. Futures are daily marked-to-market with cash flows passing between the long and the short position to reflect the daily futures price change, whereas forwards are settled once at maturity. If future interest rates are known with certainty then futures and forwards can be treated as the same for pricing purposes.

There are two sides to every forward contract. The party who agrees to buy the asset holds a long forward position, while the seller holds a short forward position. At the maturity of the contract (the 'forward date') the short position delivers the asset to the long position in return for the cash amount agreed in the contract, often called the delivery price. Figure 7.1 shows the profit and loss profile to the long forward position at the maturity of the contract. If T represents the contract maturity date, a long forward payoff is expressed as $S_T - K$, where S_T represents the asset price at time T, and K represents the agreed delivery price. The payoff can be positive or negative, depending on the relative

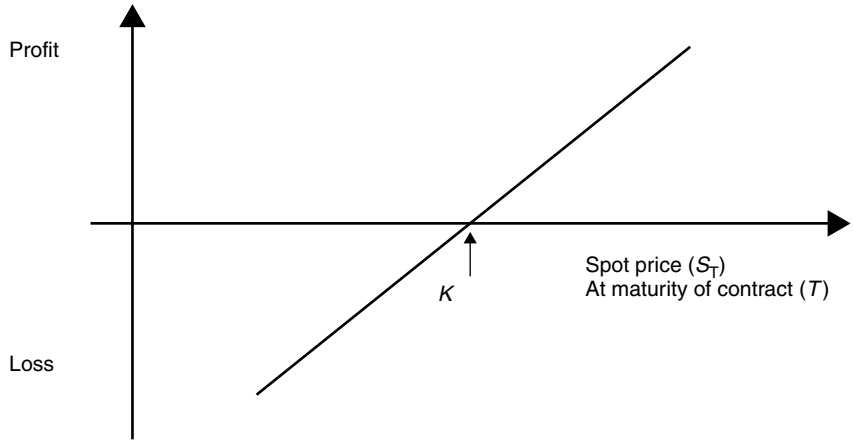

Figure 7.1 Payoff to a long forward position

values of S_T and K. The short position has the opposite payoff to the long position, that is, $K - S_T$, as every time the long position makes a profit the short incurs a loss and vice versa. As the holder of a long forward contract is guaranteed to pay a known fixed price for the spot asset, futures and forwards can be seen as insurance contracts providing protection against the price uncertainty in the spot markets.

For an arbitrage relationship to exist, the forward price has to equal the cost of financing the purchase of the spot asset today and holding it until the forward maturity date. Let F represent a forward contract price on a spot asset that is currently trading at S, T the maturity date of the contract, c the cost of holding the spot asset (which includes the borrowing costs for the initial purchase and any storage costs) and d the continuous dividend yield paid out by the underlying asset. The price of a forward contract at time t and the spot instrument on which it is written are related via the 'cost of carry' formula:

$$F = Se^{(c-d)(T-t)} \tag{7.1}$$

where $T - t$ represents years. The continuous dividend yield can be interpreted as the yield on an index for index futures, as the foreign interest rate in foreign exchange futures contracts, and as the convenience yield for various energy contracts.

Options contracts are the second foundation to derivatives markets. Options are asymmetrical relationships where the option holder has a right, but not an obligation, to transact at a contracted price, called the exercise price. There are two basic types of options. A call option gives

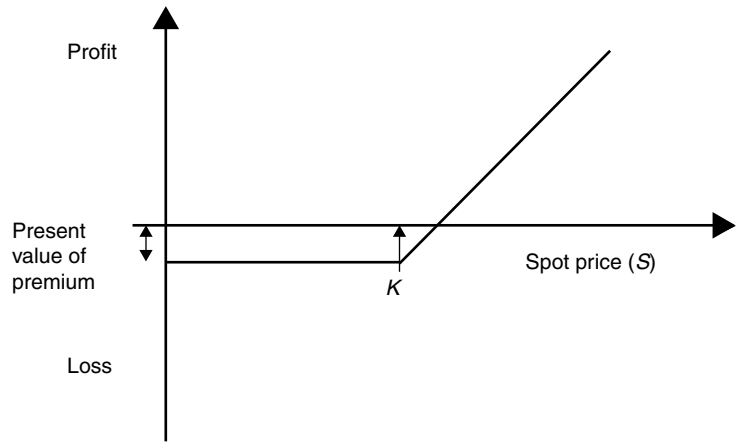

Figure 7.2 Payoff for a call option

the holder the right, but not the obligation, to buy the spot asset on or before a predetermined date (the maturity date) at a certain price (the strike price), which is agreed today. A put option is the right to sell, at the exercise price. Option sellers, or writers, are obliged to commit to the purchaser's decision. Figure 7.2 shows the payoff to the holder of a call option.

Options differ from forward and futures contracts in that a payment, or the option price or premium, must be made by the buyer, usually at the time the contract is entered into. If the spot asset price is below the agreed strike or exercise price K at the maturity or expiration date, the holder lets the option expire worthless, forfeits the premium and buys the asset in the spot market. For asset prices greater than K, the holder exercises the option, buying the asset at K and has the ability to immediately make a profit equal to the difference between the two prices (less the initial premium). The holder of the call option therefore essentially has the same positive payoff as the long forward contract without the downside risk.

The payoff to a call option can be defined as:

$$Max(S-K,0) \tag{7.2}$$

The second basic type of option, a put option, gives the holder the right, but not the obligation, to sell the asset on or before the maturity date at the strike price.

The payoff for a put option can be written as:

$$Max(K-S,0) \tag{7.3}$$

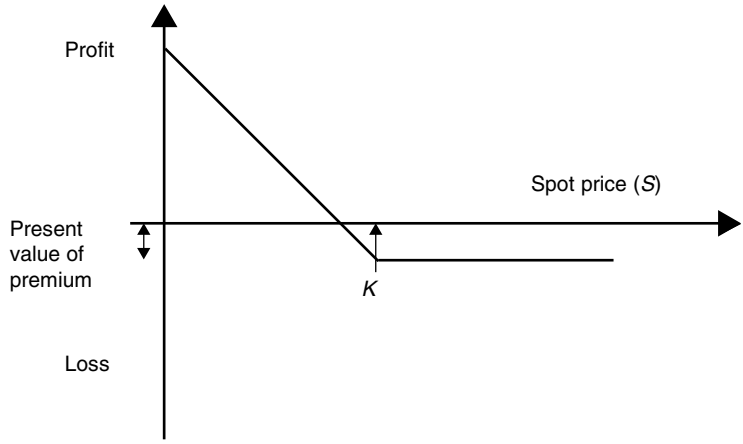

Figure 7.3 Payoff for a put option

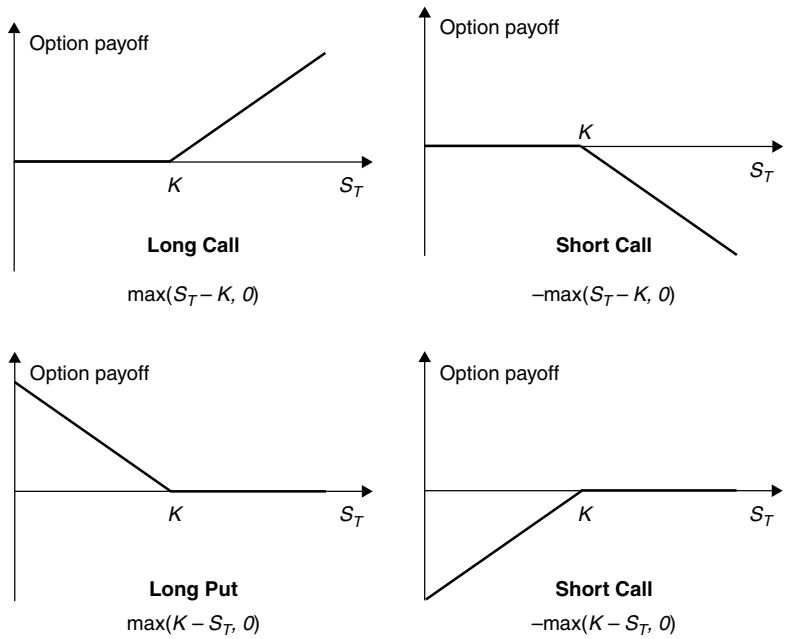

Figure 7.4 Payoffs for European options

Figure 7.3 shows the payoff to the holder of a put option.

As with forwards, there are two sides to every option contract. One party buys the option and has the long position, while the other party writes (or sells) the option and takes a short position. Figure 7.4 shows

the four possible combinations of payoffs for long and short positions in European call and put options at the maturity date T. Options are also classified with respect to their exercise conventions. European options can only be exercised on the maturity date itself, whereas American-style options can be exercised at any time up to and including the expiration date. While early exercise of an American option is generally not optimal, there are exceptions to the rule. One example is where the underlying asset pays a dividend, therefore reducing the value of the asset and any call options on that asset, in which case the call option may be exercised before maturity.

Forwards and options are also the key building blocks of more complex derivatives, and these building blocks are themselves interdependent. The decomposition of derivatives into their components assists in identifying a derivative's risk characteristics, which promotes more accurate pricing and better risk management strategies. The basic futures and options described are the building blocks of all derivative securities and the principles are consistent across all underlying markets. In some markets, however, derivative structures exhibit a number of important differences from other underlying markets. These differences arise because of the complex contract types that exist in these industries, as well as the complex characteristics of the relevant prices. Both the type of derivatives and the associated modeling need to capture the evolution of prices to reflect these differences.

7.2 The replicating portfolio and risk-neutral valuation

The modern theory of option pricing is possibly one of the most important contributions to financial economics. The breakthrough came in the early 1970s with work by Fisher Black, Myron Scholes and Robert Merton (Black and Scholes 1973; Merton 1973). The Black–Scholes–Merton (BSM) modeling approach not only proved important for providing a computationally efficient and relatively easy way of pricing an option but also demonstrated the principle of no-arbitrage risk-neutral valuation. Their analysis showed that the payoff to an option could be perfectly replicated with a continuously adjusted holding in an underlying asset and a risk-free bond. As the risk of writing an option can be completely eliminated, the risk preferences of market participants are irrelevant to the valuation problem, and it can be assumed that they are risk-neutral. In this construct all assets earn the risk-free rate of interest, and therefore the actual expected return on the asset does not appear in the Black–Scholes formula.

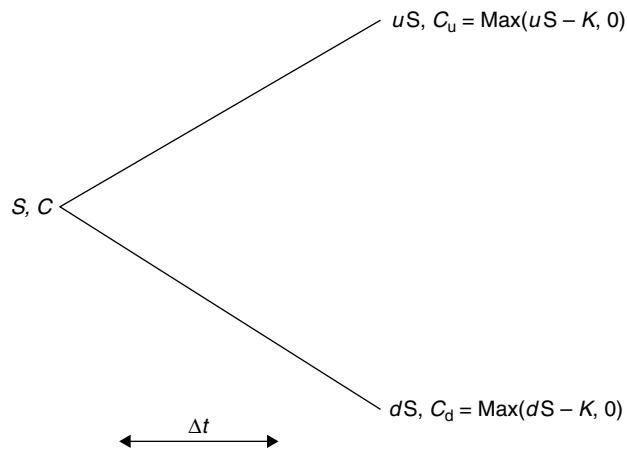

Figure 7.5 Binomial model of an asset price and call option

Options can be valued by deriving the cost of creating the replicating portfolio such that both the option and the portfolio provide the same future returns, and therefore must sell at the same price to avoid arbitrage opportunities. The portfolio consists of Δ units of an underlying asset S and an amount B borrowed against Δ units at the risk-free rate r. This combination of the borrowing and the underlying asset creates the same cash flows or returns as an option. A binomial model can be used to illustrate the replicating portfolio. The binomial model assumes that the underlying asset price follows a binomial process, where at any time the asset price S at t_0 can only change to one of two possible values over the time period Δt, either up to uS or down to dS at time t_1. Figure 7.5 is a binomial model for a one-period process, in which a risk-free portfolio consisting of the underlying asset and the call option is illustrated.

The call option has been defined as:

$$C \approx (\Delta S - B)$$

The value of the portfolio is the same regardless of whether the asset price moves up or down over the period Δt:

$$C_u = \Delta uS - (1 + r)B$$

and

$$C_d = \Delta dS - (1 + r)B$$

which after rearranging becomes:

$$-C_u + \Delta uS = -C_d + \Delta dS \tag{7.4}$$

This is the equivalent to:

$$\Delta = \frac{C_u - C_d}{(u-d)S} \tag{7.5}$$

The portfolio must earn the continuously compounded risk-free rate of interest, as it is risk-free:

$$(-C + \Delta uS) = e^{r\Delta t}(-C + \Delta S) \tag{7.6}$$

Substituting into equation (7.6) for ΔS, using equation (7.5) and rearranging for the call price at t_0 obtains:

$$C = e^{-r\Delta t}\left(\frac{e^{r\Delta t} - d}{u-d}C_u + \frac{u - e^{r\Delta t}}{u-d}C_d\right) \tag{7.7}$$

The actual probabilities of the asset moving up or down have not been used in deriving the option price, and therefore the option price is independent of the risk preferences of investors. Equation (7.7) can be interpreted as taking discounted expectations of future payoffs under the risk-neutral probabilities. This provides a means to derive the risk-neutral probabilities directly from the asset price:

$$uSp + dS(1-p) = Se^{r\Delta t} \tag{7.8}$$

for which the return can now be assumed as being the risk-free rate. Rearranging gives:

$$p = \frac{e^{r\Delta t} - d}{u-d} \tag{7.9}$$

Equation (7.7) can now be written as:

$$C = e^{-r\Delta t}\left(pC_u + (1-p)C_d\right)$$

This is the price of the call option with one period to maturity.

Note: This chapter has largely been adapted from Clewlow and Strickland (1998, 2000).

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8
Option Pricing Methods

8.1 A model for asset prices

The evolution of uncertainty over time can be conceptualized and modeled as a mathematical expression, known as a stochastic process, which describes the evolution of a random variable over time. Models of asset price behavior for pricing derivatives are formulated in a continuous time framework by assuming a stochastic differential equation (SDE) describes the stochastic process followed by the asset price. The most well-known assumption made about asset price behavior, which was made by Black and Scholes (1973), is geometric Brownian motion (GBM).

The GBM assumption in the Black–Scholes model is the mathematical description of how asset prices evolve through time. In the GBM assumption proportional changes in the asset price, denoted by S, are assumed to have constant instantaneous drift, μ, and volatility, σ. A non-dividend paying asset S following GBM is represented by the following stochastic differential equation:

$$dS = \mu S dt + \sigma S dz \tag{8.1}$$

dS represents the increment in the asset price process during a (infinitesimally) small interval of time dt, and dz is the underlying uncertainty driving the model, representing an increment in a Weiner process during dt. The risk-neutral assumption implies that the drift can be replaced by the risk-free rate of interest (that is, $\mu = r$). Any process describing the stochastic behavior of the asset price will lead to a characterization of the distribution of future asset values. An assumption in equation (8.1) is that future asset prices are lognormally distributed, or that the returns to the asset are normally distributed.

Dividing through by S gives:

$$\frac{ds}{S} = \mu dt + \sigma dz \tag{8.2}$$

In equation (8.2) the percentage change or return in the asset price dS/S has two components. The first is that during the small interval of time dt the average return on the asset is μdt, which is deterministic. The parameter μ is known as the drift. Added to this drift is the random component made up of the change dz, in a random variable z, and a parameter σ, which is generally referred to as the volatility of the asset. The random variable z or equivalently the change dz is called a Weiner process. A Weiner process is defined by two key properties. The first is that dz is normally distributed with mean zero and variance dt or the standard deviation of the square root of dt. The second is that the values of dz over two different non-overlapping increments of time are independent. Equations (8.1) and (8.2) are examples of an Itô process, as the drift and volatility only depend on the current value of the variable (the asset price) and time. In general the stochastic differential equation for a variable S following an Itô process is:

$$dS = \mu(S,t)\,dt + \sigma(S,t)\,dz \tag{8.3}$$

where the functions $\mu(S,t)$ and $\sigma(S,t)$ are general functions for the drift and volatility. Many models for the behavior of asset prices assume that the future evolution of the asset price depends only on its present level and not on the path taken to reach that level. A stochastic process possessing this property is known as Markovian.

The stochastic process followed by any derivative can be inferred from the assumption of the behavior of the asset price, on which the derivative's payoff is dependent. It follows that, using the Black–Scholes concept of constructing a riskless portfolio, a partial differential equation can be derived that governs the price of the derivative security.

8.2 The Black–Scholes formula

The stochastic differential equation for the asset price S is the starting point for any derivative model. As the process for the asset and the process for the derivative have the same source of uncertainty, it is possible to combine the two securities in a portfolio in such a way as to eliminate that uncertainty. A portfolio consisting of a short position in the option and a long position in the underlying asset can be constructed

such that the change in its value over an infinitesimal increment of time is independent of the source of randomness and is therefore risk-free. This relationship leads to the Black–Scholes partial differential equation. The Black–Scholes formulae for standard European call and put options are the result of solving this partial differential equation.

As the expected return on the underlying asset does not appear in the Black–Scholes partial differential equation, the value of the derivative is independent of the risk preferences of investors. The implication of this risk-neutral pricing is that the present value of any future random cash flow, for example the payoff for an option, is given by the expected value of the random future value discounted at the riskless rate. Replacing the expectation with the integral and solving obtains the Black–Scholes equation.

The Black–Scholes formula for a European call option on a non-dividend paying stock is:

$$c = S_0 N\left(d_1\right) - Ke^{-r(T-t)} N\left(d_2\right) \tag{8.4}$$

where:

$$d_1 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r + \frac{1}{2}\sigma^2\right)(T-t)}{\sigma\sqrt{T-t}}$$

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

The corresponding equation for the European put is:

$$p = Ke^{-r(T-t)} N\left(-d_2\right) - S_0 N\left(-d_1\right) \tag{8.5}$$

where the parameters are:

S_0 = the value of S at time zero

K = the strike price of the option

r = the risk-free interest rate

t = a point in time

T = Time at maturity of a derivative

One of the qualities that have led to the enduring success of the Black–Scholes model is its simplicity. The inputs of the model are defined by the contract being priced or are directly observable from the market. The only exception to this is the volatility parameter, and there is now a vast amount of published material in the finance literature for deriving estimates of this figure either from historical data or as implied by the market prices of options.

One widely used relaxation of the original formula takes into account assets that pay a constant proportional dividend. Assets of this kind are handled by reducing the expected growth rate of the asset by the amount of the dividend yield. If the asset pays a constant proportional dividend at a rate d, over the life of the option, then the original Black–Scholes call formula (8.4) can be used with the adjustment where the parameter S is replaced by the term $Se^{-d(T-t)}$. This adjustment has been applied to value options on broad-based equity indices, options on foreign exchange rates, and real options that allow for competition, where the fall in value due to competition is the equivalent to the dividend yield.

The intuition of the replicating portfolio concept can be illustrated with the Black–Scholes formula. The Black–Scholes formula can be defined as a combination of two binary options: a cash-or-nothing call and an asset-or-nothing call:

asset-or-nothing call:

$$Se^{-\delta(T-t)}N\left(d_1\right) \tag{8.6}$$

cash-or-nothing call:

$$Ke^{-r(T-t)}N\left(d_2\right) \tag{8.7}$$

A European call option represents a long position in an asset-or-nothing call and a short position in a cash-or-nothing call, where the cash payoff on the cash-or-nothing call is the equivalent to the strike price. A European put is a long position in a cash-or-nothing put and a short position in an asset-or-nothing put, where the strike price represents the cash payoff on the cash-or-nothing put. $N(d_1)$, the option delta, is the number of units of the underlying required to form the portfolio, and the cash or nothing term is the number of bonds each paying \$1 at expiration.

Although it is possible to obtain closed-form solutions such as equation (8.4) for certain derivative pricing problems, there are many situations when analytical solutions are not obtainable and therefore numerical techniques need to be applied. Examples include American options and other options where there are early exercise opportunities, 'path-dependent' options with discrete observation frequencies, models that incorporate jumps and models dependent on multiple random factors. The description of two of these techniques is the subject of the next section.

8.3 Numerical techniques

Two numerical techniques which are most commonly used by practitioners to value derivatives in the absence of closed-form solutions are binomial and trinomial trees and Monte Carlo simulation. Practitioners also use other techniques such as finite difference schemes, numerical integration, finite element methods and others. However, these methods require more advanced expertise in numerical techniques. It is possible to price not only derivatives with complicated payoff functions dependent on the final price using trees and Monte Carlo simulation techniques, but also derivatives whose payoff is determined also by the path the underlying price follows during its life.

8.3.1 Monte Carlo simulation

Monte Carlo simulation provides a simple and flexible method for valuing complex derivatives for which analytical formulae are not possible. The method can easily deal with multiple random factors, can also be used to value complex path dependent options, and also allows the inclusion of price processes such as price jumps. In general the present value of an option is the expectation of its discounted payoff. Monte Carlo simulation derives an estimate of this expectation by simulating a large number of possible paths for the asset price from time zero to the option maturity and computing the average of the discounted payoffs.

GBM for non-dividend spot prices with constant expected return μ and volatility σ is represented by the SDE in equation (8.1). The Black–Scholes perfect replication argument leads to the risk-neutral process in which the actual drift of the spot price m is replaced by the interest rate r:

$$dS = rSdt + \sigma Sdz \tag{8.8}$$

If the asset pays a constant continuous dividend yield δ then the risk-neutral process becomes:

$$dS = (r - \delta)Sdt + \sigma Sdz \tag{8.9}$$

Transforming the spot price to the natural log of the spot price $x = 1n(\mathrm{S})$ gives the following process for x:

$$dx = vdt + \sigma dz \tag{8.10}$$

where $v = r - \delta - \frac{1}{2}\sigma^2$. The transformed GBM process represented in equation (8.10) can be discretized in the following way:

$$x_{t+\Delta t} = x_t + (v\Delta t + \sigma\,(z_{t+\Delta t} - z_t)) \tag{8.11}$$

In terms of the original asset price the discrete form is:

$$S_{t+\Delta t} = S_t \exp(v\Delta t + \sigma(z_{t+\Delta t} - z_t)) \tag{8.12}$$

Equations (8.11) or (8.12) can be used to simulate the evolution of the spot price through time. The change in the random Brownian motion, $z_t + \Delta_t - z_t$, has a mean of zero and a variance of Δt. It can therefore be simulated using random samples from a standard normal multiplied by $\sqrt{\Delta t}$, that is, $\sqrt{\Delta t}e$ where ε~N(0,1). In order to simulate the spot price the time period $[0,T]$ is divided into N intervals such that $\Delta t = T/N$, $t_i = i\Delta t$, $i = 1,\ldots,N$. Using, for example, equation (8.12) gives:

$$S_{t_i} = S_{t_{i-1}} \exp(v\Delta t + \sigma\sqrt{\Delta t}\varepsilon_i) \tag{8.13}$$

As the drift and volatility terms do not depend on the variables S and t, the discretization is correct for any chosen time step. Therefore the option can be simulated straight to the maturity date in a single time step if the payoff is only a function of the terminal asset value and does not depend on the asset's path during the life of the option. Repeating this process N times, choosing ε_i randomly each time, leads to one possible path for the spot price.

At the end of each simulated path the terminal value of the option (C_T) is evaluated. Let $C_{T,j}$ represent the payoff to the contingent claim under the jth simulation. For example, a standard European call option terminal value is given by:

$$C_{Tj} = \max(S_{Tj} - K, 0) \tag{8.14}$$

Each payoff is discounted using the simulated short-term interest rate sequence:

$$C_{0,j} = \exp\left(-\int_0^T r_u du\right) C_{T,j} \tag{8.15}$$

In the case of constant or deterministic interest rates equation (8.15) simplifies to:

$$C_{0,j} = P(0,T)C_{T,j} \tag{8.16}$$

This value represents the value of the option along one possible path that the asset can follow. The simulations are repeated M times and

the average of all the outcomes is taken to compute the expectation, and hence the option price:

$$\hat{C}_0 = \frac{1}{M}\sum_{j=1}^{M} C_{0,j} \tag{8.17}$$

Therefore $\hat{C}_0$ is an estimate of the true value of the option, C_0, but with an error due to the fact that it is an average of randomly generated samples and so is itself random. In order to obtain a measure of the error, the standard error SE(.) is estimated as the sample standard deviation, SD(.), of $C_{t,j}$ divided by the square root of the number of samples:

$$SE(\hat{C}_0) = \frac{SD(C_{0,j})}{\sqrt{M}} \tag{8.18}$$

where $SD(C_{0,j})$ is the standard deviation of C_0:

$$SD(C_{0,j}) = \sqrt{\frac{1}{M-1}\sum_{j=1}^{M}\left(C_{0,j} - \hat{C}_0\right)^2} \tag{8.19}$$

For many American-style options early exercise can be optimal, depending on the level of the underlying price. It is rare to find closed-form solutions for prices and risk parameters of these options, so numerical procedures must be applied. Using Monte Carlo simulation for pricing American-style options, however, is difficult. The problem arises because simulation methods generate trajectories of state variables forward in time, whereas a backward dynamic programming approach is required to efficiently determine optimal exercise decisions for pricing American options. Therefore practitioners usually use binomial and trinomial trees for the pricing of American options.

8.3.2 The binomial and trinomial method

The binomial model of Cox et al. (1979) is a well-known alternative discrete time representation of the behavior of asset prices following GBM. This model is important in several ways. First, the continuous time limit of the proportional binomial process is exactly the GBM process. Second, and perhaps most importantly, the binomial model is the basis of the dynamic programming solution to the valuation of American options. Section 7.2 discussed a one-step binomial tree as part of the overview of the replicating portfolio. To price options with more than one period to maturity, the binomial tree is extended

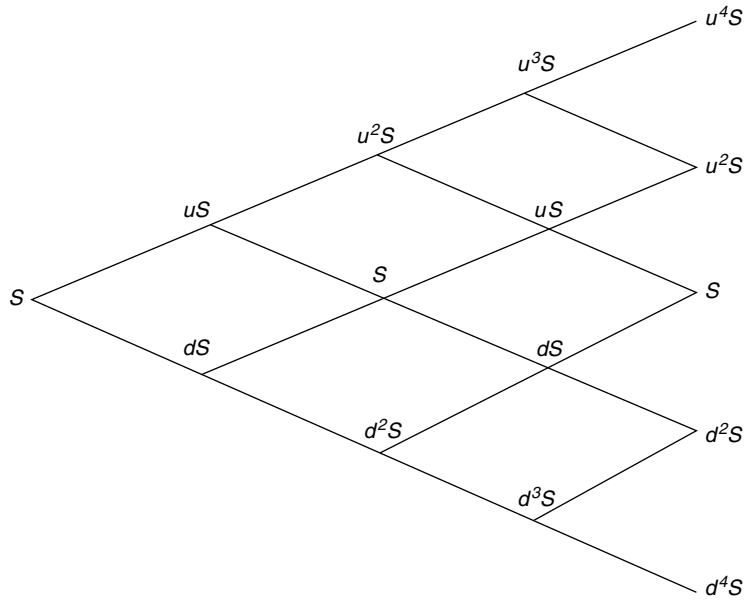

Figure 8.1 A four-step binomial tree for an asset

outward for the required number of periods to the maturity date of the option. Figure 8.1 illustrates a binomial tree for an option that expires in four periods of time.

A state in the tree is referred to as a node and is labeled as node (i,j), where i indicates the number of time steps from time zero and j indicates the number of upward movements the asset price has made since time zero. Therefore the level of the asset price at node (i,j) is $S_{i,j} = Su^j d^{i-j}$ and the option price will be $C_{i,j}$. At the lowest node at every time step $j = 0$, and j will remain the same when moving from one node to another via a downward branch, as the number of upward moves that have occurred have not changed. It is generally assumed that there are N time steps in total, where the Nth time step corresponds to the maturity date of the option. As is the case with the one period example, the value of a call option at the maturity date is the payoff:

$$C_{N,j} = \max(S_{N,j} - K, 0) \tag{8.20}$$

As the value of the option at any node in the tree is its discounted expected value, at any node in the tree before maturity:

$$C_{i,j} = e^{-r\Delta t}(pC_{i+1,j+1} + (1-p)C_{i+1,j}) \tag{8.21}$$

where the binomial risk neutral probabilities p and (1 – p) are derived as:

$$p = \frac{e^{r\Delta t} - d}{u - d}$$

and r is the risk free rate.

Using equations (8.20) and (8.21) the value of the option can be computed at every node for time step $N - 1$. Equation (8.21) can then be reapplied at every node for every time step, working backward through the tree to compute the value of the option at every node in the tree. The value of a European option can be derived using this procedure. To derive the value of an American option, the value of the option if it is exercised is compared at every node to the option value if it is not exercised, and the value at that node set to the greater of the two.

Although binomial trees are used by many practitioners for pricing American-style options, trinomial trees offer a number of advantages over the binomial tree. As there are three possible future movements over each time period, rather than the two of the binomial approach, the trinomial tree provides a better approximation to a continuous price process than the binomial tree for the same number of time steps. The trinomial tree is also easier to work with because of its more regular grid and is more flexible, allowing it to be fitted more easily to market prices of forwards and standard options, an important practical consideration. A discussion of trinomial trees as a possible numerical technique follows.

In the following it is more convenient to work in terms of the natural logarithm of the spot price as defined in equation (8.10). Consider a trinomial model of the asset price in which, over a small time interval Δt, the asset price can increase by Δx (the space step), stay the same or decrease by Δx, with probabilities p_u, p_m, and p_d respectively. This is depicted in terms of x in Figure 8.2.

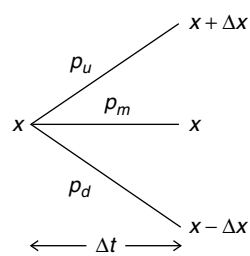

Figure 8.2 Trinomial model of an asset price

The drift and volatility parameters of the asset price are now captured in this simplified discrete process by Δx, p_u, p_m, and p_d. It can be shown that the space step cannot be chosen independently of the time step, and that a good choice is $\Delta x = \sigma\sqrt{3\Delta t}$. The relationship between the parameters of the continuous time process and the trinomial process is obtained by equating the mean and variance over the time interval Δt and requiring that the probabilities sum to one, that is:

$$E[\Delta x] = p_u(\Delta x) + p_m(0) + p_d(-\Delta x) = \nu\Delta t \tag{8.22}$$

$$E[\Delta x^2] = p_u(\Delta x^2) + p_m(0) + p_d(\Delta x^2) = \sigma^2\Delta t + \nu^2\Delta t^2 \tag{8.23}$$

$$p_u + p_m + p_d = 1 \tag{8.24}$$

Solving equations (8.22) to (8.24) yields the following explicit expressions for the transitional probabilities:

$$p_u = \tfrac{1}{2}\left(\frac{\sigma^2\Delta t + \nu^2\Delta t^2}{\Delta x^2} + \frac{\nu\Delta t}{\Delta x}\right) \tag{8.25}$$

$$p_m = 1 - \frac{\sigma^2\Delta t + \nu^2\Delta t^2}{\Delta x^2} \tag{8.26}$$

$$P_d = \tfrac{1}{2}\left(\frac{\sigma^2\Delta t + \nu^2\Delta t^2}{\Delta x^2} - \frac{\nu\Delta t}{\Delta x}\right) \tag{8.27}$$

The single period trinomial process in Figure 8.2 can be extended to form a trinomial tree. Figure 8.3 depicts such a tree.

Let i denote the number of the time step and j the level of the asset price relative to the initial asset price in the tree. If $S_{i,j}$ denotes the

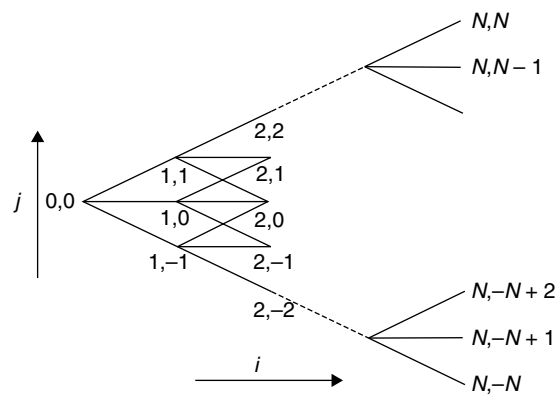

Figure 8.3 A trinomial tree model of an asset price

level of the asset price at node (i,j) then $t = t_i = i\Delta t$, and an asset price level of $S\exp(j\Delta x)$. Once the tree has been constructed the spot price is known at every time and every state of the world consistent with the original assumptions about its behavior process, and the tree can be used to derive prices for a wide range of derivatives.

The procedure is illustrated with reference to pricing a European and American call option with strike price K on the spot price. The value of an option is represented at node (i,j) by $C_{i,j}$. In order to value an option the tree is constructed as representing the evolution of the spot price from the current date out to the maturity date of the option. Let time step N correspond to the maturity date in terms of the number of time steps in the tree, that is, $T = N\Delta t$. The values of the option at maturity are determined by the values of the spot price in the tree at time step N and the strike price of the option:

$$C_{N,j} = \max(S_{N,j} - K, 0); j = -N, \ldots, N \tag{8.28}$$

It can be shown that option values can be computed as discounted expectations in a risk-neutral world, and therefore the values of the option at earlier nodes can be computed as discounted expectations of the values at the following three nodes to which the asset price could jump:

$$C_{i,j} = e^{-r\Delta t}(p_u C_{i+1,j+1} + p_m C_{i+1,j} + p_d C_{i+1,j-1}) \tag{8.29}$$

where $e^{-r}\Delta^t$ is the single period discount factor. This procedure is often referred to as 'backwards induction' as it links the option value at time i to known values at time $i+1$. The attraction of this method is the ease with which American option values can be evaluated. During the inductive stage the immediate exercise value of the option is compared with the value if not exercised as computed from equation (8.29). If the immediate exercise value is greater, then this value is stored at the node, that is:

$$C_{i,j} = \max\left\{e^{-r\Delta t}(p_u C_{i+1,j+1} + p_m C_{i+1,j} + p_d C_{i+1,j-1}), S_{i,j} - K\right\} \tag{8.30}$$

This method also provides the optimal exercise strategy for the American option, since for every possible future state of the world, that is, every node in the tree, it can be determined whether to exercise the option or not. The value of the option today is given by the value in the tree at node (0,0), $C_{0,0}$.

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9
Implementing Derivative Models

9.1 Spot price models

The Black–Scholes GBM model can be generalized to other models that are more realistic for particular markets. The various simple extensions to the Black–Scholes model assume constant parameters for ease of calculation. In reality the properties of time series such as volatility, mean reversion, long-term levels and jump behavior will at the very least vary through time with reasonably predictable patterns. These characteristics can be included in spot models.

9.1.1 Geometric Brownian motion models

The GBM assumption defined in equation (8.1) as a process that describes the dynamics of the prices of financial instruments is an approximation of the behavior observed in real markets. GBM models are frequently used for security prices, interest rates, commodities and other economic and financial variables, and they follow what has been defined as a random walk. The Weiner process is the continuous limit of a discrete time random walk. A generalized Weiner process introduces the concept of an expected drift rate. The drift rate is the average increase in a stochastic variable for each unit of time. In models for financial variables the expected drift rate is replaced with a constant drift rate. Another issue in GBM models is that the uncertainty associated with the price path is greater the longer the time horizon. As the variance of the Weiner process increases linearly as the time horizon increases, the standard deviation grows as the square root of the time horizon. This is the equivalent to the definition of volatility, where scaling the standard deviation by the square root of T annualizes the volatility σ.

The GBM process represented in equation (8.9) was discretized in equations (8.11) and (8.12) for the simulation of a spot price. Figure 9.1

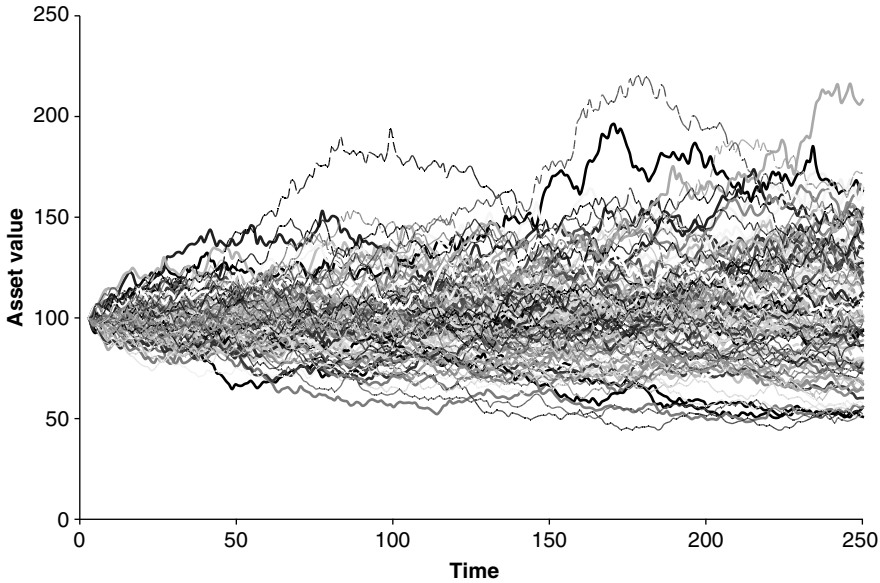

Figure 9.1 Illustration of 100 simulated GBM paths

illustrates a GBM process simulated 100 times with the parameters $S = 100$, $r - \delta = 0.05$, $\sigma = 0.30$, and $\Delta t = 1/250$. In this example $r - \delta$ is the drift, and $\sigma\varepsilon\sqrt{\Delta t}$, is the stochastic component. One observation is that the sample paths in Figure 9.1 tend to wander from the initial starting point of $S = 100$. While this may be realistic for some variables, and can be verified in tests for random walks, it may, however, not be suitable for other financial and economic time series.

9.1.2 Mean reversion

The usual assumption made for asset price evolution in many markets is the GBM model assumption. This model, however, allows prices to wander off to unrealistic levels when applied to markets such as energy and commodities. Mean reversion was first described by Vasicek (1977) for modeling interest rate dynamics and has subsequently been widely adapted. Mean reversion can be understood by looking at a simple model of a mean reverting spot price (Schwartz, 1997), represented by the following equation:

$$dS = \alpha(\mu - \ln S)Sdt + \sigma Sdz \tag{9.1}$$

Figure 9.2 illustrates the log form of a mean reverting process simulated 100 times with the parameters $S = 100$, $\alpha = 3$, $\bar{S} = 100$, $\sigma = 0.30$,

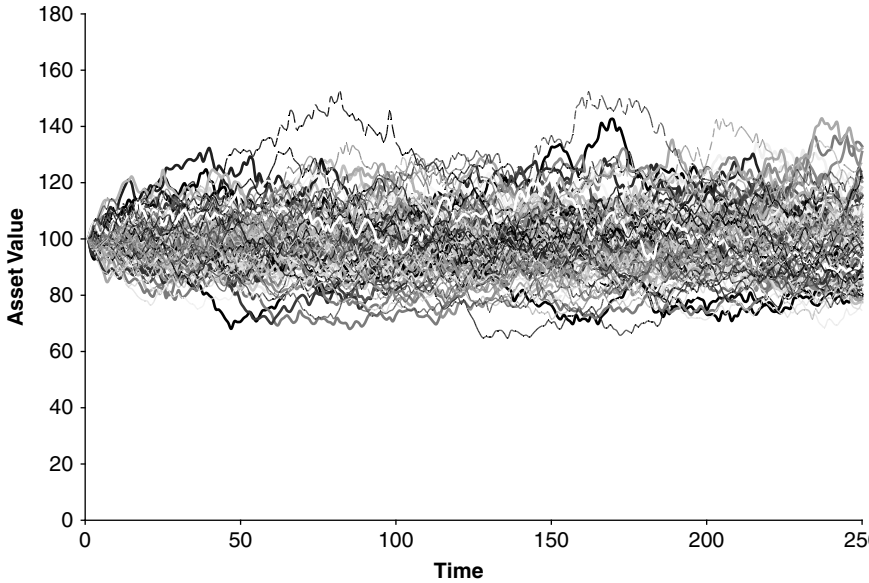

Figure 9.2 Illustration of 100 simulated mean reversion paths

and $\Delta t = 1/250$. In this model the spot price mean reverts to the long-term level $\bar{S} = e^{\mu}$ at a speed given by the mean reversion rate, α, that is taken to be strictly positive. If the spot price is above the long-term level $\bar{S}$, then the drift of the spot price will be negative and the price will tend to revert back toward the long-term level. Similarly, if the spot price is below the long-term level, then the drift will be positive and the price will tend to move back toward $\bar{S}$. Note that, at any point in time, the spot price will not necessarily move back toward the long-term level as the random change in the spot price may be of the opposite sign and greater in magnitude than the drift component. This formulation of the mean reversion process represents one of a number of possible equations that capture the same type of market evolution of prices over time. In reality the spot price does not mean revert to a constant long-term level. Information on the level to which the spot price mean reverts is contained in the forward curve prices and volatilities.

9.1.3 Jumps and seasonal patterns

Jumps can be a significant component of the behavior of spot prices. This type of behavior, where the price exhibits sudden, large changes, can be modeled by using jump processes. A simple and realistic

model for a spot price, which is identical to the Black–Scholes model except for the addition of a jump process, is the jump-diffusion model introduced by Merton (1976). This model is described by the following SDE:

$$dS = \mu S dt + \sigma S dz + \kappa S dq \tag{9.2}$$

The annualized frequency of jumps is given by ϕ, the average number of jumps per year (ϕ is defined by prob $(dq = 1) = \phi dt$). The proportional jump size is κ, which is random and determined by the natural logarithm of the proportional jumps being normally distributed:

$$\ln(1+\kappa) \sim N(\ln(1+\bar{\kappa}) - \tfrac{1}{2}\gamma^2, \gamma^2) \tag{9.3}$$

where $\bar{\kappa}$ is the mean jump size and γ is the standard deviation of the proportional jump size. The jump process (dq) is a discrete time process – jumps do not occur continuously but at specific instants of time. Therefore, for typical jump frequencies, most of the time $dq = 0$ and only takes the value 1 when a randomly timed jump occurs. When no jump occurs, the spot price behavior is identical to GBM and is only different when a jump occurs. The proportional jumps (or equivalently jump returns) in equation (9.2) are normally distributed and therefore symmetrical. That is, the number of positive and negative jumps and the range of sizes of the proportional jumps will be equal on average.

Season patterns can be taken into account by including seasonality as a deterministic process in the stochastic process for the underlying price path. Discrete methods such as Fourier Transforms that include Sine, Cosine and Fast Fourier Transforms can be specified as continuous processes and included in the specification of the underlying price path.

9.1.4 Stochastic volatility

The assumption in the Black–Scholes model that volatility is constant is not always the case. The GARCH process is one representation of a stochastic volatility model. Many other models have been proposed for the behavior of volatility. The Heston (1993) form of the stochastic volatility model is described by the following processes for the spot price and the spot price return variance $V = \sigma^2$;

$$\mathrm{dS}_t/\mathrm{S}_t = \mu \mathrm{dt} + \sqrt{\mathrm{v}_t}\mathrm{dW}_t, \tag{9.4}$$

$$\mathrm{dv}_t = \kappa\,(\theta - \mathrm{v}_t)\,\mathrm{dt} + \sigma_{\mathrm{V}}\sqrt{\mathrm{v}_t}\mathrm{dZ}_t, \tag{9.5}$$

Equation (9.4) is the GBM model with a volatility v_t which is no longer constant but which changes randomly. The behavior of the

volatility is determined by equation (9.5), which specifies the process followed by the variance, the square of the volatility. The variance mean reverts to a long-term level θ at a rate given by κ. The absolute volatility of the variance is $\sigma_v\sqrt{v}$, which is proportional to the square root of the variance; that is, the volatility of the spot price. The source of randomness in the variance, dZ_t, is different from the dW_t driving the spot price, although it may be correlated with correlation coefficient ρ.

Refer to Appendix – Parameter estimation for the Heston stochastic volatility model

9.2 Forward curve models

Forwards and futures markets are often used by risk managers to hedge risk, with liquid forward prices providing a price discovery mechanism to determine the fair value for future delivery. Forward curves contain information about the prices an investor can lock into today to buy or sell at a certain time in the future. Forward curves are well known and understood in the debt markets. Forward rate agreements and exchange traded futures contracts are heavily traded and allow users to lock in borrowing and lending rates for future time periods.

In contrast to futures and forwards, price forecasts are predictions on the likely spot price for periods in the future and can differ widely between market participants. Forward prices, however, depend on the relationship between traded instruments. Tradable prices today for future spot transactions can be locked in using forward prices, and as such capture the market reality. Therefore prices from forwards and futures markets are key inputs to many derivative pricing models and are as essential in the pricing of derivatives as spot prices.

In the past the majority of work on modeling prices has focused on stochastic processes for the spot price and other key variables, such as the dividend yields, convenience yields and interest rates. This approach, however, can have some fundamental disadvantages. The first is that key state variables, such as the convenience yield, are unobservable and, second, the forward price curve is an endogenous function of the model parameters, and therefore will not necessarily be consistent with the market observable forward prices. As a result many industry practitioners require the forward curve to be an *input* into the derivative pricing model, rather than an *output* from it.

Term structure consistent models set out to model the dynamics of the entire term structure in a way that is consistent with the

initial (observed) market data. These models can be further classified into those that fit the term structure of prices such as interest rates, and those that fit the term structure of prices and price volatilities. There are models in the interest rate world and recent developments in the energy and commodity markets that use term structure approaches. An approach based on modeling the entire forward price curve with multiple sources of uncertainty uses all the information contained in the term structure of futures prices in addition to the historical volatilities of futures returns for different maturities. The following discussion as applied to the energy markets is based on this approach and draws on material from Clewlow and Strickland (2000).

9.2.1 A single factor model for the forward curve

The expression 'forward curve models' is defined as models that explicitly model all the forward prices simultaneously rather than just the spot price. A simple single factor model of the forward curve can be represented by the following stochastic differential equation:

$$\frac{dF(t,T)}{F(t,T)} = \sigma^{-\alpha(T-t)} dz(t) \tag{9.6}$$

The inputs to the model are the observed forward curve $F(t,T)$ which denotes the forward price at time t for maturity date T, and $\sigma e^{-\alpha(T-t)}$ which is the single 'factor' or volatility function associated with the source of risk $dz(t)$. Equation (9.6) also has no drift term. As futures and forward contracts have zero initial investment, their expected return in a risk-neutral world must be zero, implying that the process describing their evolution has zero drift. The volatility function of equation (9.6) has a very simple negative exponential form illustrated in Figure 9.3.

For this volatility function, short-dated forward returns are more volatile than long-dated forwards. Information occurring in the market today has little effect on, say, the year-year forward price but can have a significant effect on the one-month forward price. The parameter values used for Figure 9.3 are $\alpha = 1.0$ and $\sigma = 0.40$. Here σ represents the 'overall' volatility of the forward curve, while α explains how fast the forward volatility curve attenuates with increasing maturity. With an α of 100% the one-month forward has a volatility of about 37%, decreasing to approximately 2% for the three-year forward.

The volatility function is not restricted to have the parameterized form of equation (9.6). The function can be generalized as:

$$\frac{dF(t,T)}{F(t,T)} = \sigma(t,T) dz(t) \tag{9.7}$$

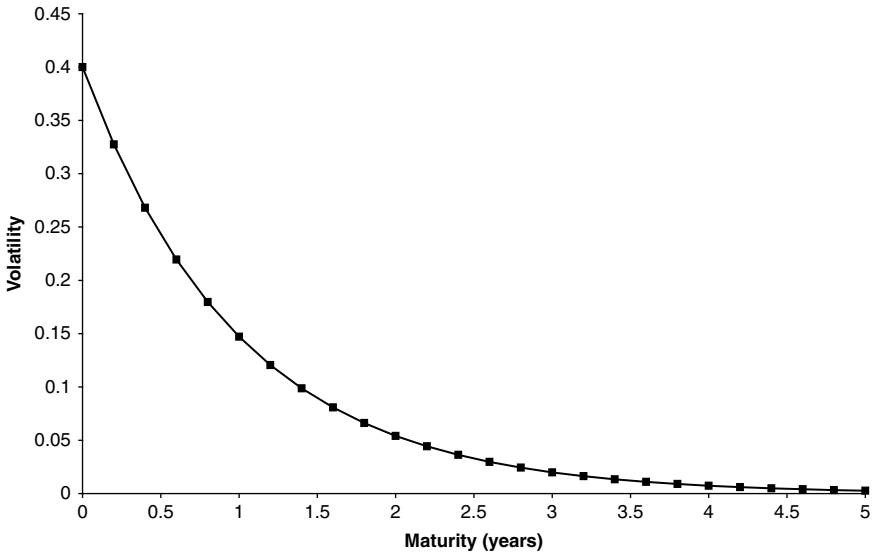

Figure 9.3 A negative exponential volatility function for forward prices

where $\sigma(t,T)$ would be read as the time t volatility of the T-maturity forward price return. The form of $\sigma(t,T)$ can be determined from market data.

9.2.2 The dynamics of the forward curve

An important observation is that forward prices of different maturities are not perfectly correlated. The curves generally move up and down together but they also change shape in apparently quite complex ways. One method that can be used to determine the set of common factors that drive the dynamics of the forward curve is principal components analysis (PCA) or eigenvector decomposition of the covariance matrix. This procedure can be utilized to simultaneously identify the number of important factors and estimate the volatility functions. The technique involves calculating the covariances between every pair of forward price returns in a historical time series to form a covariance matrix. The eigenvectors of the covariance matrix yield estimates of the factors driving the evolution of the forward curve.

The implication is that to describe effectively the evolution of the energy forward curve more than a single factor is required. The model described by equation (9.7) can be modified through the addition of sources of risk and volatility functions. For a general multifactor model the behavior of the forward curve can be represented by the following

equation:

$$\frac{dF(t,T)}{F(t,T)} = \sum_{i=1}^{n} \sigma_i(t,T) dz_i(t) \tag{9.8}$$

In this formulation there are n independent sources of uncertainty which drive the evolution of the forward curve. Each source of uncertainty has associated with it a volatility function which determines by how much, and in which direction, that random shock moves each point of the forward curve. Therefore $\sigma_i(t,T)$ are the n volatility functions associated with the independent sources of risk $dz_i(t)$. In practice n is usually set to $n = 1$, 2, or 3.

9.2.3 Relationship between forward curve and spot price models

Intuitively, a model that describes the evolution of the whole forward curve is implicitly describing the front end of the curve, which is simply the spot energy price, and so the forward curve models must be related to spot price models. The defining stochastic differential equation (9.8) can be integrated to obtain the following solution:

$$F(t,T) = F(0,T) \exp\left[\sum_{i=1}^{n} \left\{ -\frac{1}{2} \int_0^t \sigma_i(u,T)^2 du + \int_0^t \sigma_i(u,T) dz_i(u) \right\}\right] \tag{9.9}$$

This equation expresses the forward curve at time t in terms of its initially observed state (time 0) and integrals of the volatility functions. The spot price is just the forward contract for immediate delivery and so the process for the spot price can be obtained by setting $T = t$, that is:

$$S(t) = F(t,t) = F(0,t) \exp\left[\sum_{i=1}^{n} \left\{ -\frac{1}{2} \int_0^t \sigma_i(u,t)^2 du + \int_0^t \sigma_i(u,t) dz_i(u) \right\}\right] \tag{9.10}$$

Equation (9.10) can then be differentiated to yield the stochastic differential equation for the spot price:

$$\frac{dS(t)}{S(t)} = \left[\frac{\partial \ln F(0,t)}{\partial t} - \sum_{i=1}^{n} \left\{ \int_0^t \sigma_i(u,t) \frac{\partial \sigma_i(u,t)}{\partial t} du + \int_0^t \frac{\partial \sigma_i(u,t)}{\partial t} dz_i(u) \right\} \right] dt + \sum_{i=1}^{n} \sigma_i(t,t) dz_i(t) \tag{9.11}$$

The term in square parentheses in the drift can be interpreted as being equivalent to the sum of the deterministic riskless rate of interest $r(t)$ and a convenience yield $\mathrm{d}(t)$ which in general will be stochastic. Also, since the last component of the drift term involves the integration over the Brownian motions, the spot price process will, in general, be non-Markovian – that is, the evolution of the spot price will depend upon its past evolution.

One special case of the general model is the simple single factor model described by equation (9.6). For this model $n = 1$ and $\sigma_1(t,T) = \sigma e^{-\alpha(T-t)}$. Clewlow and Strickland (2000) evaluate (9.11) with this volatility function and show that the resulting spot price process is given by:

$$\frac{dS(t)}{S(t)} = \left[\frac{\partial \ln F(0,t)}{\partial t} + \alpha\left(\ln F(0,t) - \ln S(t)\right) + \frac{\sigma^2}{4}\left(1 - e^{-2\alpha t}\right)\right]dt + \sigma\, dz(t) \tag{9.12}$$

This implies:

$$\frac{dS(t)}{S(t)} = \left[\mu(t) - \alpha \ln S(t)\right]dt + \sigma\, dz(t) \tag{9.13}$$

where:

$$\mu(t) = \frac{\partial \ln F(0,t)}{\partial t} + \alpha \ln F(0,t) + \frac{\sigma^2}{4}\left(1 - e^{-2\alpha t}\right)$$

This single factor forward curve model is therefore just the single factor Schwartz (1997) model with a time dependent drift term. It is this term in the drift which allows the model to now fit the observed forward prices. Note also that this particular form of the forward curve volatility function results in a 'Markovian' spot price process – as the dependence in the drift on the path of the Brownian motion disappears.

The relationship between the forward curve model and the spot return model also shows that the mean reverting behavior of the spot price is directly related to the attenuation of volatility of the forward curve. By setting $\alpha = 0$ the Black (1976) model is obtained. This is therefore a special case of the general model in equation (9.8) with $\sigma(t,T) = \sigma$ and $n = 1$. The main advantage of the forward curve modeling approach is the flexibility that the user has in choosing both the number and form of the volatility functions. These can be chosen in one of two general ways; historically from time series analysis or implied from the market prices of options.

9.3 Alternative real options methods

The contingent claims approach as applied to valuing real options requires the spanning assumption to hold; that is, the financial markets are sufficiently complete in that there exists some traded asset, or portfolio of traded assets, that tracks the underlying asset or project. The spanning assumption should carry for most assets that are traded in spot and futures markets and for prices that correlate with equity or portfolio values. There will, however, be some cases where the spanning assumption will not hold. In these situations, two methods, dynamic programming and decision analysis, offer approaches to solving real options problems where valuations based on financial markets are not possible.

9.3.1 Dynamic programming

Dynamic programming was developed as an approach to the optimal control problem found in an area of economics called dynamic optimization. Optimal decisions problems, where current decisions influence future payoffs, can be solved using dynamic programming, and it is particularly useful when dealing with uncertainty. The method derives possible values of the underlying asset by extrapolating out over the duration of the option, and then folding back the value of the optimal future value to the present. Dynamic programming can deal with complex decision structures that include constraints and complex relationships between the option value and the underlying asset. The binomial option pricing method is a form of dynamic programming.

Dynamic programming and contingent claims analysis are based on similar partial differential equations. There are similarities in the way the Bellman equation used in dynamic programming is interpreted in terms of an asset value and to what degree investors are prepared to retain that asset, while in contingent claims analysis boundary conditions define where investors decide on the optimal exercise date that maximizes asset value. The differences lie in the definition of the rate of return. Dynamic programming specifies the discount rate exogenously, and it is therefore considered a subjective valuation of risk. In contingent claims analysis, the rate of return on an asset is derived from assets traded in financial markets.

9.3.2 Decision analysis

9.3.2.1 Decision analysis terminology

Over the course of its development decision analysis (DA) has changed from focusing on finding solutions to decision problems to providing alternative perspectives and supporting innovation in decision making. DA is about analysis, which is defined as breaking something down into its constituent components. Therefore DA involves the decomposition of a decision problem into a set of smaller problems, which are addressed separately and then integrated so that a course of action can then be determined from the results. DA is also about making rational decisions. If a set of rules regarded as being rational by the majority is accepted then a decision maker will prefer a designated choice over its alternatives. It follows that the end results from the application of decision analysis will imply how rationally decision makers would behave. DA can therefore be described as normative or prescriptive and defines the choice among alternatives for decision makers when they are consistent with their stated preferences.

Even though decision problems are usually specific to an issue, they do share some common features. An *alternative* is a possible choice in solving a problem and is assessed on the basis of the value added to various decision criteria. A decision problem's *criteria* reflect the different factors that are influenced by the alternatives and significant to the decision maker. A decision problem's states of nature define the future events that cannot be influenced by a decision maker. The outcomes for the alternative states of nature define the values for the different decision criteria under each alternative. Although a decision problem could consist of infinite possible states of nature, typically a manageable discrete set of states of nature is used in DA to encapsulate future possible events.

9.3.2.2 Decision analysis under uncertainty

The decision analysis techniques considered here are those where risk and uncertainty are central concerns of the decision maker. In these situations decision rules can be based on the probabilities of outcomes. Although probabilities can often be estimated from historical data, many decision problems represent one-off decisions where historical data may not be available. In these circumstances probabilities are often applied subjectively, either by experts or through structured interviews.

An expected value is obtained when a process is repeated a number of times, and the average is derived by multiplying each outcome by its probability of occurrence and summing the results. The expected monetary value (EMV) is the equivalent using monetary values. The EMV decision rule is the selection of the alternative with the largest EMV. The EMV of an alternative i in a decision problem is:

$$EMV = \sum_j r_{ij} p_j \tag{9.14}$$

where:

r_{ij} = the payoff for alternative i under the jth state of nature

p_j = the probability of the jth state of nature

The EMV for a decision alternative specifies the average payoff received if the identical decision problem is repeatedly encountered and the alternative always selected.

EMV does have some limitations. The decision alternative with the highest EMV may not always be the decision maker's preferred alternative. EMV focuses only on one attribute, which is money. Another problem is that EMV does not reflect the relative riskiness of an alternative.

Risk-neutral decision makers will typically make decisions that maximize the EMV. Risk-adverse decision makers tend to avoid risk, while risk seekers will typically search for risk. Determining a decision maker's risk and return profile in DA can be achieved using utility theory. Decision makers in utility theory are assumed to use a utility function to interpret a decision problem's possible payoffs. A payoff's utility is a non-monetary measure that symbolizes the total value in a decision maker's decision alternative.

9.3.2.3 Decision trees

Decision problems can be represented and analyzed effectively in a graphical form known as a decision tree. A decision tree is a collection of nodes, symbolized by circles and squares, which are linked by branches that are indicated by lines. A square node represents a decision and is therefore called a decision node. The alternatives for a particular decision are represented by branches, which extend out from the decision nodes. Event nodes are circular nodes in a decision tree that represent uncertain events. Event branches extend out from event nodes and relate to an uncertain event's possible states of nature

or outcomes. The various branches in a decision tree end at terminal nodes, which are points where the decision problem can terminate. Probabilities are associated with the event branches that extend from each event node.

Decision trees are typically used to implement the EMV rule, which is to identify a decision's largest EMV. Creating a decision tree is usually an iterative process, with the initial structure being modified numerous times as the analysis of the problem develops. Large and complex trees that attempt to capture every possible scenario can be impractical, as the intention of a decision tree is to facilitate a decision maker's analysis of a problem. Decision trees are models that represent an abstraction of a problem. The strength in a decision tree lies in the simplification of a problem through the modeling process, as it facilitates the insights and inferences that can be drawn from the analysis that would otherwise be obscured by complexity and detail.

9.4 Model risk

Over the past 30 years there has been a huge growth in the use of theoretical models for valuation and pricing in financial markets. A large body of the theory relates to derivatives, financial instruments where value is derived from underlying assets. These theories have been extended into real options, where models have been developed for options on real assets. Relying on models to analyze and quantify value and risk, however, carries its own risks. The term *model risk* has many connotations and is used in many different contexts. The following is based on Renardo's (2001) definition. Model risk is the risk, at some point in time, of a significant difference between the modeled value of a complex and/or illiquid asset and the realized value of that same asset.

In the physical sciences, where quantitative modeling originated, predictions can be made reasonably accurately. Variables in physical science models such as time, position, and mass exist regardless of the existence of humans. The fundamental unknown in financial markets, however, is certainty. Many financial and real assets only trade at certain discrete times, while financial variables also only symbolize human expectations. Risk and return refers to expected risk and return, variables that are unobserved and not realized. In most circumstances, however, models based on financial concepts and theory assume causation and stability between the values of these unobserved variables and asset values.

There are a number of ways in which the development of a financial model can go wrong:

- The most fundamental risk is that modeling is just not appropriate. Modeling requires knowledge and content of a discipline. Mathematics is a representation or an abstraction of a discipline, and it is a means to an end and is not the end itself.
- All the factors that affect valuation may not have been included in the model.
- Although a model may be theoretically correct, the model variables such as forward prices, interest rates, volatilities, correlations, and spreads may be poorly estimated. A model's variables, for example, may be based on historical data, which may be unstable and therefore not provide a good estimate of future value.
- Incorrect assumptions can be made about the properties of the asset values being modeled and the relationships between the variables in a model.
- A model may be inappropriate in the existing market environment, or some of the assumptions such as the distributions of variables may not be valid. Even if a model itself is satisfactory, the world it is predicting may be unstable.

Financial modeling draws on a multitude of disciplines, from business management practicalities and financial theory to mathematics and computer science, and is as much about art and content as it is about theory and quantitative techniques. An intimate knowledge of markets and how market participants think about valuation and risk are also part of the model practitioner's skill set. Derman (1996) provides some procedures for constructing financial valuation models:

- Identify and isolate the most important variables used by market participants to analyze value and risk and decide which variables can be used in mathematical modeling.
- Separate the dependent variables and the independent variables.
- Determine variables that are directly measurable and those that are more in the nature of human expectations, and so are only indirectly measurable.
- Specify variables that can be treated as deterministic and those that must be considered as stochastic. Uncertainty will have little effect on the future values for some variables and these therefore can be

approximated. For other variables, however, uncertainty will be a critical issue.

- Build a quantitative picture that characterizes how the dependent variables are influenced by the independent ones.
- Determine how to obtain the market values of independent observable variables, and how to derive the implied values of indirectly measurable ones.
- Create a mathematical picture of the problem and determine which stochastic process best describes the evolution of the independent stochastic variables. Determine whether an analytical or numerical solution is appropriate.
- Deliberate the issues and difficulties in solving the model, and simplify it if necessary to make the solution as easy as possible. Only give up substance, however, for a relatively easy or elegant analytical solution when it is absolutely necessary.
- Finally, program the model, test it, and apply to the valuation problem.

Therefore the application of financial modeling draws from a palette that includes knowledge of the business, the applicability of the financial model, the relevance of the mathematics used to solve the problem, the systems and software used to implement and present it, and in the accurate communication and dissemination of the information and knowledge gained from the analysis. Drawing from these various disciplines can address the issues and reduce the risks associated with the application of financial modeling.

9.5 Real options portfolios and complex payoffs

So far the quantitative material has focused on valuing individual options. Simple real options are projects or investments that are evaluated on an individual basis. Real options can exist, however, as portfolios of real options. A portfolio of real options such as options to defer, expand or abandon can exist as mutually exclusive alternatives, with each option valued independently. The portfolio in these cases is represented by the sum of the individual real options.

The options described in Chapter 8 are often defined as 'plain vanilla' or 'standard' derivatives. However, there will be many occasions when a real option's attributes will not be considered as vanilla or standard. Issues such as any interaction between real options, complex payoffs, multiple sources of uncertainty, path dependencies, sequential

decisions, and the attributes of the underlying assets will all have an impact on the specification of a valuation method.

In the financial markets 'exotic' options are derivatives that have a more complicated payoff structure than standard derivatives. Some of these non-standard derivatives are basically combinations of vanilla calls and put options. Other non-standard option types, however, have payoffs and underlying assets that are much more complex to model. The complexity issue also applies to the modeling of many real options. Some examples of complex real options are compound options, exchange options, switching options and rainbow options.

9.5.1 Compound options

If there are interactions between the real options within a portfolio, it may not then be represented by the sum of the real options. This can be the case when the options are compound options, or options on options, where the payoff is another option. Compound options allow the holder to purchase or sell another option for a fixed price. There are four main compound option types: a call on a call, a put on a put, a call on a put, and a put on a call. Projects and investments that are staged as a sequence are compound options, where the initial investment cost is the exercise price for the subsequent option on the next stage of the investment. Plant development, product development, and research and development are examples of sequential compound options.

Compound options are useful for analyzing the strategic impact of an investment on an organization. Many projects and strategic investments are not independent, as assumed in a DCF analysis, but are a series of interrelated cash flows where the initial investment is a prerequisite for the following outlays. Geske (1979) developed the original closed form solution for a compound option as a call option on a firm's equity, which itself is a European call option on the total value of the firm. The compounding in this specification occurs simultaneously, as both the firm's equity, a call option on the leveraged value of the firm, and the call option on the equity appear at the same time. Both simultaneous and sequential compound options can be solved in trees, although the valuation becomes progressively more complicated as more options are added.

9.5.2 Exchange and switching options

Exchange options give the holder the right to exchange one asset for another. Examples of exchange options can be found in takeover bids, where a corporation offers its own shares in exchange for equity in

the takeover target. An option to exchange in these situations is held by the owners of the stock in the takeover candidate. Another example of exchange options are spread options, where the payoff is the price differential between two underlying assets. Spread options are used to speculate on or hedge the comparative performance between two assets.

Other example of an exchange option is the option to switch. Switching options give the holder the right to switch between two means of operation for a fixed cost, and can be found in situations where the flexibility to switch inputs or outputs may optimize an operation or offer a competitive advantage. The flexibility to switch may exist in an organization's processes or products; for example, switching between fuel inputs such as oil or gas, within products such as pharmaceuticals, cars and electronics, the exit and re-entry of an industry, and the starting and shutting down of a resource. The opportunity cost of the premium for the option to switch may be worth the flexibility provided to respond to volatile markets.

Switching options can be path-dependent derivatives. Path-dependent options have payoffs that depend on the path that the underlying asset follows before maturity (or some part of the options life), and not solely on the terminal asset value. In financial markets, Asian options, which are based on average asset values and barrier options, which either cease to exist (knock-out) or only come into existence (knock-in) if the underlying price crosses a barrier, are examples of path-dependent options. In the case of a switching real option, the dependency could be on the price path of a product or commodity and the initial state of the operation, which could be either running or shut down. Switching options when defined as path-dependent options can be analyzed using numerical models, such as Monte Carlo simulation and binomial or trinomial trees.

9.5.3 Rainbow options

Rainbow options in the financial markets are options where the payoff depends on two or more assets. These payoffs can refer to the maximum or minimum of two or more assets, the better of two assets and cash, portfolio options and dual strike options. In the real options world, rainbow options derive value from multiple sources of uncertainty such as prices, quantities, technologies, regulation and interest rates. The real options may have not only multiple sources of uncertainty but also appear in multiple stages, in which case the real option

is specified as a compound rainbow option (Copeland and Antikarov, 2001).

9.5.4 Quantifying complex real options

The valuation of complex real options can be performed with analytical models, trees or Monte Carlo simulation. In many situations, closed form solutions may not exist, in which case numerical procedures would be used for solving complex real options problems. Simulation is generally suited to European-type options, when the payoffs are complex, and there may be several underlying state variables. The binomial and trinomial approaches are generally better suited to valuing American options and complex projects that have multiple options.

In financial markets over the past 30 years the innovations in derivative valuation methods have been almost limitless. Exotic options continue to develop to meet the demand for the pricing and hedging of specific risks. Developments in valuing complex real options will continue as research and interest in this area continues to expand. As always the trade-off in any quantitative valuation will be the development of tractable, applicable, relevant and manageable models versus capturing the substance of the complexities that exist in real options.

Appendix – Parameter estimation for the Heston stochastic volatility model

Two sources of uncertainty reflected in FX options are the stochastic FX rate and stochastic volatility. The Black–Scholes model addresses the first, while stochastic volatility models address both the first and second. The Heston model (1993) is a common method applied to capture stochastic diffusion volatility:

$$dS_t/S_t = \mu dt + \sqrt{v_t} dW_t, \tag{9.2}$$

$$dv_t = \kappa(\theta - v_t)\,dt + \sigma_v \sqrt{v_t} dZ_t, \tag{9.3}$$

$$dW_t dZ_t = \rho dt \tag{9.4}$$

Stochastic volatility induces smiles and skews that decrease as the option maturity increases. The positive volatility of volatility (σ_v) generates a smile, or fatter tails in the distribution, while a non-zero correlation (ρ) generates skew of the same sign; that is, shifts the probability weight to either one of the tails of the distribution.

Calibrating the Heston model ensures the model matches the market and avoids arbitrage. The Heston model requires the estimation of five parameters:

- kappa (κ), the rate of mean reversion in the volatility,
- theta (θ), the long run mean,
- the asset volatility (v_t),
- volatility of volatility (σ_v), which influences the kurtosis of the distribution, and
- the correlation (ρ).

This is achieved by finding the set of parameters that produce Heston model prices that match vanilla Black–Scholes option market prices.

The Black–Scholes model has a number of applications in the OTC FX options market:

- Market prices are quoted as Black–Scholes implied volatilities instead of option prices, and are provided at a Black–Scholes delta (δ) instead of the strike.
- Liquidity is typically at five delta levels, 10 δ put, 25 δ put, 0 δ straddle, 25 δ call, and 10 δ call.

USD-EUR is used as an illustration. Calibrating the Heston model consists of:

1. converting the EUR-USD option delta quotes into strikes;
2. deriving the Black–Scholes option prices using the implied volatilities, the derived strikes, EUR-USD forwards and interest rates for the two currencies; and
3. calibrating the Heston model parameters to the Black–Scholes prices across the volatility surface.

The Black–Scholes option model is the equivalent to the Black model when the risk free interest rate is zero, which reflects the forward price, and then discounted to derive the present value.

Figure 9.4 shows the EUR-USD implied volatility surface. The five FX option quotes for each maturity are:

- *A delta-neutral straddle (ATMV)* implied volatility. A straddle equals the sum of a call and a put with the same strike. Delta neutral implies that δ(c) plus δ(p) is equal to zero, with N(d+) equal to 0.5, and d+ equal to zero. Therefore ATMV $\equiv$ IV(50δc) (= IV($-$50δp) by put call parity). IV is the implied volatility, c equals

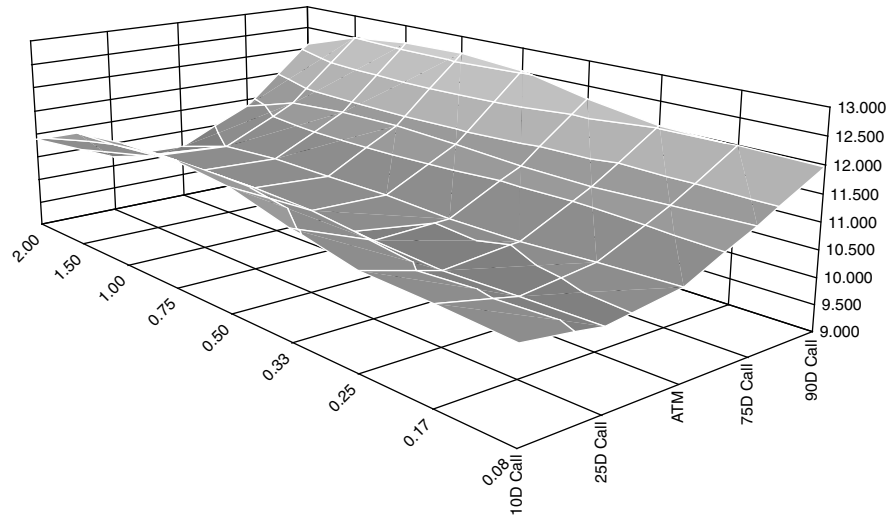

Figure 9.4 EUR-USD implied volatility surface as at 5/15/08

call, p equals put, d is the delta, and N() is a standard normal function.

- *25-delta Risk Reversal (RR25)*. The RR25 describes the slope of a smile, which represents the skew in the risk neutral distribution of the return. RR25 $\equiv$ IV $(25\delta\,\mathrm{c})$ $-$ IV $(25\delta\,\mathrm{p})$.
- *25-delta Strangle Margin (SM25)*, or a butterfly spread. A strangle equals the sum of a call and a put with two different strikes, and captures the smile curvature, or the distribution's kurtosis. SM25 $\equiv$ (IV $(25\delta\,\mathrm{c})$ + IV $(25\delta\,\mathrm{p}))/2 -$ ATMV.
- *10-delta Risk Reversal (10RR)*, and
- *10-delta Strangle Margin (10SM)*.

The implied volatility quotes for the five deltas have the following relationships:

- IV $(0\delta\,\mathrm{s}) =$ ATMV,
- IV $(25\delta\,\mathrm{c}) =$ ATMV + RR25/2 + SM25,
- IV $(25\delta\,\mathrm{p}) =$ ATMV $-$ RR25/2 + SM25,
- IV $(10\delta\,\mathrm{c}) =$ ATMV + RR10/2 + SM10, and
- IV $(10\delta\,\mathrm{p}) =$ ATMV $-$ RR10/2 + SM10.

The EUR-USD option deltas are converted into the strike surface as:

$$K = F \exp\left[\mp IV(\delta,\tau)\sqrt{\tau}N^{-1}\left(\pm e^{r}f^{\tau}\delta\right) + \frac{1}{2}IV(\delta,\tau)^{2}\tau\right] \tag{9.2}$$

where:

K = the option strike

F = FX Forward

IV = implied volatility

δ = strike delta

τ = time to expiry

$N()$ = the inverse of the standard normal cumulative distribution and

f = the USD interest rate

Out-of-the-money Black prices are then calculated across the surface using the implied volatility quotes and the derived strikes. Finally the stochastic volatility parameters are derived by minimizing the squared error, scaled by a weight derived as the inverse of the delta implied volatility bid/offer spread quote, between the Heston and Black prices across the whole surface.

Table 9.1 illustrates the Heston model parameter estimates for the EUR-USD FX option.

Table 9.1 The Heston parameters

Kappa (κ)	2.044
Theta (θ)	1.16%
Asset volatility (V)	1.57%
Vol of Vol (σ)	35.62%
Correlation (ρ)	0.173

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10
Conclusion and Practical Implications

Developments in corporate strategy have been determined predominantly by transformations in the competitive environment and the response of firms rather than the developments in theory. Firms today face a number of developments that are likely to profoundly influence corporate strategy. Globalization, information and communications technologies are expected to continue to drive the international business environment and provide the potential for business opportunities. Other developments such as access to capital, public versus private capital markets, the commodization of products and services, the breakdown of industry barriers, changes in demographics and demand patterns, the effect of creative destruction on industry value chains and the increasing dynamics and instability of markets generally are also likely to have an impact.

Strategy is still defined as a search for value despite recent events, and requires the capabilities to both manage the current portfolio and maneuver the firm through an increasingly turbulent and dynamic environment. In the short term this requires metrics that relate to a firm's a business model and reflect how value is generated in operations, and in the long term making investments to maintain a firm's continuity.

ROCE measures a firms' financial performance, while book value reflects whether value is added when compared to the market value of equity. ROCE is a function of leverage and does not include the cost of equity. These issues are addressed with residual earnings, which includes the cost of equity, and ROIC, which excludes leverage effects. Projecting the financial statements can capture business conditions, the available choices to manage change, and provide an integrated forecast of a firm's future operations and financial condition. Finally identifying a firm's stocks and flows provides a foundation for how a firm generates value and managing future cash flows.

Corporate strategy is essentially making choices and tradeoffs in the allocation of resources. Over the 20th century, corporate finance and corporate strategy evolved as complementary but, nevertheless, distinct disciplines for managerial decision-making. Analysis based on corporate finance methods developed into a focus on individual projects using DCF techniques that do not take account of the flexibility to defer, abandon or change a project after a decision. As a result DCF methods are not prominent in the strategy disciplines, where the focus has been on concepts such as competitive advantage, market leadership, and industry structure.

Established valuation methods such as DCF are sufficient when managing the current portfolio where there is little uncertainty. Real options analysis has advantages in situations where there is a contingent investment decision, where value lies in future growth options rather than current cash flows, when the associated risks or uncertainties are large and it is therefore better to wait for more information, and when there is the potential to include flexibility in assets, projects and strategy.

Firms will need to focus on maintaining its strategic portfolio by managing both the identified and the uncertain as they position themselves for the future. Creating sustainable competitive advantage and value will require the ability to identify, manage and adapt to discontinuities and creative destruction. This will require new capabilities in strategy, managing innovation, resource allocation, processes and organizational structure. These capabilities include managing portfolios of real options, linking value analysis to these issues, managing flexibility, and the communication of strategy to stakeholders and financial markets.

There are a number of potential problems, however, that need to be addressed when applying option theory to real options. Option theory is built on the premise that a replicating portfolio can be created using the underlying asset and a risk free rate. This is extended in real option theory, where a security or set of securities exist such that the cash flows in every state of nature over the life of the project are correlated with those of the project. While reasonable with options on traded financial assets, there is a potential problem when the underlying asset is not traded and the arbitrage assumption does not hold.

Using Black–Scholes models to price real options can be a problem when asset volatility is not traded, and can also be deficient as an appropriate probability distribution for project and company values.

While many real options are theoretically correct, they can be deficient in having any significant influence on management decisions.

However, real options can provide a decision tool that clarifies value in strategic decisions and opportunities by producing valuations that are aligned with those in financial markets. The significance for managers is that financial market valuations are transaction prices, and evidence of the willingness of parties to negotiate. Managers are also provided with a means of communicating the value associated with an investment strategy to the financial markets.

Real options has the potential to combine strategic *and* financial analysis in resource allocation decisions, and therefore align investment decisions with corporate strategy and value. A real options framework can also aggregate project value and risk, manage a firm's net exposure to risk, and bridge the relationship between the project level analysis of investments and the corporate strategic vision. Real options techniques can move beyond single capital investment appraisals toward becoming a significant component of an organization's management of strategic decision-making, risk management and corporate analysis. As the business environment becomes more unpredictable and the implications of making incorrect business decisions continue to rise, the demand for sophisticated analytical disciplines such as the real option approach is likely to grow.

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Index

A
abandonment option
  case study, 135–45
  and firm value, 44
accounting equation, 24–5
adaption option
  and case study, 128–35
  defined, 123
American options, 177
  and abandonment option, 157, 158
  defined, 34
  and dividends, 177
  and trees, 187, 189, 191
ARCH models, 165–6
articulation
  defined, 25
  and financial statements, 25
  and intangible assets, 62
assets
  and declining industries, 136, 138, 141, 144
  financial assets, 26, 27
  intangible assets, 2, 15, 46, 62
  operating assets, 26, 27
  and physical assets, 2, 15, 46
  and valuation, 61–3

B
balance sheet, 24
  intangible assets, 62
  and stocks and flows, 25–7
Baldwin and Clark (2000), 77
Berger, Ofck and Swary, 140
binomial trees, 187–9
  and corporate real estate, 155
  and drug development, 115–19
  and information technology, 79–81
  and the replicating portfolio, 178
  and trinomial trees, 187
biotechnology
  and cost of capital, 111
  drugs, defined, 106
  industry, 106
  and pharmaceutical alliances, 106–7
  and valuation, 112–15
Black–Scholes model, 177
  dividend adjustment, 184
  formula, 182–3
  and the replicating portfolio, 184
  and risk neutral valuation, 177
  and Schwartz model, 93, 94, 104
  and volatility, 196, 210–11
Black–Scholes–Merton model, *see* Black–Scholes model
Book value
  defined, 61
  and equity valuation, 63, 64
  and exit values, 141, 142
  and ratios, 64
  and residual earnings, 65
Boston Consulting Group's growth/share matrix, 17–18
Brownian motion, 170, 181, 186, 193–4, 201
business cycles
  defined, 9, 116
  and Joseph Schumpeter, theories of, 1, 9
  and Kondratiev waves, 9
  and technology waves, 1–2, 9
business model
  and biotechnology firms, 106
  and climate change, 129
  defined, 24
  and financial statements, 23, 24

C
call option, 174–5
  and binomial model, 178, 179
  and compound options, 208
  defined, 34
  and drug development, 111, 116, 118
  and energy, 91, 92, 93
  on a firm, 41, 171, 172
  formula, 183, 184
  and growth, 129, 131, 133
  payoff, 174, 175
  and real options, 34, 37–8, 43, 80–2

capabilities
  strategy and value, 19–20
  and value, 123
capital asset pricing model (CAPM), 35, 49, 50, 51, 52
capital structure
  defined, 40
  and enterprise value, 61
  and financial options, 44
  and firm value, 39
  and market value or debt, 63
  and Miller and Modigliani, 40–1
  and optimization, 42, 44, 45
  and pharmaceutical firms, 114
capitalization rates, cap rates, 153, 154, 155, 156
  defined, 151
carbon dioxide (CO_2)
  and concentrations, 125, 126
  and emissions, 85, 125–8
cash conservation equation, 27, 68
cash flow at risk, 53
cash flow statement, 25
  and stocks and flows, 25, 26
cash from operations, 25, 27
climate change, 128–9
  and adaption, 128–9
  defined, 127
  and industry evolution, 124
compound option, 39, 41
  defined, 208
  and drug valuation, 111
  and firm market value, 131, 134
  and real options, 208
contingent claims, 42, 173, 202
  and Schwartz single factor model, 94
continuity, 16–17
  and climate trends, 128, 129
  firm life, decline in, 139
  and strategy, 3
convenience yield, 174, 197, 201
Copeland, T., 34, 42, 210
corporate finance
  defined, 39
  and risk, 52, 56
  and strategy, 216
corporate planning, 17, 18
correlation
  and basis risk, 53
  and commercial real estate, 155
  and portfolio theory, 50
  and power, 86, 97–8
cost of capital
  and DCF valuation, 31, 51
  and growth, 130
  and hurdle rates, 33
  and Modigliani Miller theory, 41, 42
  and the pharmaceutical industry, 110–11, 112
  and residual earnings, 120
  and ROCE, 65
  and ROIC, 29
  and value, 3, 18, 60, 134
  weighted average, 51
creative destruction, 1, 9, 16, 139, 215, 216

D
debt
  and financing flows, 26, 27
  and firm value, 26
  and Geske (2009), 41
  and leverage, 28, 40
  and valuation, 41, 63
decision analysis, 202, 203
  defined, 35–6
  and real options, 36
  and spanning, 35, 202
  terminology, 203
  under uncertainty, 203
declining industries, 135–6
derivatives, 173–9
  decomposition of, 177
  defined, 173
  energy, 91–2
  exotic, defined, 208
  valuation of, 181–91
derivative models
  and asset prices, 181–2
  forward curve, 197–200
  forward curve and spot price relationship, 200–1
  multi-factor, 87
  numerical, 185–91
  single factor, 198–9, 93–4
  spot price, 193–6
Derman, Emanuel, 206
descriptive statistics, 168–9
  histogram, 168
  Jarque-Bera statistic, 168
  kurtosis, 168
  mean, 168
  median, 168
DiMasi et al., 108, 111
discontinuities, 16, 33, 56, 139, 216

discount rate, 35, 36, 60, 70, 202
  risk adjusted, 51
  and pharmaceutical valuation, 111, 112, 113
  and uncertainty, 32, 49, 50
discounted cash flow (DCF)
  and assumptions, 58
  and drug development, 112–13
  and cash cows, 33
  and commercial real estate, 147
  decision rule, 78
  and energy, 89, 91, 104, 105
  and information technology, 77–8, 80, 81, 82
  and investment, 4, 30
  limitations of, 33, 60
  and project independence, 60–61
  and real options, 33
  and relative valuation, 30
  and shareholder value, 18
  and strategy, 60, 216
  and valuation, 31, 41
dividend
  and Black–Scholes model, 184
  dividend yield, 174, 184, 185
  net, to shareholders, 26, 27
  and options, 36
  payout ratio, 3
drift
  defined, 193
  and energy prices, 91
  and GBM, 181, 182, 193, 194
  and mean reversion, 98, 195
  and Monte Carlo simulation, 185, 186
  and single factor forward curve model, 198, 201
  and trees, 190
drug development, 107
  and costs, 110
  development stages, 107–8
  and revenues, 108–9
DuPont Formula, 28
dynamic programming, 35, 202
  and contingent claims, 187
  and real options, 202

E
earnings
  and forecasts, 141, 143
  and growth, 119, 120, 129, 130
  and intangible assets, 62
  and ratios, 63, 64
economic profit, 60, 130
economy, the
  transformations in, 1–2, 14–15
electricity, *see* power
energy
  consumption forecasts, 82, 83–4
  demand forecasts, 82
  efficiency, defined, 83
  global markets, 82–4
  infrastructure, and investment, 84
  types by market share, 84
entrepreneur, the, 9
equity
  as a call option on a firm's assets, 41, 171, 172
  free cash flows to, 65–6
  stocks and flows equation, 26–7
  valuation, 63–4, 68, 70, 72
European options
  and Black-Scholes, 183–4
  defined, 34
  and energy, 91, 92, 102, 104
  and growth, 43, 44
  payoffs, 176–7
expected monetary value (EMV), 204
expected net present value (ENPV), 113–14

F
fade rates, 29
financial statements, 23
  defined, 24
  and pro-forma, 66
  and stocks and flows, 25
firm, the
  free cash flows to, 65–6
  and technology transformations, 10
firm value, 26, 39–40, 129–131
  assets-in-place and growth options, 114, 129, 131
  book value, 61
  break-up value, 61
  and compound option model, 131–3
  enterprise value, 61
  liquidation value, 61
  market value, 61
  and the primitive firm, 41–44
  and theories of, 40–5
Forbes 100, 16
forward contracts, 173–4
  and arbitrage pricing, 174

and cost-of-carry formula, 174
defined, 173
payoffs, 173–5
forward curve
and backwardation, 94
and contango, 94
and electricity, 87
and energy markets, 94–5
models, 104, 197–201
free cash flows, 27
to equity, 65–6
to the firm, 65–6
and GARP Statement Of Cash Flows, 68
life cycles, 120
pro forma analysis, 66, 68, 70, 71, 72
fuel cells, 121
futures, 173–5
defined, 173
and derivative valuation, 197, 198
payoffs, 174–5
pricing with Schwartz single factor model, 94–7

G
GARCH models, 165–6
and stochastic volatility, 196
gas markets, the, 84–5
Geske, Robert, 41, 44, 63, 131–3, 208
Global Industry Classification Standard (GICS), 21
global warming, 127–8
greenhouse gases (GHG), 125–8
growth firm
and biotech firms, 114, 115
and growth options, 39, 43, 123
and pharma capital structure, 114–15
and valuation, 115, 129–35

H
half life, 102
heat rate, 87, 93, 105
Heston stochastic volatility model, 196
parameter estimation, 210–13
hurdle rate, 33, 51
and biotech firms, 111–12
defined, 49

I
income statement, 24, 25
and free cash flows, 65
and intangible assets, 62
and stocks and flows, 25, 26
industry evolution, 1–2, 12–16, 123
and climate change, 124–6
industry sectors
classifying, 20–1
high tech and mature, 20
information technology
and corporate investment in, 76
rise of, 2, 15
sector, 12, 14, 20, 21
innovation
and climate change, 124
defined, 1, 10
and financing, 2–3
and the firm, 10, 11, 123
and invention, 10
and linear model of, 11
and open systems of, 11–12, 62
and the pharmaceutical industry, 106, 107
and Schumpeter, 1, 9
and technology waves, 1, 2, 9
intangible assets, 62
and intellectual property rights (IPR), 62
patents, copyrights and trademarks, 62
and the post-industrial economy, 2, 15
and valuation, 62
internal rate of return (IRR), 31
investments
and declining industries, 136
defined, 30
and information technology, 76
irreversible, 32
and the NPV rule, 41–2
and real options, 41–2
and risk, 49, 51
Itô process, 182

J
jumps, 184, 185, 195–6
and energy, 98

K
Kellogg and Charnes (2000), 115
KMV, 171–2

L
liabilities, 24
liquidation, 138, 139
  and abandonment option, 140
  value, 61
lognormal distribution, 169, 171

M
Markovian process, 182, 201
Markowitz, and portfolio theory, 49–50
mean reversion
  and derivative models, 194, 195
  and energy, 91
  and half-life, 102
  parameter estimation, 98, 99
  and Schwartz single factor model, 93–5
  and simulation, 98
  and stochastic volatility, 211
  and volatility, 96, 97
Merton, Robert, 35, 146, 177
  and the call option on a firm, 41, 132, 171
  and jumps, 196
model risk, 205–7
  defined, 205
Modigliani–Miller theory, 40, 41, 42
modularity, 43–4, 45, 46–7
Monte Carlo simulation, 155–7
  and mean reversion, 98
Myers, Stewart, 33, 41, 42
Myers and Howe (1997), 108, 109, 111
Myers and Shyam-Sunder (1995), 111

N
net present value (NPV)
  assumptions, 31–2
  decision rule, 31
  decision rule and IT, 76
  and shareholder value, 60
new drug application (NDA), 108
new molecular entities, 107
newspaper industry, 136–7

O
operating leverage, 43
options
  Asian options, 209
  barrier, 209
  binary options, 184
  defined, 34, 177
  exotic, 208
  path dependent, 209
  pricing, 181–91
  and spark spreads, 93
  spread options, and energy, 92, 97, 102, 104
Orstein–Uhlenbeck process, 93

P
partial differential equation, 182, 183
patents, 62
  defined, 63
  and embedded options, 63
pharmaceutical (pharma) industry, 13, 106
  and capital structure, 115
pharmaceutical
  cost of capital, 110–12
  drugs, defined, 106
Porter, Michael, 18
portfolio
  of assets, 18, 26, 50, 60
  of real options, 20, 33, 37, 42, 55, 207
  strategic, 19, 20
portfolio planning, 17
portfolio theory, 49–50
power generator
  case study, 87–106
  and dispatch model, 87
power markets, the, 85–7
pro forma analysis, 66–7
  percentage-of-sales method, 67
  and pro forma statements, 66
  and sensitivity analysis, 67
put option
  defined, 175–6
  payoff, 175–6

R
rainbow options, 39, 209–10
random walk, 164
  and correlogram, 165
  and Dickey–Fuller test, 165
  and GBM models, 193, 194
real options
  and commercial real estate, 145–158
  and complex payoffs, 207–10
  compound options, 39, 111, 208
  and decision analysis, 35, 36, 202, 203
  and drug development, 114–16
  exchange options, 208–9

and firm value, 42–4
and growth options, 39
and information technology, 78–82
option to abandon, 38, 44, 140
option to defer, 37
option to expand or contract, 37
option to switch, 38
portfolio of, 19–20, 207
rainbow options, 39, 209–10
and spanning, 35
ratio analysis
DuPont Formula, 28
return on assets (ROA), 28
ROCE, 28
ROIC, 28–30
replicating portfolio, 35, 177–9
and real options, 184
research and development(R&D)
and drug development costs, 110–11, 114
and the firm, 11, 15
and innovation, 9, 10
and pharmaceutical industry, 106
residual earnings, 64–5
and growth, 120
return on invested capital (ROIC)
defined, 28–9
and fade rates, 28
forecasts of, 68, 70, 72, 73
and industries, 28–9
return on common equity (ROCE)
and asset turnover, 28
defined, 28
financial leverage, 28
and firm value, 65
forecasts of, 68, 70, 73
net profit margin, 28
return on assets (ROA), 28, 29
return on equity (ROE), *see* ROCE
risk
and CAPM, 35
and climate change, 128–9
defining, 52–3
and investment, 49–51
management, 51–2
and models, 205–7
private, 35
and sensitivity analysis, 67
and value, 55–6
risk-adjusted discount rate, 51
Risk-adjusted Net Present Value (rNPV) method, *see* ENPV
risk drivers, 53–5
commodity risk, 54
financial risk, 53
legal risk, 54
operational, 54
political risk, 55
product risk, 55
strategic risk, 54
technology risk, 55
risk-neutral probabilities, 116, 179, 189
risk-neutral valuation, 177–9

S
S&P Index, 16
Standard & Poor's (S&P) 500, 166–9
Schumpeter, Joseph, 1, 9, 10, 16, 124, 139
Schwartz, Eduardo, 93, 201
statement of shareholders equity, 25
shareholder value
and discounted cash flows, 18
and earnings, 24, 119–20
strategy and, 18
sustainable, 3, 23
theory, 18, 60
single factor spot price models, 198–9, 201
and futures and forward pricing, 93–4
spark spread, 87, 89, 91, 94, 104, 105, 106
stakeholder value, 19
statement of cash flows
and free cash flows, 65
and GAAP, 68
stochastic differential equation, 181, 182, 198, 200
stochastic process
defined, 164
and spot prices, 181
and time series, 171
stocks and flows, 25–7
and articulation, 25
and stocks and flows equation, 25, 26
and value, 25
strategic planning, 54
and finance theory, 33
strategy
and analysis, 59, 60
and continuity, 16, 17
and corporate finance, 216
corporate versus business, 17
defined, 17
history of, 17–18
and innovation, 9, 10, 11, 12

strategy (*cont.*)
and real options, 4, 5, 32, 33
and risk, 54–5
and value, 3, 19–20, 61, 65, 215

T
technology, defined, 1
and transformations in, 10
time series, 163
and autocorrelation, 165
and the correlogram, 165
defined, 164
non-linear, 164
and seasonality, 164
and trends, 164
trees
binomial, 114–19, 177–9, 187–9
trinomial, 189–91

V
valuation
and the abandonment option, 140–2
and drug development, 108–12
and growth, 119–21
value, 3–4
and business models, 24
and financial statements, 24
and flexibility, 78–9
and risk, 55–6
and stocks and flows, 25–7
and strategy, 19–20
value at risk, 53
variance, conditional, 165
Vasicek, Oldrich, 194
volatility, 164–9, 182
Black–Scholes and, 183
estimation of, 167–8
and mean reverting processes, 96–7
stochastic, 196–7, 210–13
term structure, energy, 99, 101
and Weiner process, 193

W
Weiner process, 171, 181, 182, 193