Quantitative Finance

Applied Quantitative Finance series

Applied Quantitative Finance is a new series developed to bring readers the very latest market tested tools, techniques and developments in quantitative finance. Written for practitioners who need to understand how things work 'on the floor', the series will deliver the most cutting-edge applications in areas such as asset pricing, risk management and financial derivatives. Although written with practitioners in mind, this series will also appeal to researchers and students who want to see how quantitative finance is applied in practice.

Also available

Chris Kenyon, Roland Stamm
DISCOUNTING, LIBOR, CVA AND FUNDING
Interest Rate and Credit Pricing

Marc Henrard
INTEREST RATE MODELLING IN THE MULTI-CURVE FRAMEWORK
Foundations, Evolution and Implementation

Ignacio Ruiz
XVA DESKS: A NEW ERA FOR RISK MANAGEMENT
Understanding, Building and Managing Counterparty and Funding Risk

Leo Krippner
ZERO LOWER BOUND TERM STRUCTURE MODELLING
A Practitioner's Guide

Quantitative Finance

Back to Basic Principles

Adil Reghai
NATIXIS, France

palgrave
macmillan

© Adil Reghai 2015

Foreword I @ Cedric Dubois. 2015

Foreword II @ Eric Moulines. 2015

Softcover reprint of the hardcover 1st edition 2015 978-1-137-41449-6

All rights reserved. No reproduction, copy or transmission of this publication may be made without written permission.

No portion of this publication may be reproduced, copied or transmitted save with written permission or in accordance with the provisions of the Copyright, Designs and Patents Act 1988, or under the terms of any licence permitting limited copying issued by the Copyright Licensing Agency, Saffron House, 6–10 Kirby Street, London EC1N 8TS.

Any person who does any unauthorized act in relation to this publication may be liable to criminal prosecution and civil claims for damages.

The author has asserted his right to be identified as the author of this work in accordance with the Copyright, Designs and Patents Act 1988.

First published 2015 by
PALGRAVE MACMILLAN

Palgrave Macmillan in the UK is an imprint of Macmillan Publishers Limited, registered in England, company number 785998, of Houndmills, Basingstoke, Hampshire RG21 6XS.

Palgrave Macmillan in the US is a division of St Martin's Press LLC, 175 Fifth Avenue, New York, NY 10010.

Palgrave Macmillan is the global academic imprint of the above companies and has companies and representatives throughout the world.

Palgrave® and Macmillan® are registered trademarks in the United States, the United Kingdom, Europe and other countries

ISBN 978-1-349-49028-8 ISBN 978-1-137-41450-2 (eBook)
DOI 10.1057/9781137414502

This book is printed on paper suitable for recycling and made from fully managed and sustained forest sources. Logging, pulping and manufacturing processes are expected to conform to the environmental regulations of the country of origin.

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

A catalog record for this book is available from the Library of Congress.

To my parents, my spouse Raja, and my daughters Rania, Soraya, Nesma & Amira

This page intentionally left blank

Contents

<i>List of Figures</i>	xi
<i>List of Tables</i>	xv
<i>Foreword I</i>	xvii
<i>Cédric Dubois</i>	
<i>Foreword II</i>	xix
<i>Eric Moulines</i>	
<i>Acknowledgments</i>	xxii
1 Financial Modeling	1
Introduction	1
2 About Modeling	3
A Philosophy of modeling	3
B An example from physics and some applications in finance	11
3 From Black & Scholes to Smile Modeling	28
A Study of derivatives under the Black & Scholes model	28
Methodology	29
The search for convexity	31
Vanilla European option	34
Numerical application	34
Price scenarios	35
Delta gamma scenarios:	35
European binary option	37
Price Scenario	38
Delta and gamma scenarios	38
American binary option	40
Numerical application	40
Price scenario	40
Delta and gamma scenarios	41
Barrier option	42
Price scenario	43
Delta and gamma scenarios	44

	Asian option	45
	Numerical application	45
	Price scenario	46
	Delta and gamma scenarios	46
	When is it possible to use Black & Scholes	48
B	Study of classical Smile models	56
	Black & Scholes model	56
	Term structure Black & Scholes	58
	Monte Carlo simulation	61
	Terminal smile model	61
	Replication approach (an almost model-free approach)	64
	Monte Carlo simulation (direct approach)	65
	Monte Carlo simulation (fast method)	65
	Classic example	67
	Separable local volatility	68
	Term structure of parametric slices	69
	Dupire/Derman & Kani local volatility model	70
	Stochastic volatility model	78
C	Models, advanced characteristics and statistical features	83
	Local volatility model	91
	Stochastic volatility model	91
4	What is the Fair Value in the Presence of the Smile?	94
A	What is the value corresponding to the cost of hedge?	94
	The Delta spot ladder for two barrier options	96
	The vega volatility ladder	96
	The vega spot ladder	97
	Conclusion	99
5	Mono Underlying Risk Exploration	101
	Dividends	102
	Models: discrete dividends	102
	Models: cash amount dividend model	103
	Models: proportional dividend model	104
	Models: mixed dividend model	105
	Models: dividend toxicity index	105
	Statistical observations on dividends	106
	Interest rate modeling	109
	Models: why do we need stochastic interest rates?	109
	Models: simple hybrid model	110
	Models: statistics and fair pricing	111
	Forward skew modeling	112
	The local volatility model is not enough	113

Local volatility calibration	115
Alpha stable process	115
Truncated alpha stable invariants	117
Local volatility truncated alpha stable process	119
6 A General Pricing Formula	122
7 Multi-Asset Case	124
A Study of derivatives under the multi-dimensional Black & Scholes . .	124
Methodology	124
PCA for PnL explanation	127
Eigenvalue decomposition for symmetric operators	127
Stochastic application	128
Profit and loss explanation	129
The source of the parameters	131
Basket option	132
Worst of option (wo: call)	135
Best of option (Bo: put)	139
Other options (Best of call and worst of put)	141
Model calibration using fixed-point algorithm	145
Model estimation using an envelope approach	148
Conclusion	152
8 Discounting and General Value Adjustment Techniques	153
Full and symmetric collateral agreement	154
Perfect collateralization	156
Applications	157
Repo market	158
Optimal posting of collateral	158
Partial collateralization	159
Asymmetric collateralization	159
9 Investment Algorithms	161
What is a good strategy?	162
A simple strategy	167
Reverse the time	169
Avoid this data when learning	170
Strategies are assets	175
Multi-asset strategy construction	176
Signal detection	176
Prediction model	180
Risk minimization	181
10 Building Monitoring Signals	184
A Fat-tail toxicity index	184

B	Volatility signals	187
	Nature of the returns	189
	The dynamic of the returns	193
	Signal definition	194
	Asset and strategies cartography	198
	Asset management	200
C	Correlation signals	201
	Simple basket model	201
	Estimating correlation level	202
	Implied correlation skew	206
	Multi-dimensional stochastic volatility	208
	Local correlation model	211
	<i>General Conclusion</i>	215
	<i>Solutions</i>	216
	<i>Bibliography</i>	220
	<i>Index</i>	222

List of Figures

1	Number of random numbers simulated during a day for a segment of a derivative activity	4
2	Kepler Aires law	12
3	Incremental modeling approach from physics	12
4	Sample implied volatility surface	14
5	Smile slice observation	16
6	Implied volatility slice (Keplerian type of model)	17
7	Fitting the backbone volatility without the interest rates contribution	20
8	Fitting the backbone volatility with the interest rates contribution	21
9	Implied volatility surface obtained from previous dynamic	23
10	Slope as a function of the inverse of the square root of maturity	23
11	Curvature as a function of the inverse of time	24
12	FGamma smile calibration with zero mixing weight	25
13	FGamma smile calibration with 50% mixing weight	26
14	FGamma smile calibration with 100% mixing weight	26
15	Convexity search for three extra parameters	33
16	Vanilla call pricing graph	35
17	Vanilla call delta graph	36
18	Vanilla call gamma graph	36
19	European binary call price graph	38
20	European binary call delta graph	39
21	European binary call gamma graph	39
22	American binary pricing graph	41
23	American binary delta graph	41
24	American binary gamma graph	42
25	Barrier option pricing graph	43
26	Barrier option delta graph	44
27	Barrier option gamma graph	44
28	Asian option pricing graph	46
29	Asian option delta graph	47
30	Asian option gamma graph	47
31	Gamma map European call	50
32	Gamma map European call with 1 dividend	51
33	Gamma map European call with 3 dividends	51

34	Gamma map American call	52
35	Gamma map American call with 1 dividend	52
36	Gamma map American call with 3 dividends	53
37	Gamma map barrier option call up & out with no dividends	54
38	Choice of the time convention and its impact on the theta calculation	57
39	Black & Scholes calibration set	57
40	Term structure Black & Scholes calibration set	59
41	Vega (T) for a five-year Asian option (five fixings)	60
42	Terminal smile calibration set	62
43	Equity-like smile: local volatility versus implied volatility	63
44	FX-like smile: local volatility versus implied volatility	64
45	Commodity (Gold)-like smile: local volatility versus implied volatility	64
46	Markov chain calculation representation	67
47	Separable local volatility calibration set	69
48	Dupire local volatility calibration set	71
49	The most likely path	72
50	The fixed point algorithm scheme	74
51	FTSE local volatility as of 1 February 2008	74
52	NKY local volatility surface as of 1 February 2008	75
53	SX5E local volatility surface as of 1 February 2008	75
54	Vega KT of a call up & out	76
55	Vega KT for put down & in	77
56	Vega KT for an Asian option	77
57	Dynamic of the at the money volatility	86
58	SX5E spot and volatility times series	87
59	Volatility evolutions (historical versus the model ones)	87
60	Volatility of volatility under theoretical models and historical observations	88
61	SX5E Estimation of the mixing weight per maturity over time	89
62	Delta spot ladder for two barrier options	96
63	Vega volatility ladder for the barrier option	97
64	Vega spot ladder of two different barrier options	98
65	Incremental model identification in the presence of the smile	100
66	Black & Scholes Spot Path with and without dividends	102
67	Cash amount dividend modeling	104
68	Proportional dividend modeling	104
69	Mixed dividend modeling	105
70	FTSE index and dividend futures evolution	106
71	Trend for the dividend mixing weight as a function of time	107
72	Annual dividend yield distribution for the Euro top 600	107
73	Quartile dividend yield distribution	108

74	Incremental model identification in the presence of the dividend risk	108
75	The interest rate model fudge approach	111
76	Incremental model identification in the presence of interest rate risk	112
77	Fast decay of the forward skew SPX	114
78	Fast decay of the forward skew SX5E	114
79	A possible path issued from the alpha spot path	117
80	Implied 3m forward skew in the alpha stable model	118
81	3m Forward skew as a function of the volatility level	119
82	Dupire local volatility versus alpha local volatility	120
83	Incremental model identification in the presence of Forward skew	121
84	Comparison between the historical correlation and the basket-implied correlation	132
85	Basket price spot ladder (correlated and uncorrelated move)	133
86	Basket delta spot ladder (correlated and uncorrelated move)	134
87	Gamma price spot ladder (correlated and uncorrelated move)	134
88	Cega spot ladder (correlated and uncorrelated move)	135
89	Worst of price spot ladder (correlated and uncorrelated move)	136
90	Worst of delta spot ladder	137
91	Worst of Gamma spot ladder	138
92	Cega spot ladder worst of	138
93	Best of put spot ladder	139
94	Best of put delta spot ladder	140
95	Best of put gamma spot ladder	140
96	Cega spot ladder	141
97	Fixed point algorithm calibration of the local volatility local	146
98	Super Cega KT for the call on worst of	147
99	Lambda estimation for a conservative business level	149
100	Lambda estimation for a moderate business level	150
101	Lambda estimation for an acceptance business level	150
102	SX5E spot chart for the period 2007–2013	166
103	Kelly mean reverting strategy chart compared with the buy and hold strategy	168
104	Kelly strategy performance on reverse SX5E	169
105	Gold path where learning is biased due to the poorness of the structure	170
106	Crude oil where learning is biased due to the presence of a jump	171
107	A good performance obtained randomly	172
108	Random Sharpe distribution versus Kelly mean reverting SX5E strategy	173

109	Typical strategy with a region of performance and a region of underperformance	175
110	Kelly Strategy applied to a given VIX future strategy	176
111	Illustration of random matrix theory	178
112	Autocorrelation results	180
113	Volatility strategy equity line	182
114	Comparison of normal volatility and alpha volatility	185
115	Fat tail toxicity indicator for several stocks	185
116	Comparison of harmonic volatility swap with the alpha volatility and normal volatility	186
117	q-Gaussian distribution	190
118	q Estimation for different sectors before and after the crisis	191
119	SPX Prices and returns. Clusters are clearly identified	191
120	SX5E daily returns and Value at Risk under the Gaussian and q Gaussian models	192
121	Trend for the number of Gaussian VaR exceptions for SX5E index	193
122	ARPI indicator filtered by HMM algorithm	195
123	CSV for a non-linear portfolio	197
124	HMM model applied to cross sectional volatility	198
125	Strategies based on the HMM algorithm	200
126	Average historical correlation for the SX5E universe	204
127	Average Implied correlation using the skew calculation	205
128	Comparison of three different correlation estimators (historical, implied from volatilities and implied from skews)	205
129	Ratio of the implied correlations from the skew and the historical correlation	206
130	Proportion of the index skew from the individual skews	211
131	Calculation of the correlation skew premium	213

List of Tables

1	Black & Scholes pricing formula	14
2	Stylized facts from data observations	18
3	Vanilla call payoff and pricing formula	34
4	European binary	37
5	American binary	40
6	Barrier option payoff and pricing formula under the Black & Scholes model	43
7	Asian option pricing formula	46
8	Is Black & Scholes an appropriate model?	54
9	Gamma smoothing technique	55
10	European binary smoothing (by a call spread)	55
11	Stochastic volatility parameters and their impact on the shape of the smile	80
12	Stochastic volatility model and its local volatility counterpart	81
13	Toxicity index for several products	82
14	Volatility dynamic for different models	85
15	Typical mixing weights for different markets	89
16	Different models and summary of pricing formulae	92
17	Barrier option pricing in two different markets	99
18	Power law estimates and impact of the 2008 crisis	118
19	Comparison of prices of a 1y crash put option on SX5E under two different models	120
20	Worst of put and best of call sensitivity analysis	142
21	Valuation best of put	147
22	PnL Option and its hedge during a large stress test similar to that observed during a crisis	151
23	Classical measures of performance	165
24	Buy and hold SX5E from Jan 2007 to Jan 2013	166
25	Table 25 Kelly mean reverting strategy on SX5E from Jan 2007 to Jan 2013	169
26	Good performance obtained on a random path	172
27	Volatility scenario and impact of the strategy on the Sharpe	174
28	Lambda scenario and impact of the strategy on the Sharpe	174
29	Volatility of volatility scenario and impact of the strategy on the Sharpe	174

30	Performance for a volatility index strategy based on VIX futures	176
31	Performance of a Kelly Strategy applied on a volatility index strategy	177
32	Central limit theorems under different assumptions	189
33	US and EUR equity market	194
34	A signal for the Chinese equity market	196
35	Returns by asset class and regime	198
36	Volatilities by asset class and regime	199
37	Cartography of value and growth strategies	199

Foreword I

The valuation of financial derivatives instruments, and to some extent the way they behave, rests on a numerous and complex set of mathematical models, grouped into what is called quantitative finance. Nowadays, it should be required that each and every one involved in financial markets has a good knowledge of quantitative finance. The problem is that the many books in this field are too theoretical, with an impressive degree of mathematical formalism, which needs a high degree of competence in mathematics and quantitative methods.

As the title suggests, from absolute basics to advanced trading techniques and P&L explanations, this book aims to explain both the theory and the practice of derivatives instruments valuation in clear and accessible terms. This is not a mathematical textbook, and long and difficult equations that are not understandable by the average person are avoided wherever possible.

Practitioners have lost faith in the ability of financial models to achieve their ultimate purpose, as those models are not at all precise in their application to the complex world of real financial markets. They need to question the hypotheses that are behind models and challenge them. The models themselves should be applied in practice only tentatively, with careful assessment of their limitations in each application and in their own validity domain, as these can vary significantly across time and place.

This is especially true after the global financial crisis. The financial world has changed a lot and witnesses a much faster pace of crisis. New regulations and their application in modeling have become a very important topic which is enforced through regulatory regimes, especially Basel III and fundamental review of the trading book for the banking industry.

This book nicely covers all these subjects from a pragmatic point of view. It shows that stochastic calculus alone is not enough for properly evaluating and hedging derivatives instruments. It insists on the importance of data analysis in parameters estimation and how this extra information can be helpful in the construction of the fair valuation and most importantly the right hedging strategy.

At first sight, this ambitious objective seems to be tough to achieve. As a matter of fact, Adil Reghai has done it and furthermore treated it in a very pedagogical way.

Finally, the reader should appreciate the overall aim of Adil's book, allowing for useful comparisons – some valuation methods appearing to be more robust and trustworthy than others – and often warning against the lack of reliability of some quantitative models, due to the hypotheses on which they are built.

For all these reasons, this book is a must have for all practitioners and should be a great success.

Cédric Dubois
Global Head of Structured Equity and Funds
Derivatives Trading Natixis SA London

Foreword II

Quantitative finance has been one of the most active research fields in the last 50 years. The initial push in mathematical finance was the ‘portfolio selection’ theory invented by H. Markowitz. This work was a first mathematical attempt towards trying to identify and understand the trade-offs between risks and returns that is the central problem in portfolio theory. The mathematical tools used to develop portfolio selection theory resulted in a rather elementary combination of the analysis of variance and multivariate linear regression. This model of assets price immediately leads to the optimization problem of choosing the portfolio with largest return subject to a given amount of risk (measured here rather simplistically as the variance of the portfolios, ignoring fat tails and non Gaussianness). The work by H. Markowitz was considerably extended by W. Sharpe, who proposed using dimension reduction: instead of modeling the covariance of every pair of stocks, W. Sharpe proposed to identify only a few factors and to regress asset prices on these factors. For these pioneering works, H. Markowitz and W. Sharpe received 1990 Nobel prizes in economics, the first ever awarded to work in finance.

The work of Markowitz and Sharpe introduced mathematics into what was previously considered mainly as the ‘art’ of portfolio management. Since then, the mathematical sophistication of models for assets and markets increased quite rapidly. ‘One-period’ investment models were quickly replaced by continuous-time, Brownian-motion driven models of assets (among others, the emblematic geometric Brownian motion, soon followed by more complex diffusion models with stochastic volatilities); the quadratic risk measure was substituted by much more sophisticated increasing, concave utility functions. Most importantly, the early work of R. Merton and P. Samuelson (among others!) laid the foundations of thinking about assets prices, corporate finance, and exchange rate fluctuations with sophisticated mathematical (mostly stochastic) models.

A second revolution was triggered by the appearance in the mid 1980s of the market of derivative securities. The pioneering work in this domain is due to F. Black, R. Merton and M. Scholes, who laid down the theory and the methods to price the value of an option to buy a share of a stock at a given maturity and strike price (a European call option). The basic idea to compute the price of this derivative security (etymologically, which derives its value from the underlying asset) is to construct a hedging portfolio, defined as a combination of a (fraction) of the share on which the call is written and a riskless asset, to replicate the option. The hedging portfolio is constructed in such a way that at any time the option should be

worth as much as the portfolio, to eliminate arbitrage opportunities. Based on the principle of absence of arbitrage (which is highly controversial), Black and Scholes have derived an explicit expression for the price of a European call. This work, soon extended by R. Merton, was also awarded with a Nobel prize in economics.

This initial push was immediately followed by an amazing number of works providing theoretical foundations for the financial world. Most of the early developments were based on stochastic calculus making heavy use of Itô Calculus and continuous diffusion. Later, the much more demanding theory of Levy processes and jump-diffusion enters into the scene. High-frequency trading and the modeling of market microstructure naturally draws attention to discrete-event stochastic models like interacting point processes to model, at a very fine time scale, order book dynamic. Of course, all these financial models need to be calibrated to the observed prices of assets and derivatives securities using sometimes very advanced statistical estimation methods. Derivative securities pricing and arbitrage strategy also rely on accurate and fast numerical analysis. This has naturally led to an escalation in the level of mathematics (probability, statistics, partial differential equation and numerical analysis) used in finance, to a point where research problems in mathematics are completely intertwined with the theory and the practice of finance. This has also caused a proliferation of financial instruments (barrier, binary, American options, among many others), whose complexity and sophistication sometimes defies understanding! There are only a few domains in science in which there exists such an intense cross-fertilization between theory and applications.

As masterfully pointed out by the author, despite their considerable mathematical sophistications the models used today in financial mathematics are in general fragile, being based on over-simplistic models of assets and market dynamics. For example, most financial models will still presuppose the absence of arbitrage opportunities (no trading opportunities yield profit without any downside risk), which implies the existence of an equivalent martingale measure under which discounted prices have the martingale property. These are of course the very beginning of a long list of half plausible assumptions, unverifiable axioms, which in practice have proved to be sometimes devastatingly erroneous! The book proposes novel approaches to pricing and hedging financial products safely and effectively, replacing elegant but erroneous assumptions with more realistic ones, taking into account that we live in a world of more frequent crises and fatter tail risks. Based on many years of academic research and practical trading experience, Adil Reghai convincingly assembles both proven and new approaches to answer the challenges of today's highly volatile financial markets. These models not only take their inspiration from probability and statistics, but also from physics and engineering.

This book very nicely offers an original explanation covering the field. It proposes amazing new insights and techniques and opens exciting avenues of research.

The vision developed in this book, questioning the foundations of mathematical finance, is truly unique. I have learned a lot reading this amazing book and I sincerely hope that the reader will enjoy reading these pages as much as I did!

Eric Moulines
Professor at Télécom-Paris Tech

Acknowledgments

I would like to thank Nicole El Karoui, who taught me so much, and Jean Michel Lasry, who introduced me to this fascinating field and with whom I started my career. Also I would like to thank Christophe Chazot. He was my boss back in the late 1990s in London. One day, he asked me to step in for him to give a lecture for the Masters of Finance programme in Nice. I accepted without really knowing what I was in for. This programme is unique. Most of the teachers are practitioners, while students are carefully chosen from the top engineering and business schools. The aim is to provide them with insights into the business and ensure their familiarity with the requisite tools is operative by the end of their training. I am delighted to have taken part in this unique experience, especially as this Masters is currently ranked among the top 10 in the world by the *Wall Street Journal*. I share this success with my colleagues, especially Tarek Amyuni, head of the Specialized Masters in Financial Markets, Innovations and Technologies (FMIT) at SKEMA. I would like to thank him as a friend and colleague who devotes huge energy to this programme and to working in the interest of his students.

Quant work is collaborative. Progress is achieved by talking to people, reading papers and testing. I would like to thank many of my colleagues and peers. In particular, I would like to mention here some people whom I know well and who have unconsciously shaped the way I present this book.

Nicole El Karoui: for her friendship and advice over the years. She was in favour of mixing stochastics and statistics. On my undergraduate course she insisted on avoiding the perfect fit paradigm in favour of studying errors of fit when using statistical models.

Bruno Dupire: for his friendship and timely explanations and exchanges. I always enjoy talking with Bruno. He is innovative, detail-oriented, focused on creating value, yet modest.

Jim Gatheral: for sharing ideas and concepts and his enlightening explanations on several subjects. Among other things he offers is an excellent best starting point to understand any topic.

Lorenzo Bergomi: as a friend who has brought so much to the discipline. I bear in mind one of his descriptions of a ‘quant’: “quants are like doctors, they need to prepare the medicine before the patient is sick. If they bring the medicine too late the patient has suffered for too long and it won’t work. If the medicine is provided in advance, the patient is unconscious and will not take it. A good quant is one who has the medicine and waits until the patient suffers just a little before delivering it”.

Philippe Balland: for teaching me so much when I was in his team at Merrill Lynch. He taught me how to separate technical knowledge (stochastic calculus) from transient issues (statistical nature of the knowledge). Thanks to his teaching and years of work afterwards, I have been able to reconcile the two areas of knowledge in a clear way and effectively produce models for pricing and hedging. I also learnt how to move around with my laptop and undertake fascinating work on the move (I'm not sure my wife much appreciated this!).

Alex Langnau: for a unique and timely friendship beyond description, and for sharing thoughts and exchanging ideas and concepts. His thinking, derived from his background in physics, has profoundly influenced my own. Thanks to him, I have been able to complete the bridge between derivatives quants and investment quants.

I would also like to thank Mohamed El Babsiri, Taoufik Cherif and Michel Crouhy for encouraging me to make the effort to write a book from my lecture notes.

My thanks to many who have helped me in my thinking, exchanged with me on different issues: this book is a synthesis of our common knowledge. Any errors are, however, mine.

I thank the following: M. Messaoud, E. Giraud, A. Ben Haj Yedder, J. Luu, M. Souaille, M. Lakhdar, J.M. Prevost, G. El Boury, G. Boya, L. Jacquiel, A. Moulim, F. El Khyari, S. Mielnik, T. Combarel, V. Garcin, M. Irsutti, O. Aw, E Tetard, F Hihi, L. Mathieu, M. Rivaud, L. Tur and A. Ibrahim.

I would like also to express my appreciation of Gisele Masante. She has dealt with a host of administrative and logistical tasks for many years.

Finally, my thanks go to all the students over the years who have attended my classes. They asked questions and helped me progress.