

QUANTITATIVE TRADING

Algorithms, Analytics, Data, Models, Optimization

Xin Guo

University of California, Berkeley, USA

Tze Leung Lai

Stanford University, California, USA

Howard Shek

Tower Research Capital, New York City, New York, USA

Samuel Po-Shing Wong

5Lattice Securities Limited, Hong Kong, China



CRC Press

Taylor & Francis Group

Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an Informa business

A CHAPMAN & HALL BOOK

Contents

Preface	xiii
List of Figures	xvii
List of Tables	xxi
1 Introduction	1
1.1 Evolution of trading infrastructure	1
1.2 Quantitative strategies and time-scales	5
1.3 Statistical arbitrage and debates about EMH	6
1.4 Quantitative funds, mutual funds, hedge funds	8
1.5 Data, analytics, models, optimization, algorithms	10
1.6 Interdisciplinary nature of the subject and how the book can be used	11
1.7 Supplements and problems	13
2 Statistical Models and Methods for Quantitative Trading	17
2.1 Stylized facts on stock price data	18
2.1.1 Time series of low-frequency returns	18
2.1.2 Discrete price changes in high-frequency data	18
2.2 Brownian motion models for speculative prices	22
2.3 MPT as a “walking shoe” down Wall Street	22
2.4 Statistical underpinnings of MPT	24
2.4.1 Multifactor pricing models	24
2.4.2 Bayes, shrinkage, and Black-Litterman estimators	25
2.4.3 Bootstrapping and the resampled frontier	26
2.5 A new approach incorporating parameter uncertainty	27
2.5.1 Solution of the optimization problem	27
2.5.2 Computation of the optimal weight vector	28
2.5.3 Bootstrap estimate of performance and NPEB	29
2.6 From random walks to martingales that match stylized facts	30
2.6.1 From Gaussian to Paretian random walks	31
2.6.2 Random walks with optional sampling times	32
2.6.3 From random walks to ARIMA, GARCH	35
2.7 Neo-MPT involving martingale regression models	37

2.7.1	Incorporating time series effects in NPEB	38
2.7.2	Optimizing information ratios along efficient frontier	38
2.7.3	An empirical study of neo-MPT	39
2.8	Statistical arbitrage and strategies beyond EMH	41
2.8.1	Technical rules and the statistical background	41
2.8.2	Time series, momentum, and pairs trading strategies	43
2.8.3	Contrarian strategies, behavioral finance, and investors' cognitive biases	44
2.8.4	From value investing to global macro strategies	44
2.8.5	In-sample and out-of-sample evaluation	45
2.9	Supplements and problems	46
3	Active Portfolio Management and Investment Strategies	61
3.1	Active alpha and beta in portfolio management	62
3.1.1	Sources of alpha	63
3.1.2	Exotic beta beyond active alpha	63
3.1.3	A new approach to active portfolio optimization	64
3.2	Transaction costs, and long-short constraints	67
3.2.1	Cost of transactions and its components	67
3.2.2	Long-short and other portfolio constraints	68
3.3	Multiperiod portfolio management	69
3.3.1	The Samuelson-Merton theory	69
3.3.2	Incorporating transaction costs into Merton's problem	72
3.3.3	Multiperiod capital growth and volatility pumping	73
3.3.4	Multiperiod mean-variance portfolio rebalancing	74
3.3.5	Dynamic mean-variance portfolio optimization	75
3.3.6	Dynamic portfolio selection	76
3.4	Supplementary notes and comments	78
3.5	Exercises	101
4	Econometrics of Transactions in Electronic Platforms	103
4.1	Transactions and transactions data	104
4.2	Models for high-frequency data	104
4.2.1	Roll's model of bid-ask bounce	105
4.2.2	Market microstructure model with additive noise	106
4.3	Estimation of integrated variance of X_t	107
4.3.1	Sparse sampling methods	108
4.3.2	Averaging method over subsamples	109
4.3.3	Method of two time-scales	109
4.3.4	Method of kernel smoothing: Realized kernels	110
4.3.5	Method of pre-averaging	111
4.3.6	From MLE of volatility parameter to QMLE of $[X]_T$	112
4.4	Estimation of covariation of multiple assets	113

4.4.1	Asynchronicity and the Epps effect	113
4.4.2	Synchronization procedures	114
4.4.3	QMLE for covariance and correlation estimation . . .	115
4.4.4	Multivariate realized kernels and two-scale estimators	116
4.5	Fourier methods	118
4.5.1	Fourier estimator of $[X]_T$ and spot volatility	118
4.5.2	Statistical properties of Fourier estimators	120
4.5.3	Fourier estimators of spot co-volatilities	121
4.6	Other econometric models involving TAQ	122
4.6.1	ACD models of inter-transaction durations	123
4.6.2	Self-exciting point process models	124
4.6.3	Decomposition of D_i and generalized linear models . .	125
4.6.4	McCulloch and Tsay's decomposition	126
4.6.5	Joint modeling of point process and its marks	127
4.6.6	Realized GARCH and other predictive models	128
4.6.7	Jumps in efficient price process and power variation .	130
4.7	Supplementary notes and comments	132
4.8	Exercises	139
5	Limit Order Book: Data Analytics and Dynamic Models	143
5.1	From market data to limit order book (LOB)	144
5.2	Stylized facts of LOB data	145
5.2.1	Book price adjustment	145
5.2.2	Volume imbalance and other indicators	148
5.3	Fitting a multivariate point process to LOB data	151
5.3.1	Marketable orders as a multivariate point process . . .	151
5.3.2	Empirical illustration	153
5.4	LOB data analytics via machine learning	157
5.5	Queueing models of LOB dynamics	159
5.5.1	Diffusion limits of the level-1 reduced-form model . . .	160
5.5.2	Fluid limit of order positions	163
5.5.3	LOB-based queue-reactive model	166
5.6	Supplements and problems	169
6	Optimal Execution and Placement	183
6.1	Optimal execution with a single asset	184
6.1.1	Dynamic programming solution of problem (6.2) . . .	185
6.1.2	Continuous-time models and calculus of variations . .	187
6.1.3	Myth: Optimality of deterministic strategies	189
6.2	Multiplicative price impact model	190
6.2.1	The model and stochastic control problem	190
6.2.2	HJB equation for the finite-horizon case	191
6.2.3	Infinite-horizon case $T = \infty$	193

6.2.4	Price manipulation and transient price impact	196
6.3	Optimal execution using the LOB shape	196
6.3.1	Cost minimization	199
6.3.2	Optimal strategy for Model 1	202
6.3.3	Optimal strategy for Model 2	203
6.3.4	Closed-form solution for block-shaped LOBs	204
6.4	Optimal execution for portfolios	204
6.5	Optimal placement	207
6.5.1	Markov random walk model with mean reversion	208
6.5.2	Continuous-time Markov chain model	211
6.6	Supplements and problems	215
7	Market Making and Smart Order Routing	221
7.1	Ho and Stoll's model and the Avellanedo-Stoikov policy	222
7.2	Solution to the HJB equation and subsequent extensions	223
7.3	Impulse control involving limit and market orders	225
7.3.1	Impulse control for the market maker	225
7.3.2	Control formulation	226
7.4	Smart order routing and dark pools	228
7.5	Optimal order splitting among exchanges in SOR	230
7.5.1	The cost function and optimization problem	231
7.5.2	Optimal order placement across K exchanges	232
7.5.3	A stochastic approximation method	233
7.6	Censored exploration-exploitation for dark pools	234
7.6.1	The SOR problem and a greedy algorithm	234
7.6.2	Modified Kaplan-Meier estimate \hat{T}_i	235
7.6.3	Exploration, exploitation, and optimal allocation	236
7.7	Stochastic Lagrangian optimization in dark pools	237
7.7.1	Lagrangian approach via stochastic approximation	238
7.7.2	Convergence of Lagrangian recursion to optimizer	240
7.8	Supplementary notes and comments	241
7.9	Exercises	248
8	Informatics, Regulation and Risk Management	251
8.1	Some quantitative strategies	253
8.2	Exchange infrastructure	255
8.2.1	Order gateway	258
8.2.2	Matching engine	258
8.2.3	Market data dissemination	259
8.2.4	Order fee structure	260
8.2.5	Colocation service	262
8.2.6	Clearing and settlement	263
8.3	Strategy informatics and infrastructure	264

8.3.1	Market data handling	264
8.3.2	Alpha engine	265
8.3.3	Order management	266
8.3.4	Order type and order qualifier	266
8.4	Exchange rules and regulations	269
8.4.1	SIP and Reg NMS	269
8.4.2	Regulation SHO	272
8.4.3	Other exchange-specific rules	273
8.4.4	Circuit breaker	274
8.4.5	Market manipulation	274
8.5	Risk management	274
8.5.1	Operational risk	275
8.5.2	Strategy risk	277
8.6	Supplementary notes and comments	279
8.7	Exercises	289
A	Martingale Theory	295
A.1	Discrete-time martingales	295
A.2	Continuous-time martingales	298
B	Markov Chain and Related Topics	303
B.1	Generator Q of CTMC	303
B.2	Potential theory for Markov chains	304
B.3	Markov decision theory	304
C	Doubly Stochastic Self-Exciting Point Processes	307
C.1	Martingale theory and compensators of multivariate counting processes	307
C.2	Doubly stochastic point process models	308
C.3	Likelihood inference in point process models	309
C.4	Simulation of doubly stochastic SEPP	312
D	Weak Convergence and Limit Theorems	315
D.1	Donsker's theorem and its extensions	316
D.2	Queuing system and limit theorems	317
	Bibliography	319
	Index	349