Index

Note: Page numbers followed by f and t refer to figures and tables, respectively.

ABD test, 138–139, 142–146
list of studies on, 147t
ACF, see autocorrelation function (ACF)
additive regression model, 254
ADF test, see augmented Dickey–Fuller test (ADF test)
adiabatic quantum computing, 79–80
age, generic diversity in fossil record, 372
AIC of models, 335t, 420t
algorithms, 77
classes, 78
complexity, 77–78
performance, 78–79
ARCH effect, 311, 311t, 312f, 313, 334t, 420t
ARFIMA(p,q)-GARCH(r,s) process, 299–300
ARFIMA(p,q) model, 299
ARMA(2,1) model, 154, 155t, 168t, 169
ARMA(p,q) model, 297
augmented Dickey–Fuller test (ADF test), 302–303, 334t, 419t
autocorrelation function (ACF), 64, 65f
backward-looking test, 139, 158–161, 160, 162–164
Bai–Perron test, 64–65
of coal/WTI log prices ratio, 64f, 65
Bayes methodology, 109
BIC of models, 335t, 421t
bicubic interpolation, 276–277
biharmonic interpolation, 277, 278f–279f, 279, 280f–281f, 281
bilinear interpolation, 272–276
algorithm, 272–274, 273f
nonlinear, 274, 275f–276f, 276
unit square, 274
bipower variation (BP), 142
BNS tests, 140–142
BP, see bipower variation (BP)
Brownian distance correlation, 62–63, 67–68
and Granger causality test, 68
significance level of, 67t
Cauchy (Lorentz) distribution, 368
CDO, see collateralized debt obligation (CDO)
Chimera graph, 86
classical optimization techniques, 74
class NP algorithms, 78
class NP-complete algorithms, 78
class NP-hard algorithms, 78
class P algorithms, 78
collateralized debt obligation (CDO), 51–52
tranche loss function and, 52–53
combinatorial optimization, 74, 82–83
conditional mean model (returns), 309
correlation sensitivities, for tranche loss, 55–58
critical region selection, high-frequency prices jumps, 152–153
cumulative sum (CUSUM) timing examples, 12–24, 12f–15f
lazy simple random walk, 21–24, 23f, 25–26
random walk expected gain over subperiod, 15–18
simple random walk, 18–20, 19f overview, 1–3
process, 7–10
scheme, 10–12, 11f
stopping time, 7–10
two-sided, 10
CUSUM statistic process, 7–10
CUSUM stopping rule, 8–9
CUSUM strategy Monte Carlo, 24–27
data-driven testing procedure, for high-frequency prices jumps
microstructure noise, 146, 148–149
SPY data, 146, 148–149, 148f
d Estimate, long-memory volatility models, 335t, 421t
deterministic model, governing equations for, 342–345
application to geophysical (earthquake data), 343–344, 346f–352f, 353t
results, 344–345, 345f
distance correlation, 63–64
distance covariance, 63
diversified portfolio, 82
diversity, in fossil record, 372
DJIA, see Dow Jones Index (DJIA)
Dow Jones Index (DJIA) returns, 306, 307f–309f
D-wave simulator, 98
D-wave system, 78–79
mapping for, 86–87
results from, 98
distance covariance, 63
diversity, in fossil record, 372
diverse portfolio, 82
diversity, in fossil record, 372
delay, generic diversity in fossil record, 372
filtered empirical distributions at
$t_1, \ldots, t_F$, 110–112
evolution step for, 111
selection step, 112
financial model for optimization, 81
forward-looking tests, 139, 158
fossil fuels prices, 61–62
Bai–Perron test for, 64–66
data for, 64, 64f–65f
electricity generation and, 68–69, 68t
log prices, correlation matrix of, 66t
fractional Brownian motion, 224–226
fractional IGARCH (FIGARCH) model, 296, 300–302, 373
functional central limit theorem for multivariate linear Hawkes processes, 190
for univariate nonlinear Hawkes processes, 190
Index

gain over subperiod, 5–7
 calculation for, 6–7
 random walk expected, 15–18
 GARCH(p,q) model, 296–298, 373
 geophysics and finance using, 295–337
 Gaussian copula model, 51–52
 tranche loss function and, 52–53
 Gaussian inequalities, 54–58
 generalized extreme value (GEV) distribution, 139–140, 152–153
 generalized method of moments, 196
 generic diversity in fossil record, analysis of
 introduction, 371–373
 Johnson transformation (JT) function for, 378, 379f–380f, 380, 381f–383f
 Lévy distribution for, 380
 data analysis with TLF distribution, 389–390, 390f
 stable distributions, characterization of, 383–384
 sum of random variables with different parameters, 390–394, 391f–393f
 truncated, 384–389
 statistical and numerical analysis, 377–380, 378f
 statistical preliminaries and results, 373–377
 general version for n random variables, 376–377
 sum of exponential random variables with different parameters, 374–377
 genetic algorithm formulation, 76
 geophysics and finance using
 GARCH models, volatility structures in, 295–337
 data collection, analysis, and result, 306–335
 ARCH effect, 311, 311t, 312f, 313
 ARMA(2,2), 309, 310f, 311
 conditional mean model (returns), 309
 on Dow Jones Index (DJIA) returns, 306, 307f–309f
 on high-frequency, earthquake, and explosives series, 320f–329f, 330, 331f–332f, 333
 model diagnostic of conditional returns with conditional variance, 318, 319f, 330t
 model diagnostics, 314–315, 315f
 model selection and specification, 306, 309t, 311t, 313, 313t
 one-step ahead prediction of last 10 observations, 330, 330t
 returns and variance equation, 315, 316f, 317, 317t
 standardized residuals test, 314, 314f, 317–318, 318f
 long memory models, 298–305
 ARFIMA(p,d,q)-GARCH(r,s), 299–300
 ARFIMA(p,d,q) model, 299
 detection and estimation of, 302–305
 short memory models, 297–298
 ARMA(p,q) model, 297
 GARCH(p,q) model, 297–298
 IGARCH(1,1) model, 298
 geophysics (earthquake data)
deterministic model, application to, 343–344
 Lévy flights application to, 345, 353
 MATLAB program code description for, 362–364
 using GARCH models, 295–337
<table>
<thead>
<tr>
<th>Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granger causality, 62–63, 65, 68</td>
</tr>
<tr>
<td>and Brownian distance correlation, 68</td>
</tr>
<tr>
<td>definition of, 63</td>
</tr>
<tr>
<td>significance level of, 67t</td>
</tr>
<tr>
<td>testing of, 63</td>
</tr>
<tr>
<td>vector autoregressive (VAR) model for, 67</td>
</tr>
<tr>
<td>graph-theoretic combinatorial optimization models, 82–83</td>
</tr>
<tr>
<td>Grey relational analysis approach, 76</td>
</tr>
<tr>
<td>Gumbel distribution, 139, 144–145, 145t</td>
</tr>
<tr>
<td>HAR-MA model, least-square estimation of, 167t, 168</td>
</tr>
<tr>
<td>Hawkes processes, 186–191</td>
</tr>
<tr>
<td>applications of, 198–206</td>
</tr>
<tr>
<td>measuring endogeneity (reflexivity), 205–206</td>
</tr>
<tr>
<td>modeling jump-diffusion, 205</td>
</tr>
<tr>
<td>modeling order arrivals, 199–200</td>
</tr>
<tr>
<td>modeling price jumps, 200–204, 202f</td>
</tr>
<tr>
<td>branching structure representation, 188</td>
</tr>
<tr>
<td>brief history of, 211–212</td>
</tr>
<tr>
<td>convergence of, 189</td>
</tr>
<tr>
<td>functional central limit theorem for multivariate linear Hawkes processes, 190</td>
</tr>
<tr>
<td>functional central limit theorem for univariate nonlinear Hawkes processes, 190</td>
</tr>
<tr>
<td>law of large numbers for multivariate linear Hawkes processes, 189–190</td>
</tr>
<tr>
<td>nearly unstable univariate linear Hawkes processes, 191</td>
</tr>
<tr>
<td>estimation, 194–197</td>
</tr>
<tr>
<td>expectation maximization, 194–196</td>
</tr>
<tr>
<td>generalized method of moments, 196</td>
</tr>
<tr>
<td>maximum likelihood estimation, 194</td>
</tr>
<tr>
<td>nonparametric, 196–197</td>
</tr>
<tr>
<td>in high frequency financial data modeling, 211–212</td>
</tr>
<tr>
<td>hypothesis testing of, 197–198</td>
</tr>
<tr>
<td>approximate thinning, 198</td>
</tr>
<tr>
<td>random time change, 197–198</td>
</tr>
<tr>
<td>linear, 187–188</td>
</tr>
<tr>
<td>multivariate marked, 186–187</td>
</tr>
<tr>
<td>simulation, 191–193</td>
</tr>
<tr>
<td>by branching structure, 193</td>
</tr>
<tr>
<td>inverse CDF transform, 192</td>
</tr>
<tr>
<td>Ogata’s modified thinning, 192–193</td>
</tr>
<tr>
<td>stationarity, 188–189</td>
</tr>
<tr>
<td>statistical inference of, 191–198</td>
</tr>
<tr>
<td>Hermite multifractal random walk (HMRW), 231–234</td>
</tr>
<tr>
<td>simulation of, 235–241, 239f–240f</td>
</tr>
<tr>
<td>Hermite processes, 223</td>
</tr>
<tr>
<td>financial applications, 234–243</td>
</tr>
<tr>
<td>simulation of HMRW, 235–241, 239f–240f</td>
</tr>
<tr>
<td>statistical properties, 241–243, 243f–246f</td>
</tr>
<tr>
<td>fractional Brownian motion and, 224–226</td>
</tr>
<tr>
<td>infinitely divisible cascading noise, 229–231</td>
</tr>
<tr>
<td>multifractal random walk driven by, 231–234</td>
</tr>
<tr>
<td>definition, 231–233</td>
</tr>
<tr>
<td>existence, 231–233</td>
</tr>
<tr>
<td>properties of, 233–234</td>
</tr>
<tr>
<td>properties of, 225–226</td>
</tr>
<tr>
<td>Wiener integrals with respect to, 226–228</td>
</tr>
<tr>
<td>Hermite random variable, 225</td>
</tr>
</tbody>
</table>
Index

heuristic optimization techniques, 74, 76
hidden Markov process, 108
high-frequency market data, application to
methodology, 360–361, 362f
results, 361
high-frequency prices jumps, stochastic volatility, 137–175
data-driven testing procedure
microstructure noise, 146, 148–149
SPY data, 146, 148–149, 148f
empirical results, 161–165
backward-looking test, 162–164, 162t, 163f, 164t
interpolated test, 165
generalized testing procedure
critical region selection, 152–153
spot volatility estimation, 149–152, 149f, 150t–151t
intraday jump tests
ABD test, 142–146
BNS test, 140–142
LM test, 142–146
realized volatility measure test, 140–142
simulation study
model specification, 153–158, 155t–156t, 157f
results, 158–161, 159f–160t
high-frequency (tick) data, analysis of, 394, 395f, 396, 397f–408f, 409, 410f–415f
HMRW, see Hermite multifractal random walk (HMRW)

idle time, of trading strategy, 25
index of stability, 383
ininitely divisible cascading noise, 229–231

integrated GARCH (IGARCH) model, 296, 298, 373
integrated volatility (IV), 141
intermediate memory process, 300
interpolated test, 160–161, 165
interpolation methods, 271–287
bicubic interpolation, 276–277
biharmonic interpolation, 277, 278f–279f, 279, 280f–281f, 281
bilinear interpolation, 272–276
algorithm, 272–274, 273f
nonlinear, 274, 275f–276f, 276
unit square, 274
nearest-neighbor interpolation, 271
numerical applications of, 285–287
thin plate splines, 282–285
physical analogy, 282
radial basis function, 283, 284f–285f
smoothness measure, 283
intraday price jump tests
ABD test, 142–146
BNS test, 140–142
LM test, 142–146
realized volatility measure test, 140–142
simulation study
model specification, 153–158, 155t–156t, 157f
results, 158–161, 159f–160t
high-frequency (tick) data, analysis of, 394, 395f, 396, 397f–408f, 409, 410f–415f
HMRW, see Hermite multifractal random walk (HMRW)

idle time, of trading strategy, 25
index of stability, 383
ininitely divisible cascading noise, 229–231

integrated GARCH (IGARCH) model, 296, 298, 373
integrated volatility (IV), 141
intermediate memory process, 300
interpolated test, 160–161, 165
interpolation methods, 271–287
bicubic interpolation, 276–277
biharmonic interpolation, 277, 278f–279f, 279, 280f–281f, 281
bilinear interpolation, 272–276
algorithm, 272–274, 273f
nonlinear, 274, 275f–276f, 276
unit square, 274
nearest-neighbor interpolation, 271
numerical applications of, 285–287
thin plate splines, 282–285
physical analogy, 282
radial basis function, 283, 284f–285f
smoothness measure, 283
intraday price jump tests
ABD test, 142–146
BNS test, 140–142
LM test, 142–146
realized volatility measure test, 140–142
simulation study
model specification, 153–158, 155t–156t, 157f
results, 158–161, 159f–160t
high-frequency (tick) data, analysis of, 394, 395f, 396, 397f–408f, 409, 410f–415f
HMRW, see Hermite multifractal random walk (HMRW)
Lagrangian relaxation, 76
law of large numbers for multivariate linear Hawkes processes, 189–190
lazy simple random walk, CUSUM timing, 21–24, 23f, 25–26, 41t, 42t
least-square estimation of HAR-MA model, 167t, 168
Lévy distribution, for analysis of generic diversity in fossil record, 380
data analysis with TLF distribution, 389–390, 390f
stable distributions, characterization of, 383–384
sum of random variables with different parameters, 390–394, 391f–393f
truncated, 384–389
Lévy flights model
application to geophysics, 345, 353
to estimate crash dates, 366, 366t results, 356–360, 357f–359f, 360t truncated distribution, 353–356
Lévy–Smirnov distribution, 368
Limit Order Books (LOB), 183
characteristics of, 183–184 resiliency of, 200
Linear Hawkes process, 187–188 convergence of nearly unstable univariate, 191
functional central limit theorem for multivariate, 190
law of large numbers for multivariate, 189–190
LM test, 138–139, 142–146 list of studies on, 147t
LOB, see Limit Order Books (LOB)
Local polynomial regression models, 255
multiple regression, 256
simple regression, 255
Loess curve, 257
long-memory generalized autoregressive conditionally heteroskedastic (LMGARCH) models, 296
long memory models, 298–302
ARFIMA(p,d,q)-GARCH(r,s), 299–300
ARFIMA(p,d,q) model, 299
detection and estimation of, 302–305 augmented Dickey–Fuller test (ADF test), 302–303 KPSS test, 303–304, 304t Whittle method, 304–305
Lowess curve, 257
Lowess/loess method, nonparametric regression models, 257–258
marked point process (MPP), 185
Markov chain, 107 continuous time, 108
obtaining parameters of, 112–113 parameter estimation, 131
Markov processes, 187
Markowitz mean-variance model, 73
Matlab code in geophysics, 362–364, 363f–364f
WMIS, 100–103
maximum independent set (MIS), 75, 82–83
maximum likelihood estimation (MLE), 194
minimum error thresholding method, 112
minorize-maximization (MM) algorithm, 197
Index

MIS, see maximum independent set (MIS)
mixed models, 84
MLE, see maximum likelihood estimation (MLE)
Monofractal process, 222
Monte Carlo, CUSUM strategy, 24–27
MPP, see marked point process (MPP)
MRW, see multifractal random walk (MRW)
multifractality, 222
multifractal random walk (MRW) defined, 222
by Hermite processes, 231–234
definition, 231–233
existence, 231–233
properties of, 233–234
overview, 221–224
properties, 223
statistical properties of, 241–243
multivariate marked Hawkes process, 186–187
multivariate point process, 185, 199
nearest-neighbor interpolation, 271
negative signals, 4
nonparametric estimation of Hawkes process, 196–197
nonparametric regression models, 253–271
application to financial data sampled with high frequency, 260, 266–269
geophysics, 259–260, 261f–265f, 266t–268t, 269f–270f
highlights and discussions, 270–271, 270t
generalized, 254
local polynomial regression, 255
multiple regression, 256
simple regression, 255
lowess/loess method, 257–258
NP algorithms, 78
NP-complete algorithms, 78
NP-hard algorithms, 78
Ogata’s modified thinning method, 192–193
optimization, portfolio, 76–77
background of, 75–80
binary optimization on, 77
discussion, 95–97
diversified, 82
financial model for, 81
future research on, 98–100
graph-theoretic combinatorial models for, 82–83
hardware limitations in, 97
implementation limitations in, 98
Ising model for, 83
methods for, 84–88
input data, 85
mapping implementation, 86–88, 87f
mean-variance calculations, 85–86
model implementation, 85
risk measures implementation, 86
mixed models for, 84
model limitations in, 97–98
models, 80–84
QUBO model for, 83
results of, 88–95
restricted minimum-risk model, 91–94, 92f–93f
simple correlation model, 88–91, 89f–91f
WMIS minimum-risk, max return model, 94–95, 94f–95f
Orig, generic diversity in fossil record, 372
Ornstein–Uhlenbeck (OU) process, 153, 155t
P algorithms, 78
Phanerozoic, 372
point processes, 184–186. See also Hawkes processes
Poisson processes, 186
random time change, 211
stochastic intensities and, 185–186, 209–210
Poisson processes, 186, 198
portfolio optimization, 76–77
Quadratic unconstrained binary optimization (QUBO), 74, 83
quadratic variation (QV), of price, 141
QUBO, see quadratic unconstrained binary optimization (QUBO)
random walk expected gain over subperiod, 15–18, 43t–46t
realized volatility measure test, 140–142
regime switching volatility model, 107–133
restricted minimum-risk model, 91–94, 92f–93f
Rosenblatt process, 223, 225
scale invariance model, application to methodology, 360–361, 362f
results, 361
scale invariance model, application to high-frequency market data methodology, 360–361, 362f
results, 361
scatterplot smoothing, see nonparametric regression models
short memory models, 297–298
ARMA(p,q) model, 297
Index

GARCH(p,q) model, 297–298
IGARCH(1,1) model, 298
Sidák correction, 144, 145t
signals, 3–5
negative, 4
positive, 3–4
properties, 4–5
sequence of, 4
and subperiod, 5–7
simple correlation model, 88–91, 89f–91f
simple random walk, CUSUM timing, 18–20, 19f
simulation
of Hawkes processes, 191–193
by branching structure, 193
inverse CDF transform, 192
Ogata’s modified thinning, 192–193
of HMRW, 235–241, 239f–240f
speed of reaction, CUSUM, 39
spot volatility estimation,
high-frequency prices jumps, 149–152, 149f, 150t–151t
square-root effect, threshold parameter, 38
stable distributions
characterization of, 367–368
introduction of, 366–367
standard maximum likelihood method, 153
stochastic intensities, point processes and, 185–186
stochastic volatility model, 107–133
in analysis of
during earthquake, 125–127, 125f–126f
earthquake signal, 123–124, 123f–124f, 125f
end of earthquake signal, aftershocks, 127
seismometer readings during earthquake, 121–123, 122f
empirical testing of, 132–133
in finance area, 109–110, 113–119, 115f–118f
with hidden Markov process, 108–133
historical note on, 109–110
jumps in high-frequency prices under, 137–175
methodology, 110–113
obtaining filtered empirical distributions at $t_1, \ldots, t_T$, 110–112
obtaining parameters of Markov chain, 112–113
in physical data application, 119–121, 120f, 120t
and problem, 108–109
theoretical results of
about convergence, 129–131
about parameter estimation, 129–131
Markov chain parameter estimation, 131
particle filter, working of, 128–129
stock indices, analysis of, 394, 395f, 396, 397f–408f, 409, 410f–415f
stopping time, CUSUM, 7–10
subperiod, 4
gain over, 5–7
signal and, 5–7
SV2FJ_2 model, 154, 156, 157f
calibration of $\xi$ under, 170–175, 170t–175t
minimized loss function loss for, 169, 169t
parameter values of, 156t
thin plate splines (TPSs), 282–285
physical analogy, 282
radial basis function, 283, 284f–285f
smoothness measure, 283
threshold GARCH (TGARCH) model, 296, 373
TPSs, see thin plate splines (TPSs)
tranche, 53
tranche loss function, 52–53
correlation sensitivities for, 55–58
trend-based trading strategy, 3–7
gain over subperiod, 5–7
signaling, 3–5
threshold parameter, effect of, 27–28, 28f, 29t–33t, 34, 34f, 35t–37t, 38–39
trends, 3–5
for US treasury notes, 11–12, 11f–12f
trends, 3–5
truncated Lévy flights (TLF) distribution, 353–356, 384–389
data analysis with, 389–390, 390f
infinite divisibility, 388–389
kurtosis, 387–388
two-sided CUSUM (2-CUSUM), 10
US Clean Air Act, 69
US treasury notes, trading strategy for, 11–24, 11f–12f
variance–covariance matrix, 85–86
vector autoregressive (VAR) model, 67
volatility, 113
clustering, 222
structures in geophysics and finance using GARCH models, 295–337
data collection, analysis, and result, 306–335
long memory models, 298–305
short memory models, 297–298
weighted MIS (WMIS), 82–83, 88
Matlab Code, 100–103
White/Terasvirta test, 67t
Whittle estimate of long-memory parameter ($d$), 420t
Whittle method, 304–305, 334t
Wiener–Hopf equation, 197
Wiener integrals with respect to Hermite processes, 226–228
Wiener process, 224–225
WMIS, see weighted MIS (WMIS)
WMIS minimum-risk, max return model, 94–95, 94f–95f
The dynamic and interaction between financial markets around the world have changed dramatically under economic globalization. In addition, advances in communication and data collection have changed the way information is processed and used. In this new era, financial instruments have become increasingly sophisticated and their impacts are far-reaching. The recent financial (credit) crisis is a vivid example of the new challenges we face and continue to face in this information age. Analytical skills and ability to extract useful information from mass data, to comprehend the complexity of financial instruments, and to assess the financial risk involved become a necessity for economists, financial managers, and risk management professionals. To master such skills and ability, knowledge from computer science, economics, finance, mathematics and statistics is essential. As such, financial engineering is cross-disciplinary, and its theory and applications advance rapidly.

The goal of this Handbook Series is to provide a one-stop source for students, researchers, and practitioners to learn the knowledge and analytical skills they need to face today’s challenges in financial markets. The Series intends to introduce systematically recent developments in different areas of financial engineering and econometrics. The coverage will be broad and thorough with balance in theory and applications. Each volume will be edited by leading researchers and practitioners in the area and covers state-of-the-art methods and theory of the selected topic.

Published Wiley Handbooks in Financial Engineering and Econometrics

Bauwens, Hafner, and Laurent · Handbook of Volatility Models and Their Applications
Brandimarte · Handbook in Monte Carlo Simulation: Applications in Financial Engineering, Risk Management, and Economics
Chan and Wong · Handbook of Financial Risk Management: Simulations and Case Studies
Cruz, Peters, and Shevchenko · Fundamental Aspects of Operational Risk and Insurance Analytics: A Handbook of Operational Risk
Florescu, Mariani, Stanley, and Viens · Handbook of High-Frequency Trading and Modeling in Finance
James, Marsh, and Sarno · Handbook of Exchange Rates
Peters and Shevchenko · Advances in Heavy Tailed Risk Modeling: A Handbook of Operational Risk
Viens, Mariani, and Florescu · Handbook of Modeling High-Frequency Data in Finance
Szylar · *Handbook of Market Risk*
Veronesi · *Handbook of Fixed-Income Securities*

**Forthcoming Wiley Handbooks in Financial Engineering and Econometrics**

Bali and Engle · *Handbook of Asset Pricing*
Chacko · *Handbook of Credit and Interest Rate Derivatives*
Jacquier · *Handbook of Econometric Methods for Finance: Bayesian and Classical Perspectives*
Longin · *Handbook of Extreme Value Theory and Its Applications to Finance and Insurance*
Starer · *Handbook of Equity Portfolio Management: Theory and Practice*
Szylar · *Handbook of Hedge Fund Risk Management and Performance: In a Challenging Regulatory Environment*
Szylar · *Handbook of Macroeconomic Investing*