## Index

### A

- Accounting 405–6
- Accrual accounting 405
- Actual P&L 337
- Aggregation risk 323, 355, 403, 422–4
- Alpha model 311
- Alpha strategies 7
- Antithetic variance reduction 207–9
- Apple 183
- Archimedean copulas 229
- Asymmetric volatility clustering  see GARCH model
- At-the-money (ATM) volatility 252, 306
- Auditing 408
- Autocorrelation 61–2, 138, 218, 292, 319

### B

- Backtesting 312, 313, 322, 332–55
  - banking regulations 335–7, 404
  - basic methodology 332–5
  - coverage tests 337–40
  - ETL 344–5
  - regression-based 341–2
  - volatility clustering, effect on 342–4
- Banking book 406
- Banking regulations 6, 14
  - Basel Accords 404–5
  - incremental risk charge 412–16
  - internal models 408–11
  - standardized rules 411–12
  - stress testing 378–84
- Bank insolvency 364–6
- Bank for International Settlements 404
- Banks
  - accounting framework 405–6
  - capital requirements 403–16
  - Citigroup 183
  - economic capital 416–33
  - market risk requirement 406–8
  - Northern Rock 421
- Base case scenarios 360
- Basel Accords 404–5
- Bayesian VaR 375–8, 399
- Bayes’ rule 375
- Behavioural models 232
- Beliefs 375
- Benchmark VaR 34–5, 48
- Bernoulli process 334
- Bias 206, 366
- Bias statistics 345–8
- Bid–ask spread 392
- Black–Scholes–Merton formula 265
- Bootstrap simulation 345

### C

- Candidate portfolio 332
- Capital allocation 316, 401–35
- Capitalization 403, 417
- Cash flow
  - historical VaR 176–9, 190–2
  - linear VaR 67–78
- Cash-flow maps 29, 76
  - interest rate sensitive portfolios 119
  - model risk 313–23
  - PCA 81–5
- Cash-flow portfolios 69, 202, 236–9
Cash positions 86–7
CDO (Collateralized debt obligations) xxx–xxxiv, 421
CDS (Credit default swap) xxvi, 135
Chicago Mercantile Exchange 357
Cholesky matrix 180, 213, 226–7
Cleaned P&L 337
Closeness (matrix norm) 389
Cognitive biases 366
Coherent risk metrics 3, 38–41
Collateralized debt obligations (CDO) xxx–xxxiv, 421
Commodity futures 158
   normal linear VaR 55, 103–6, 139
   scenario-based VaR 369–71
Commodity portfolios 72
Commodity VaR 32, 64
Common trend 231
Compound distribution scenario 360, 367, 374
Compound distribution scenario VaR 371–5
Conditional coverage tests 337
Conditional distributions 201, 367
Conditional marginals 242
Conditional probability 376
Conditional scenarios 364
Conditional VaR, see Expected tail loss
Conditional volatility, see GARCH model
Confidence level 13
Congruence 203
Cooke ratio 407
Copula VaR, 236–9
Copulas 1, 225, 229, 242
   Monte Carlo VaR for cash-flow portfolios 236–9
Core capital 407
Cornish–Fisher approximation 144, 170–2, 199, 261, 322
Correlation clustering 202, 242–4, 245
Correlation matrix 229, 231, 389–90
Cost accounting 405
Cost of capital coefficient 427
Cost of risk capital 421
Covariance matrix 54, 68, 85, 119, 153, 231, 293
Covariance VaR model 41
Coverage tests 337–40
Crack spread futures 192–4
Crash market 240
Credit crunch xxx–xxxiv, 264
Credit default swap (CDS) xxvi, 135
Credit rating 420
Credit risk factors 359
Credit spreads 53, 55, 60, 135–40, 231
Credit spread VaR 64, 75–8, 135–8, 368–9
Cross-gamma effects 305
Crude oil futures 192, 280–2, 302, 307
Currency 215, 411
   portfolios 60, 241–4
   volatility 158–63, 235
D
   Data frequency
      Historical simulation 145
   DAX 30 97, 150, 276
   Default intensities 359
   Delta approximation to option VaR 257–59
   Delta effect 252–3
   Delta–gamma approximation 250
   Delta–gamma VaR approximation 261–2
   Delta–gamma–vega approximation 252
   Monte Carlo VaR 298–9
   Delta–normal VaR 257–59, 308
   Dimension reduction 79, 85, 237, 302–8
   Discounted P&L 15, 29
   Discounting effect on VaR 23–5
   Distribution aggregation 420
   Distribution forecasts 348–51
   Distribution scenarios 358, 360, 361–2, 366–7, 379, 399
   DJIA (Dow Jones Industrial Average) 36
   Domestic stock portfolios
      systematic linear VaR 87–90
      systematic historical VaR 179–85
   Dow Jones Industrial Average (DJIA) 36
   Downside risk metrics 9–13
   Drift adjustment 58
   Dynamically hedged option portfolios 272–3
   Dynamic VaR 21, 247, 254–7, 267–8, 309
E
   Economic capital (EC) 8, 416–33
      aggregation 422–4
      allocation 416–33
      banking 421
      measurement 416–20
      minimum capital requirement 419–20
      model 402
      optimal allocation 430–3
   Economic value 405
   Eligible capital 407
Index

F

Factor push stress testing 363, 382–3
Fair value accounting 405
Faure sequences 206
Filtered historical simulation (FHS) 143, 163–5, 199, 234, 397
Financial risk factors 359–67
Foreign exchange rates 26
Forex 26, 72, 93, 215
Forex VaR 32, 64, 95–7, 185–94, 200
Frobenius norm 389
FTSE 100 95, 101–3, 115, 125–6, 149, 185–90
Funded activities 428
Funding liquidity risk 392

G

Gamma effect 250–2, 255, 256, 268, 290–2, 299, 303, 308
GARCH model 54, 61, 159
filtered historical simulation 163–5
Monte Carlo VaR 218–23, 242–4, 294–6
option VaR 294–6
Gasoline futures VaR 192–4
Gaussian copula 229
Gaussian kernel 144, 168
Generalized autoregressive conditional heteroscedasticity, see GARCH model
Generalized extreme value (GEV) 167
Generalized Pareto distribution (GPD) 167, 199
General risk 434
General risk charge (GRC) 407, 409–11
GEV (Generalized extreme value) 167
Ghost features 20, 156
Gold 411
GPD (Generalized Pareto distribution) 167, 199
Gradient vector 33, 66–7, 73–4, 76–8, 95–6, 99, 190
GRC (General risk charge) 407, 409–10
Greens approximation 248, 249, 273–8, 310

H

Heating oil futures VaR 192
Herd behaviour 381
Historical accounting 405
Historical ETL 195–8
delta-hedged option 269–71
disaggregation 197–8
Historical scenarios 358, 360, 361–2, 401
Historical simulation 141–4, 198–200
dynamic VaR estimation 248
multi-step 151–2

Historical VaR 3, 43–4, 46, 50, 51, 141–4, 175–94, 244, 309
accuracy 152–65
case study 153–6
cash flows 176–9
crack spread futures 192–4
data frequency 145–6
definition 144
delta-hedged option 269–71
energy options trading book 280–2
ETL 144, 195–8
exact revaluation 263–72
Greens approximation 274–7
international stock portfolios 185–90
linear portfolios 175–94
marginal VaR 186, 190
option portfolios 262–82
overlapping data 323
path-dependent options 278–80
precision 165–75
sample size 145–6, 155
scaling 146–51
specific returns 184–5
square-root scaling, errors from 151
systematic VaR 175–94
volatility adjustment 153, 158–63, 180

Holdings 20, 57
Homogeneity 39
Horizontal disallowance 412
Hyperbolic sine function 172
Hypercube 209
Hypothetical covariance matrices 388–90
Hypothetical distribution scenario 364
Hypothetical scenarios 358, 359, 360, 362–6, 402

Incremental VaR 3, 32–3, 56, 139
approximating 70–2
cash flow 70–2
equity 66–7

Independence of exceedances 337
Independence test 339–40
In the money (ITM) 279
Insolvency 14, 418
Intelligent aggregation 420
Interest rates 53, 176–7, 231
PCA 79–85, 237
scenarios for 368–9
Interest rate sensitive securities 72
Interest rate swaps 429
Interest rate term structures 231
Interest rate VaR 32, 64, 85, 199
equity portfolios 100
forex exposure 100
international bond 190–2
vertex choice 314–16
Internal models 434
Internal MRC 414–16
International bond position 190–4
International commodity portfolios 72
International equity portfolios 101–3
International stock portfolios 185–90
Inverse marginal distribution function 229
Investor confidence 421
IRC (Incremental risk charge) 403, 407, 413–16, 434
ITM (In the money) 279
iTraxx Europe index 135–6, 140

J
Johnson SU distribution 144, 172–5, 199, 261, 300
Johnson SU VaR 174–5
Junk bonds 359

K
Kernel fitting 165–7
Kurtosis 106–7, 166, 242

L
Latin hypercube sampling 210
Leptokurtosis 106–7, 242
Leverage effect 160
LIBOR rates 53, 55, 67, 75
Likelihood ratio backtest 351
Linear congruential generator 203, 245
Linear portfolio 4
  historical VaR 150–1, 175–94
  historical ETL 195–8
  mixture VaR 111–20
  mixture ETL 132–5
  Monte Carlo VaR 234–44
  normal linear VaR 42, 56–106
  normal linear ETL 129–30
  Student t VaR 106–11
  Student t ETL 130–2
Liquidity 14, 359, 381, 384, 399
  Liquidity horizon 413
  Liquidity risk 392, 420
  Local maximum 260
  Lognormal kernel 166
  Low discrepancy sequences 201, 204–6
  Lower partial moment (LPM) 9–11

M
  Marginal VaR 3, 32–3, 48, 54–5, 64, 66–7
    approximating 70–2
    cash flows 73–4
    commodities 105–6
    credit spread 77–8
    equity 66–7, 95–7, 99
    forex 96–7, 99
    historical simulation 186–90
  Margins 358
  Market crash scenario VaR 372–3
  Market depth 381
  Market discipline 406
  Market impact 392
  Market regimes 111
  Market risk regulatory framework 406–8
  Market Risk Amendment (1996) 379, 388, 403
  Market risk capital charge (MRC) 407, 414–16
  Market spread 392
  Marking to model xxx, xxxv, 403, 405
  Markov switching GARCH 223
  Matrix norm 389
  Maturity ladder 412
  Maximum likelihood estimation (MLE) 109
  Maximum loss 401
  MBS (Mortgage backed securities) 421
  Mean reversion 201, 218–23, 248
  Mersenne prime 204
  Mesokurtosis 178
  Method of moments 109, 114
  Minimum capital requirement 419–20
  Minimum solvency ratio 407, 434
  Mixing law 114
  Mixture distributions 111–12
  Mixture linear VaR 113, 115–18
  Mixture parameter estimation 114–15
  MLE (Maximum likelihood estimation) 109
  Model risk 135, 202, 312, 316–17, 354, 403
  Model validation 332–53
    backtesting guidelines 335–7
    backtesting methodology 332–5
    bias statistics 345–8
    coverage tests 337–40
    distribution forecasts 348–51
    ETL forecasts 345
    regression 340–4
  Monotonic transformation 38, 186
  Monte Carlo credit spread VaR 236–8
  Monte Carlo interest rate VaR 238–9
  Monte Carlo simulations
    path dependency 292–6
    static VaR 255
  Monte Carlo VaR 3, 44–5, 46–7, 51, 141,
    201–2, 214–15, 245, 309
    behavioural models 232
    copulas 229–30
    delta–gamma–vega mapping 298–9
    energy options 302–7
    exact revaluation 283–6
    linear portfolios 233–44
    low discrepancy sequences 204–6
    multivariate delta–gamma–vega mapping 299–300
    multivariate delta–gamma–vega mapping
      300–1
    multivariate distribution 213
    multivariate normal 227–8
    multivariate student t 228–9
    non-linear, non-normal 289–90
    option portfolios 282–307
    path-dependent option 295–6
    PCA 305
    pseudo-random number generation 203–4
    regime switching models 223–5
    short strangle position 296–8
    univariate distributions 211–13
    variance reduction 206–10
    volatility clustering 218–23
  Mortgage backed securities (MBS) 421
  Moving average models 54
  MRC (Market risk capital charge) 407, 414–16
  Multi-step historical simulation 278
Multi-step Monte Carlo 201, 215–18, 244, 293
asymmetric GARCH volatility 221–3
EWMA volatility 218–20
Multivariate delta–gamma approximation 250, 251
Multivariate delta–gamma–vega approximation 300
Multivariate distribution 213, 226–30
Multivariate normal distribution 1, 53, 226, 228
Multivariate normal mixture distribution 202, 235
Multivariate student $t$ 227–8, 287

N
Natural gas futures VaR 104
Net asset value 417
Non-linearity in risk factor dependence 287–90
Non-normality in risk factors 287–90
Normal copula 229
Normal distribution 42, 56, 138, 227, 320, 367–71

Normal linear VaR 3, 41–2, 45–6, 51, 56–67
bias statistics 345–8
cash-flow maps 67–78
commodity futures 103–6
certainty intervals 325–8
credit spread 75–8, 135–8
equity 27–8, 85–103
ETL 129–30
formula 18–20, 56–60
interest rate 29–30, 67–8, 72–4
stock portfolios 85–92
Normal mixture ETL 133
Normal mixture risk factor VaR 119–20
Normal mixture scenario VaR 373–5
Normal mixture VaR 115–16
Northern Rock 421
NYMEX futures 103

O
Off balance sheet instruments 406
OLS (Ordinary least squares) 316
Operational risk factors 359
Option portfolios 307
delta effect 252–3
dynamically hedged 272–3
gamma effect 250–1
historical VaR 263–82
Monte Carlo VaR 282–307
P&L 260
rho effect 253–4
risk factors 250–7, 308
theta effect 253–4
VaR 247–308
vega effect 252–3
Option price 217
Option pricing theory 257
Ordinary least squares (OLS) 316
OTC trades 135, 403
Out-of-sample diagnostic analysis 312
Over-the-counter (OTC) trades 135, 403
Overlapping data 151–2, 323, 336

P
Parametric linear VaR 53–140, 121–8, 324–9
Parametric simulation 248
Pareto distribution 144, 167, 199
Path dependency 292–6
Path-dependent options 278–80
PCA (Principal component analysis) 55, 79, 81–5, 140, 230–1
crude oil futures 304–6
interest rates 235
stress tests 359, 390–2, 399
Portfolio management
diversification 89–90
risk adjusted performance measures 23–4
risk measurement 6–7
VaR 20–1, 48
Portfolio sensitivity analysis 380
Portfolio theory 430
Posterior distribution 375–8
Power law scale exponents 143, 146–7
Present value of basis point (PV01), see PV01
Price beta mapping 250–1
Price process 217
Price-quantity impact 395–6
Price risk 271
Price sensitivities 2
Price-volatility relationship 232, 233, 253, 295
Pricing model 403
Primitive roots 204
Principal component analysis (PCA) 55, 79, 81–5, 140, 230–1
crude oil futures 304–6
interest rates 235
stress tests 359, 390–2, 399
Index

Principal component risk factors 202
Principal component stress tests 391–2
Prior density 376
Prior distribution 375
Probability 364, 375, 379, 399
Probability distributions 366–7
Probability weights 157
Profit and loss (P&L) actual 336–7
                   cleaned 337
                   discounted 15, 29
                   funded activities 428
                   option portfolios 259–60
                   Taylor expansions 255
                   uncertainty 1
                   VaR estimation 13–20
Pseudo-random numbers 201, 203–4
Public disclosure 406
PV01 (Present value of basis point) 29, 53, 55, 57, 63, 65, 68–83, 100, 102, 176–7, 179

Q
Quantile risk metrics 11–13, 48
Quantiles 32, 165, 186
                   confidence levels 330–2
Quanto correlation 93
Quasi Monte Carlo methods 201

R
RAPM (Risk adjusted performance measure) 421, 424–30, 431
RAROC (Risk adjusted return on capital) 427, 430–1, 434
RORAC (Return on risk adjusted capital) 425–9
Rating agencies 421
Realized P&L 336–7
Real-time VaR calculations 249
Rebalancing assumption 3, 20, 150, 254–7
Reference volatility 252
Regression 340–4
Regulatory capital 401, 403–16
Regulatory matrix 126
Resolution methods 2, 311, 322–3
Return on risk adjusted capital (RORAC) 425–9
Reward to risk ratio 425
Rho effects 253–4
Risk adjusted performance measure (RAPM) 421, 424–30, 431
Risk adjusted return on capital (RAROC) 427, 430–1, 434
Risk aggregation 420, 422–4
Risk attribution 26
Risk budgeting 8, 421
Risk drivers 358, 364
Risk factor dependence 225–33
Risk factor mapping 26, 27, 43, 49, 182, 311, 314–19
Risk factor models 225–34, 287, 319–22
Risk factors 26, 202
                   dynamic 152, 215–25
                   iTraxx Europe index 135–6
                   multivariate distribution 311
                   option portfolios 250–7, 297
                   orthogonalizing 230–1
                   principal components as 79, 81–5, 140, 230–1
                   scale exponents 147–50
                   trust region 383
                   volatility as 252, 280–2, 287–307
Risk factor sensitivities 21, 300
                   see also Equity beta, PV01, Greeks
Risk factor volatility 6
Risk free condition 39
Risk horizon 7, 13–15, 420
Risk limits 5
Risk metrics 1, 38, 47–8
                   ETL defined 36, 345
                   downside 9–13
                   VaR defined 13–17
                   Quantiles 11–13
RiskMetrics™ 126–8, 344
Risk–return space 430
Rolling windows 332–3

S
S&P 500 153, 186, 385
                   EWMA 123
                   filtered historical simulation VaR 163–5
                   GARCH parameters 160
                   historical VaR 154
                   moments 115
                   normal linear VaR 155
RiskMetrics™ VaR and ETL 343–7
VaR comparison 45–7
volatility adjusted VaR 159–62, 166
volatility index 149, 288–9, 300
Sample likelihood 376
Sample size 145, 155–6, 316
Sampling error 312, 313

estimation risk 329, 355
Sampling methods 203–11, 245
Scale exponent 143, 146, 200

major risk factors 147–50
Scaling VaR
different risk horizons 323–4, 357
Scenario analysis 357–78, 410
Scenario VaR 367–78, 399
Semi-standard deviation 9–10
Semi-variance 9
Sensitivity analysis 358
SER (Standardized exceedance residuals) 345, 346
Sharpe ratio 430
Shocks 357
Short strangle position 296–7
Significance level 13
Silver futures VaR 105
Simulation errors 202, 206
Single case scenarios 358, 360
Six sigma event 382
Skewness 111–17, 137, 166, 242
Sobol sequences 206
Solvency condition 419
Solvency ratio 407
SPAN (Standard Portfolio Analysis of Risk) 358
Specific risk charge (SRC) 407, 411, 434
Specific VaR 27, 31, 48, 54

empirical estimation 90–1
EWMA 91–2
historical simulation of 199
stock portfolio 87–90, 179–84
volatility adjustment of 182
Square-root-of-time rule 54, 146, 152
SRC (Specific risk charge) 407, 411, 434
Stable distribution 146
Stand-alone VaR 32–3, 48, 54, 56, 139, 199
bond positions 190–2
commodity futures 103–6, 199
normal linear 64–6
stock portfolios 93–100, 185–90
see also – credit spread VaR,
commodity VaR
equity VaR, forex VaR, interest rate VaR
Standardized exceedance residuals (SER) 345, 346
Standardized MRC 414–16
Standardized rules 411–12, 434
Standard normal density function 129
Standard normal distribution function 18
Standard Portfolio Analysis of Risk (SPAN) 358
Standard uniform distribution 209–10
Static portfolio 20–1
Static VaR 21, 247, 254–7, 267–8, 309
Statistical bootstrap 163
Stock portfolios
historical VaR 179–89
normal linear VaR 55, 85, 103
systematic VaR 88–90, 93–103, 179–85
Stratified sampling 209, 212
Stressed covariance matrices 384, 385–8
Stressed VaR 387–8, 393–4
Stress event 357
Stress scenario 357
Stress testing 27, 85, 357, 378–84, 390–2, 399
bias 366
factor push 363, 382–3
FHS 397–8
GARCH model 398
regulatory guidelines 379–81, 408
systemic risk 381
volatility clustering 397–9
worst case loss 381–4
Structured Monte Carlo 201
Student t copulas 229
Student t distributed ETL 131
Student t distributed portfolio returns 327–8
Student t distribution 53, 106, 138
Student t linear VaR 108–9
Student t mixture ETL 134
Sub-additivity 32, 39, 55
Sub-prime mortgage crisis xxx–xxxv, 264
Sub-supplementary capital 407
Supervisory review 406
Supplementary capital 407
Systemic return 63
Systemic risk 31
Systematic VaR 31–2, 48, 54
decomposition 93–103
domestic stock portfolios 87–90
equity factor model 88–90
historical simulation 179–92
normal linear 63–4
T
Tangency portfolio 430
Target return 10
Taylor approximation 308
Taylor expansions 248, 255
Theoretical P&L 337
Theta effect 254, 255, 256, 290–2, 308
Threshold return 9
Tilt component 231
Time aggregation 186, 200
Total capital charge 407
Total VaR 31
Tracking error 6, 35, 48
Trading book 406
Trust region 383
Tuenter’s algorithm 261, 262
U
UK bonds 79, 140, 176
Uncertainty 39, 359
Unconditional coverage tests 337, 338–9
Unconditional distributions 201
Undiversifiable risk 8
Unexpected return 5, 220
Unfunded activities 428
Unit interval 209
Unlisted securities 367
Unrealized P&L 15, 337
V
Value at risk (VaR) 1, 2, 48, 59–60, 137–8, 324–32, 333, 350
aggregation 63–6, 182–6
confidence level 13, 169
decomposition 30–3, 93–100, 189–92
defining 13–17
disaggregation 72–5, 90–1, 187
discounting, effect on 23
equally weighted averages 121
gamma effects 250–2, 308
mathematical definition 15–17
resolution method 322–3
risk attribution 26
risk factor mapping 26
risk horizon 13
risk metrics associated with VaR 33–41
scaling 21–3
significance level 13
Van der Corput sequences 206
Variance reduction 206–10, 245
Variance of simulation error 206
VaR, see Value at risk
Vega effect 252–3, 256, 268, 290–1
Vega mapping 299, 306–7
Vertex choice 314–16
Vertical disallowance 412
Volatility 1, 20, 80–1, 245, 312
adjustment 153, 158–63, 179, 182, 199
annualized 136
conditional 121
EWMA estimates 122
historical 121
mapping 252, 307
mean reversion 220
price relationship 232–3, 253, 295
risk factors 271, 306, 319
weighting 159
Volatility clustering 54, 141, 165, 201, 354, 399
coverage tests 342–4
GARCH models 54, 61, 159, 162–5, 218–25, 242–4, 294–5
Monte Carlo simulations 218–23
path dependency 292–6
stress testing 397–8
Volatility indices 150, 185–9, 252, 288–90
Volatility surface 308
Volatility term structures 231
W
Weak stochastic dominance 38
Worst case loss 357, 380, 381–4
Worst case scenarios 360, 361–2, 390
Z
Zero-coupon yield curves 26, 67–85, 140, 176–9, 236–9