Thierry Roncalli

Handbook of Financial Risk Management

Contents

Preface

Teaching risk management in finance

This book is a handbook for students of Master's in finance, who want to learn risk management. It corresponds to the lecture notes of my course "*Risk Management & Financial Regulation*" at the University of Paris Saclay. This title highlights the role of financial regulation. Indeed, it appears that financial regulation is an important component to understand the practice of risk management in finance. This is particularly true in the banking sector, but it is also valid in other financial sectors. At first sight, it may be curious to teach for example the standards developed by the Basel Committee. They are freely available and any student may consult them. However, the regulation is so complex and the documentation produced is so abundant that students (but also professionals) may be lost when they want to have an overview on a specific topic or seek particular information. Therefore, I consider that the primary role of a course in risk management is to understand in general terms the financial regulation and be able to navigate between the various regulatory standards. This is all the more important that financial regulation is everywhere since the 2008 Global Financial Crisis (GFC). Today, most of the resources of a risk management department within a bank are dedicated to the regulation, and this is also the case of big projects. Understanding risk management requires them to know the regulation. Nevertheless, teaching risk management cannot be limited to the study of the regulation. Another important component of risk management is risk measurement. This requires having a statistical model for calculating the probability of a loss. A brief review shows that there are many risk models from the simplest to the most complicated because there are many types of risk and many risk factors. Moreover, the modeling of risk factors is not an easy task and requires making assumptions, and the complexity of a model can increase with the likelihood of these assumptions[1]. Therefore, the second role of a course in risk management is to distinguish between the mathematical models of risk measurement and study those that are actually used by professionals. From an academic point of view, some models may appear to be outdated or old-fashioned. However, they can continue to be used by risk managers for many reasons: more robust, easier to calibrate, etc. For example, the most important risk measurement model is certainly the historical value-at-risk. This is why it is important to choose the right models to study. A handbook cannot be a comprehensive catalogue of risk management methods. But it must present the most frequently used models and the essential mathematical tools in order to help the Master student when he will be faced with reality and situations that will require a more complex modeling.

[1] However, a complex model does not mean that the assumptions are more realistic.

About this book

These lecture notes are divided into two parts. After an introductory chapter presenting the main concepts of risk management and an overview of the financial regulation, the first part is dedicated to the risk management in the banking sector and is made up of seven chapters: market risk, credit risk, counterparty credit risk, operational risk, liquidity risk, asset liability management risk and systemic risk. I begin with the market risk, because it allows to introduce naturally the concept of risk factor, describe what a risk measure is and define the risk allocation approach. For each chapter, I present the corresponding regulatory framework and the risk management tools. I continue with five chapters that are mainly focused on the banking sector. However, even if these six chapters are dedicated to the banking sector, these materials also establish the basics of risk management in other financial sectors. They are the common language that is shared by all risk managers in finance. This first part ends with a eighth chapter on systemic risk and shadow banking system. In particular, this chapter supplements the introductory chapter and shows that the risk regulation culture has affected the other non-banking financial sectors such as asset management, insurance, pension funds and market infrastructure. The second part of these lecture notes develops the mathematical and statistical tools used in risk management. It contains seven chapters: model risk of exotic derivatives, statistical inference and model estimation, copula functions, extreme value theory, Monte Carlo simulation, stress testing methods and credit scoring models. Each chapter of these lecture notes is extensively illustrated by numerical examples and contains also tutorial exercises. Finally, a technical appendix completes the lecture notes and contains some important elements on numerical analysis.

The writing of these lecture notes started in April 2015 and is the result of twenty years of academic courses. When I began to teach risk management, a large part of my course was dedicated to statistical tools. Over the years, financial regulation became however increasingly important. I am convinced that risk management is now mainly driven by the regulation, not by the progress of the mathematical models. The writing of this book has benefited from the existing materials of my French book called "*La Gestion des Risques Financiers*". Nevertheless, the structure of the two books is different, because my previous book only concerned market, credit and operational risk before Basel III. Some years ago, I decided to extend the course to other financial sectors, especially insurance, asset management and market infrastructure. In fact, it appears that the quantitative methods of risk management are the same across the different financial areas even if each sector presents its particular aspects. But they differ mainly by the regulation, not by the mathematical tools. The knowledge of the different regulations is not an easy task for students. However, it is necessary if one would like to understand what the role of risk management is in financial institutions in the present-day world. Moreover, reducing the practice of risk management to the assimilation of the regulation rules is not sufficient. The sound understanding of the financial products and the mathematical models are essential to know where the risks are. This is why some parts of this book can be difficult because risk management is today complex in finance. A companion book, which contains the solutions of the tutorial exercises, is available in order to facilitate learning and knowledge assimilation at the following internet web page:

`http://www.thierry-roncalli.com/RiskManagementBook.html`

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[2]In particular, the chapter dedicated to the ALM owes a great deal to the works of Paul Demey, Antoine Frachot and Gaël Riboulet while the chapter on credit scoring is influenced by the unpublished lecture notes of Pierre Georges and Etienne Marot.

List of Symbols and Notations

Symbol Description

$\times$	Arithmetic multiplication
$\cdot$	Scalar, vector and matrix multiplication
$*$	Convolution
$\circ$	Hadamard product: $(x \circ y)_i = x_i y_i$
$\otimes$	Kronecker product $A \otimes B$
$\lvert\mathcal{E}\rvert$	Cardinality of the set $\mathcal{E}$
$\prec$	Concordance ordering
$\langle x, x' \rangle$	Inner product of x and x'
$\mathbf{1}$	Vector of ones
$\mathbb{1}\{\mathcal{A}\}$	The indicator function is equal to 1 if $\mathcal{A}$ is true, 0 otherwise
$\mathbb{1}_{\mathcal{A}}\{x\}$	The characteristic function is equal to 1 if $x \in \mathcal{A}$, 0 otherwise
$\mathbf{0}$	Vector of zeros
$(A_{i,j})$	Matrix A with entry $A_{i,j}$ in row i and column j
A^{-1}	Inverse of the matrix A
$A^{1/2}$	Square root of the matrix A
$A^\top$	Transpose of the matrix A
A^+	Moore-Penrose pseudo-inverse of the matrix A
b	Vector of weights $(b_1, \ldots, b_n)$ for the benchmark b
$B_t(T)$	Price of the zero-coupon bond at time t for the maturity T
$B(t,T)$	Alternative form of $B_t(T)$
$\mathcal{B}(p)$	Bernoulli distribution with parameter p
$\mathcal{B}(n,p)$	Binomial distribution with parameter n and p
β_i	Beta of asset i with respect to portfolio w
$\beta_i(w)$	Another notation for the symbol β_i
$\beta(w \mid b)$	Beta of portfolio w when the benchmark is b
$\mathcal{B}(\alpha,\beta)$	Beta distribution with parameter α and β
$\mathfrak{B}(\alpha,\beta)$	Beta function defined as $\int_0^1 t^{\alpha-1}(1-t)^{\beta-1}\,\mathrm{d}t$
$\mathfrak{B}(x;\alpha,\beta)$	Incomplete beta function $\int_0^x t^{\alpha-1}(1-t)^{\beta-1}\,\mathrm{d}t$
$\boldsymbol{c}$	Coupon rate of the CDS premium leg
$\mathbb{C}$ (or ρ)	Correlation matrix
$\mathfrak{C}$	OTC contract
$\mathbf{C}(u_1,u_2)$	Copula function
$\mathcal{C}$	Set of copula functions
$\mathcal{C}(i)$	Mapping function
$\breve{\mathbf{C}}(u_1,u_2)$	Survival copula
$\mathbf{C}^-$	Fréchet lower bound copula
$\mathbf{C}^\perp$	Product copula
$\mathbf{C}^+$	Fréchet upper bound copula
$\boldsymbol{\mathcal{C}}_t$	Price of the call option at time t
$C(t_m)$	Coupon paid at time t_m
$\mathbb{C}_n(\rho)$	Constant correlation matrix of dimension n with $\rho_{i,j} = \rho$
$\mathrm{CE}(t_0)$	Current exposure at time t_0
$\mathrm{cov}(X)$	Covariance of the random vector X
$\chi^2(\nu)$	Chi-square distribution with ν degrees of freedom
D	Covariance matrix of idiosyncratic risks
$\mathcal{D}(t)$	Liquidity duration of the new production
$\mathcal{D}^\star(t)$	Liquidity duration of the production stock
$\mathbf{D}_k(x)$	Debye function
$\det(A)$	Determinant of the matrix A
$\mathrm{diag}\, v$	Diagonal matrix with elements $(v_1, \ldots, v_n)$
$\boldsymbol{\Delta}_t$	Delta of the option at time t
Δ_h	Difference operator $\Delta_h V_t = V_t - V_{t-h}$ with lag h

$\Delta\,\mathrm{CoVaR}_i$ Delta CoVaR of institution i
Δt_m Time interval $t_m = t_{m-1}$
$\delta_x(y)$ Dirac delta function
$\mathbf{e}_i$ The value of the vector is 1 for the row i and 0 elsewhere
$\mathbb{E}[X]$ Mathematical expectation of the random variable X
$\mathcal{E}(\lambda)$ Exponential probability distribution with parameter λ
$e(t)$ Potential future exposure at time t
$\mathrm{EE}(t)$ Expected exposure at time t
$\mathrm{EEE}(t)$ Effective expected exposure at time t
$\mathrm{EEPE}(0;t)$ Effective expected positive exposure for the time period $[0,t]$
$\mathrm{EnE}(t)$ Risk-neutral expected negative exposure at time t
$\mathrm{EpE}(t)$ Risk-neutral expected positive exposure at time t
$\mathrm{EPE}(0;t)$ Expected positive exposure for the time period $[0,t]$
$\mathrm{ES}_\alpha(w)$ Expected shortfall of portfolio w at the confidence level α
$\exp(A)$ Exponential of the matrix A
$f(x)$ Probability density function
$f_{i:n}(x)$ Probability density function of the order statistic $X_{i:n}$
$f_y(\lambda)$ Spectral density function of the stochastic process y_t
$\mathbf{F}(x)$ Cumulative distribution function
$\mathbf{F}_{i:n}(x)$ Cumulative distribution function of the order statistic $X_{i:n}$
$\mathbf{F}^{-1}(\alpha)$ Quantile function
$\mathbf{F}^{n\star}$ n-fold convolution of the probability distribution $\mathbf{F}$ with itself
$\mathcal{F}$ Vector of risk factors $(\mathcal{F}_1,\ldots,\mathcal{F}_m)$
$\mathcal{F}_j$ Risk factor j
$\mathcal{F}_t$ Filtration
$f_t(T)$ Instantaneous forward rate at time t for the maturity T
$f(t,T)$ Alternative form of $f_t(T)$
$F_t(T_1,T_2)$ Forward interest rate at time t for the period $[T_1,T_2]$
$F(t,T_1,T_2)$ Alternative form of $F_t(T_1,T_2)$
$\mathfrak{F}(\nu_1,\nu_2)$ Fisher-Snedecor distribution with parameters ν_1 and ν_2
$\mathcal{G}(p)$ Geometric distribution with parameter p
$\mathcal{G}(\alpha)$ Standard gamma distribution with parameter α
$\mathcal{G}(\alpha,\beta)$ Gamma distribution with parameters α and β
γ_1 Skewness
γ_2 Excess kurtosis
$\mathbf{\Gamma}_t$ Gamma of the option at time t
$\Gamma(\alpha)$ Gamma function defined as $\int_0^\infty t^{\alpha-1}e^{-t}\,\mathrm{d}t$
$\gamma(\alpha,x)$ Lower incomplete gamma function defined as $\int_0^x t^{\alpha-1}e^{-t}\,\mathrm{d}t$
$\Gamma(\alpha,x)$ Upper incomplete gamma function defined as $\int_x^\infty t^{\alpha-1}e^{-t}\,\mathrm{d}t$
$\mathcal{GEV}(\mu,\sigma,\xi)$ GEV distribution with parameters μ, σ and ξ
$\mathcal{GPD}(\sigma,\xi)$ Generalized Pareto distribution with parameters σ and ξ
h Holding period
$\boldsymbol{h}$ Kernel or smoothing parameter
$\mathbf{H}^-$ Lower half-space
$\mathbf{H}^+$ Upper half-space
$\mathcal{H}$ Hyperplane
$H(X)$ Shannon entropy of X
$H(X,Y)$ Cross-entropy of X and Y
$H(Y \mid X)$ Conditional entropy of Y with respect to X
i Asset (or component) i
I_n Identity matrix of dimension n
$I(X,Y)$ Mutual information of X and Y
$\mathcal{I}(\theta)$ Information matrix
$\mathcal{IB}(x;\alpha,\beta)$ Regularized incomplete beta function
$\mathcal{J}(\theta)$ Fisher information matrix
$\mathcal{K}$ Regulatory capital
$\mathcal{K}(x,x')$ Kernel function of x and x'
$\boldsymbol{\ell}(\theta)$ Log-likelihood function with θ the vector of parameters to estimate
$\boldsymbol{\ell}_t$ Log-likelihood function for the observation t
L Lag operator: $Ly_t = y_{t-1}$
L or $L(w)$ Loss of portfolio w
$\mathcal{L}(x;\lambda)$ Lagrange function, whose Lagrange multiplier is λ
$\ln A$ Logarithm of the matrix A
$\mathcal{LG}(\alpha,\beta)$ Log-gamma distribution with parameters α and β
$\mathcal{LL}(\alpha,\beta)$ Log-logistic distribution with parameters α and β
$\mathcal{LN}(\mu,\sigma^2)$ Log-normal distribution with parameters μ and σ
λ Parameter of exponential survival times
$\lambda(t)$ Hazard function

λ^- Lower tail dependence
λ^+ Upper tail dependence
$\mathbf{\Lambda}(x)$ Gumbel distribution
$\Lambda(t)$ Markov generator
MDA $(\mathbf{G})$ Maximum domain of attraction of the extreme value distribution $\mathbf{G}$
MES_i Marginal expected shortfall of institution i
$\text{MPE}_\alpha(0;t)$ Maximum peak exposure for the time period $[0,t]$ with a confidence level α
$\mathcal{MR}_i$ Marginal risk of asset i
MtM Mark-to-market of the portfolio
μ Vector of expected returns $(\mu_1,\ldots,\mu_n)$
μ_i Expected return of asset i
μ_m Expected return of the market portfolio
$\hat{\mu}$ Empirical mean
$\mu(w)$ Expected return of portfolio w
$\mu(X)$ Mean of the random vector X
$\mu_m(X)$ m-th centered moment of the random vector X
$\mu'_m(X)$ m-th moment of the random vector X
$\mathcal{N}(\mu,\sigma^2)$ Normal distribution with mean μ and standard deviation σ
$\mathcal{N}(\mu,\Sigma)$ Multivariate normal distribution with mean μ and covariance matrix Σ
n_S Number of scenarios or simulations
$N(t)$ Poisson counting process for the time interval $[0,t]$
$N(t_1;t_2)$ Poisson counting process for the time interval $[t_1,t_2]$
$\mathcal{NB}(r,p)$ Negative binomial distribution with parameters r and p
Ω Covariance matrix of risk factors
P Markov transition matrix
$\mathbb{P}$ Historical probability measure
$P(\Sigma)$ Cholesky decomposition of Σ
$\mathcal{P}(\lambda)$ Poisson distribution with parameter λ
$p(k)$ Probability mass function of an integer-valued random variable
$\boldsymbol{\mathcal{P}}_t$ Price of the put option at time t
$\mathcal{P}(\alpha,x_-)$ Pareto distribution with parameters α and x_-
$\mathcal{P}(\alpha,\theta)$ Pareto distribution with parameters α and θ
$\text{PE}_\alpha(t)$ Peak exposure at time t with a confidence level α
$PV_t(\mathcal{L})$ Present value of the leg $\mathcal{L}$
Π or $\Pi(w)$ P&L of the portfolio w
$\phi(x)$ Probability density function of the standardized normal distribution
$\phi_2(x_1,x_2;\rho)$ Probability density function of the bivariate normal distribution with correlation ρ
$\phi_n(x;\Sigma)$ Probability density function of the multivariate normal distribution with covariance matrix Σ
$\Phi(x)$ Cumulative density function of the standardized normal distribution
$\Phi^{-1}(\alpha)$ Inverse of the cdf of the standardized normal distribution
$\Phi_2(x_1,x_2;\rho)$ Cumulative density function of the bivariate normal distribution with correlation ρ
$\Phi_n(x;\Sigma)$ Cumulative density function of the multivariate normal distribution with covariance matrix Σ
$\mathbf{\Phi}_\alpha(x)$ Fréchet distribution
$\mathbf{\Psi}_\alpha(x)$ Weibull distribution
$\varphi_X(t)$ Characteristic function of the random variable X
$q_\alpha(n_S)$ Integer part of αn_S
$q_{\bar{\alpha}}(n_S)$ Integer part of $(1-\alpha)n_S$
$\mathbb{Q}$ Risk-neutral probability measure
$\mathbb{Q}_T$ Forward probability measure
$\mathfrak{R}(t)$ Rating of the entity at time t
r Return of the risk-free asset
R Vector of asset returns $(R_1,\ldots,R_n)$
R_i Return of asset i
$R_{i,t}$ Return of asset i at time t
$R_{m,t}$ Return of the market portfolio at time t
$R(w)$ Return of portfolio w
$\mathcal{R}(w)$ Risk measure of portfolio w
$\mathcal{R}(L)$ Risk measure of loss L
$\mathcal{R}(\Pi)$ Risk measure of P&L Π
$R_t(T)$ Zero-coupon rate at time t for the maturity T
$\mathcal{RC}_i$ Risk contribution of asset i
$\mathcal{RC}_i^\star$ Relative risk contribution of asset i
$\boldsymbol{\mathcal{R}}$ Recovery rate
RPV_{01} Risky PV01

ρ (or $\mathbb{C}$) Correlation matrix of asset returns
$\rho_{i,j}$ Correlation between asset returns i and j
$\rho(x, y)$ Correlation between portfolios x and y
$\mathcal{s}$ Credit spread
$\mathbf{S}(x)$ Survival function
$\mathbb{S}$ Stress scenario
S_t Price of the underlying asset at time t
$\mathbf{S}_t(T)$ Survival function of T at time t
$\mathbf{S}(t, u)$ Amortization function of the new production
$\mathbf{S}^\star(t, u)$ Amortization function of the production stock
$\mathcal{S}(y_t)$ Stationary form of the process y_t
SES_i Systemic expected shortfall of institution i
$\mathcal{SN}(\xi, \Omega, \eta)$ Skew normal distribution
SRISK_i Systemic risk contribution of institution i
$\mathcal{ST}(\xi, \Omega, \eta, \nu)$ Skew t distribution
$SV_t(\mathcal{L})$ Stochastic discounted value of the leg $\mathcal{L}$
Σ Covariance matrix
$\hat{\Sigma}$ Empirical covariance matrix
σ_i Volatility of asset i
σ_m Volatility of the market portfolio
$\tilde{\sigma}_i$ Idiosyncratic volatility of asset i
$\hat{\sigma}$ Empirical volatility
$\sigma(w)$ Volatility of portfolio w
$\sigma(X)$ Standard deviation of the random variable X
t_ν Student's t distribution with ν degrees of freedom
$t_n(\Sigma, \nu)$ Multivariate Student's t distribution with ν degrees of freedom and covariance matrix Σ
$\mathbf{t}(x; \nu)$ Probability density function of the univariate t distribution with number of degrees of freedom ν
$\mathbf{t}_n(x; \Sigma, \nu)$ Probability density function of the multivariate t distribution with parameters Σ and ν
$\mathbf{t}_2(x_1, x_2; \rho, \nu)$ Probability density function of the bivariate t distribution with parameters ρ and ν
T Maturity date
$\mathbf{T}(x; \nu)$ Cumulative density function of the univariate t distribution with number of degrees of freedom ν
$\mathbf{T}^{-1}(\alpha; \nu)$ Inverse of the cdf of the Student's t distribution with ν the number of degrees of freedom
$\mathbf{T}_n(x; \Sigma, \nu)$ Cumulative density function of the multivariate t distribution with parameters Σ and ν
$\mathbf{T}_2(x_1, x_2; \rho, \nu)$ Cumulative density function of the bivariate t distribution with parameters ρ and ν
$\mathcal{T}$ return period
$\text{tr}(A)$ Trace of the matrix A
θ Vector of parameters
$\hat{\theta}$ Estimator of θ
$\boldsymbol{\Theta}_t$ Theta of the option at time t
$\boldsymbol{\tau}$ Default time
τ Time to maturity $T - t$
$\mathcal{U}_{[a,b]}$ Uniform distribution between a and b
$\text{var}(X)$ Variance of the random variable X
$\text{VaR}_\alpha(w)$ Value-at-risk of portfolio w at the confidence level α
$\boldsymbol{\upsilon}_t$ Vega of the option t
w Vector of weights $(w_1, \ldots, w_n)$ for portfolio w
w_i Weight of asset i in portfolio w
$W(t)$ Wiener process
X Random variable
x^+ Maximum value between x and 0
$X_{i:n}$ i^{th} order statistic of a sample of size n
y_t Discrete-time stochastic process
$\boldsymbol{y}$ Yield to maturity

Abbreviations

ABCP Asset-backed commercial paper
ABS Asset-backed security
ADF Augmented Dickey-Fuller unit root test
ADV Average daily volume
AER Annual equivalent rate
AFME Association for Financial Markets in Europe
AFS Available-for-sale
AIC Akaike information criterion
AIFMD Alternative investment fund managers directive

AIRB	Advanced internal ratings-based approach (credit risk)
ALCO	ALM committee
ALM	Asset liability management
AM-CVA	Advanced method (credit valuation adjustment)
AMA	Advanced measurement approaches (operational risk)
AMF	Autorité des Marchés Financiers
AMLF	ABCP money market mutual fund liquidity facility
AR	Autoregressive process
ARCH	Autoregressive conditional heteroskedasticity process
ARMA	Autoregressive moving average process
AT1	Additional tier 1
ATM	At-the-money (option)
BA-CVA	Basic approach (credit valuation adjustment)
BAC	Binary asset-or-nothing call option
BaFin	Bundesanstalt für Finanzdienstleistungsaufsicht
BAP	Binary asset-or-nothing put option
BCBS	Basel Committee on Banking Supervision
BCC	Binary cash-or-nothing call option
BCP	Binary cash-or-nothing put option
BCVA	Bilateral CVA
BD	Broker-dealer
BFGS	Broyden-Fletcher-Goldfarb-Shanno algorithm
BGD	Batch gradient descent
BIA	Basic indicator approach (operational risk)
BIS	Bank for International Settlement
BLUE	Best linear unbiased estimator
BoJ	Bank of Japan
BS	Black-Scholes model
BSM	Basic structural model
BUE	Best unbiased estimator
CAD	Capital adequacy directive
CAM	Constant amortization mortgage
CaR	Capital-at-risk
CB	Conservation buffer (CET1)
CBO	Collateralized bond obligation
CCB	Countercyclical capital buffer (CET1)
CCF	Credit conversion factor
CCP	Central counterparty clearing house
CCR	Counterparty credit risk
CDF	Cumulative distribution function
CDO	Collateralized debt obligation
CDS	Credit default swap
CDT	Credit default tranche
CDX	Credit default index
CE	Current exposure
CEM	Current exposure method (CCR)
CET1	Common equity tier 1
CFH	Cash flow hedge
CFI	Captive financial institution
CFO	Chief financial officer
CGFS	Committee on the Global Financial System
CIR	Cox-Ingersoll-Ross process
CISC	Constant inter-sector correlation model
CLO	Collateralized loan obligation
CMBS	Commercial mortgage-backed security
CMO	Collateralized mortgage obligation
CoVaR	Conditional value-at-risk
CP	Consultation paper
CPM	Constant payment mortgage
CPR	Conditional prepayment rate
CRA	Credit rating agency
CRD	Capital requirements directive
CRM	Comprehensive risk measure
CRO	Chief risk officer
CRR	Capital requirements regulation
CSRBB	Credit spread risk in the banking book
CVA	Credit valuation adjustment
DF	Dickey-Fuller unit root test
DFAST	Dodd-Frank Act stress testing
DFP	Davidon-Fletcher-Powell algorithm
DFT	Discrete Fourier transform
DGAP	Duration gap
DIC	Down-and-in call option
DIP	Down-and-in put option
DOC	Down-and-out call option
DOP	Down-and-out put option
DP	Dynamic programming
DRC	Default risk capital
DV01	Dollar value of a one basis point decrease in interest rates
DVA	Debit valuation adjustment
EAD	Exposure at default
EaR	Earnings-at-risk
EAR	Effective annual rate
EBA	European Banking Authority

ECB	European Central Bank
ECM	Error correction model
ECRA	External credit risk assessment
EE	Expected exposure
EEE	Effective expected exposure
EEPE	Effective expected positive exposure
EL	Expected loss
EMIR	European market infrastructure regulation
ENE	Expected negative exposure
EPE	Expected positive exposure
ERBA	External ratings-based approach
ES	Expected shortfall
ESMA	European Securities and Markets Authority
ETF	Exchange traded fund
EV	Economic value
EVaR	Economic value-at-risk
EVE	Economic value of equity
EVT	Extreme value theory
FASB	Financial Accounting Standards Board
FBA	Fall-back approach
FC	Finance company
FDIC	Federal Deposit Insurance Corporation
FDML	Frequency domain maximum likelihood
FFT	Fast Fourier transform
FHFA	Federal Housing Finance Agency
FICO	Fair Isaac Corporation score
FIR	Finite impulse response filter
FIRB	Foundation internal ratings-based approach (credit risk)
FNMA	Fannie Mae
FRA	Forward rate agreement
FRB	Board of Governors of the Federal Reserve System
FRTB	Fundamental review of the trading book
FSAP	Financial sector assessment program
FSB	Financial Stability Board
FtD	First-to-default swap
FTP	Funds transfer pricing
FV	Fair value
FVA	Founding valuation adjustment
FVH	Fair value hedge
FVOCI	Fair value through other comprehensive income
FVTPL	Fair value through profit and loss
FWN	Fractional white noise
GAAP	Generally accepted accounting principles (US)
GARCH	Generalized autoregressive conditional heteroskedasticity process
GBM	Geometric Brownian motion
GCV	Generalized cross-validation
GEV	Generalized extreme value distribution
GFC	Global Financial Crisis (2008)
GMM	Generalized method of moments
GMM	Gaussian mixture model
GNMA	Ginnie Mae
GPD	Generalized Pareto distribution
HELOC	Home equity line of credit
HF	Hedge fund
HFT	Held-for-trading
HJM	Heath-Jarrow-Morton model
HLA	Higher loss absorbency
HPP	Homogeneous Poisson process
HQLA	High-quality liquid assets
HTM	Held-to-maturity
HY	High yield entity
IAIS	International Association of Insurance Supervisors
IAS	International accounting standard
ICAAP	Internal capital adequacy assessment process
ICP	Insurance Core Principles
ICPF	Insurance companies and pension funds
IF	Investment fund
IFG	Infinitely fine-grained portfolio
IFRS	International financial reporting standard
IG	Investment grade entity
ILAAP	Internal liquidity adequacy assessment process
IMA	Internal model-based approach (market risk)
IMCC	Internally modelled capital charge (Basel III)
IMF	International Monetary Fund
IMM	Internal model method (counterparty credit risk)
IOSCO	International Organization of Securities Commissions
IPP	Integration by parts
IRB	Internal ratings-based approach (credit risk)

IRRBB	Interest rate risk in the banking book
IRC	Incremental risk charge
IRS	Interest rate swap
ISDA	International Swaps and Derivatives Association
ITM	In-the-money (option)
JTD	Jump-to-default
KF	Kalman filter
KIC	Knock-in call option
KIP	Knock-in put option
KOC	Knock-out call option
KOP	Knock-out put option
KPSS	Kwiatkowski-Phillips-Schmidt-Shin stationary test
KRI	Key risk indicator
L&R	Loans and receivables
LAD	Least absolute deviation estimator
LCG	Linear congruential generator
LCR	Liquidity coverage ratio
LDA	Loss distribution approach (operational risk)
LDA	Linear discriminant analysis
LDCE	Loss data collection exercise
LEE	Loan equivalent exposure
LGD	Loss given default
LL	Local level model
LLT	Local linear trend model
LMM	Libor market model
LTA	Look-through approach
LtD	Last-to-default swap
LTI	Linear time-invariant filter
LTV	Loan-to-value ratio
M	Effective maturity
MA	Moving average process
MBS	Mortgage-backed security
MC	Monte Carlo
MCMC	Markov chain Monte Carlo
MCR	Minimum capital requirement
MDA	Maximum domain of attraction
MDB	Multilateral development bank
MES	Marginal expected shortfall
MEV	Multivariate extreme value
MF	Mutual fund
MGD	Mini-batch gradient descent
MiFID	Markets in financial instruments directive
MiFIR	Markets in financial instruments regulation
ML	Maximum likelihood
MLE	Maximum likelihood estimator
MM	Method of moments
MMF	Money market fund
MPE	Maximum peak exposure
MPOR	Margin period of risk
MPP	Mixed Poisson process
MSMVE	Min-stable multivariate exponential distribution
MtM	Mark-to-market
MUNFI	Monitoring universe of non-bank financial intermediation
NHPP	Non-homogeneous Poisson process
NIH	Net investment hedge
NII	Net interest income
NIM	Net interest margin
NIS	Net interest spread
NMD	Non-maturity deposit
NMF	Non-negative matrix factorization
NN	Neural network
NOW	Negotiable order of withdrawal
NQD	Negative quadrant dependence
NSFR	Net stable funding ratio
OCC	Office of the Comptroller of the Currency
ODE	Ordinary differential equation
OFI	Other financial intermediary
OLS	Ordinary least squares
ORSA	Own risk and solvency assessment
OTC	Over-the-counter
OTM	Out-of-the-money (option)
OTS	Office of Thrift Supervision
OU	Ornstein-Uhlenbeck process
P&L	Profit and loss
PCA	Principal component analysis
PD	Probability of default
PDE	Partial differential equation
PDF	Probability density function
PE	Peak exposure
PFE	Potential future exposure
PLA	Profit and loss attribution (Basel III)
PMF	Probability mass function
POT	Peak over threshold
PP	Phillips-Perron unit root test
PQD	Positive quadrant dependence
PRESS	Predicted residual error sum of squares
PSE	Public sector entity
PV01	Present value of one bp
QDA	Quadratic discriminant analysis
QIS	Quantitative impact study
QMC	Quasi-Monte Carlo

QP Quadratic programming
RBC Risk-based capital (US insurance)
REIT Real estate investment trust
RFET Risk factor eligibility test (Basel III)
RLS Recursive least squares
RMBS Residential mortgage-backed security
ROE Return-on-equity
RRAO Residual risk add-on
RW Risk weight
RWA Risk-weighted assets
RWR Right way risk
SA Standardized approach (credit risk)
SA-CCR Standardized approach (counterparty credit risk)
SA-CVA Standardized approach (credit valuation adjustment)
SA-TB Standardized approach for the trading book (market risk)
SABR Stochastic alpha-beta-rho model
SBE Shadow banking entity
SBS Shadow banking system
SCR Solvency capital requirement
SCRA Standardized credit risk approach
SDE Stochastic differential equation
SES Systemic expected shortfall
SFT Securities financing transaction
SFV Structured finance vehicle
SGD Stochastic gradient descent
SIFI Systemically important financial institution
SIFMA Securities Industry and Financial Markets Association
SIR Sampling importance resampling
SIS Sequential importance sampling
SIV Structured investment vehicle
SLA Single loss approximation
SLN Shifted log-normal model
SM-CCR Standardized method (counterparty credit risk)
SM-CVA Standardized method (credit valuation adjustment)
SMC Sequential Monte Carlo
SME Small and medium-sized enterprises
SMM Standardized measurement method (market risk)
SMM Swap market model
SN Skew normal distribution
SPV Special purpose vehicle
SQP Sequential quadratic programming
SRC Specific risk charge
SREP Supervisory review and evaluation process
SRISK Systemic risk contribution
SRP Supervisory review process
SSFA Simplified supervisory formula approach
SSM Single supervisory mechanism
SSM State space model
ST Skew t distribution
STC Simple, transparent and comparable (securitization)
StD Second-to-default swap
SVaR Stressed value-at-risk
SVI Stochastic volatility inspired
SVM Support vector machine
T1 Tier 1
T2 Tier 2
TC Trust company
TDML Time domain maximum likelihood
TDRR Term deposit redemption ratio
TLAC Total loss absorbing capacity
TSA The standardized approach (operational risk)
UCITS Undertakings for collective investment in transferable securities (directive)
UCVA Unilateral CVA
UDVA Unilateral DVA
UL Unexpected loss
UIC Up-and-in call option
UIP Up-and-in put option
UOC Up-and-out call option
UOP Up-and-out put option
UVM Uncertain volatility model
VaR Value-at-risk
VAR Vector autoregressive process
VARMA Vector autoregressive moving average process
VECM Vector error correction model
WAL Weighted average life
WLS Weighted least squares
WWR Wrong way risk
XO Crossover (or sub-investment grade) entity

Other scientific conventions

YYYY-MM-DD	We use the international standard date notation where YYYY is the year in the usual Gregorian calendar, MM is the month of the year between 01 (January) and 12 (December), and DD is the day of the month between 01 and 31.
USD (or $)	US dollar
EUR (or €)	Euro
KUSD	One thousand dollars
$1 mn/bn/tn	One million/billion/trillion dollars
bp	Basis point or 0.01%

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