

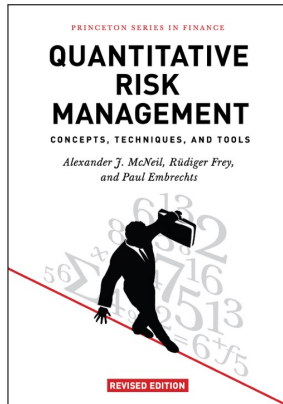
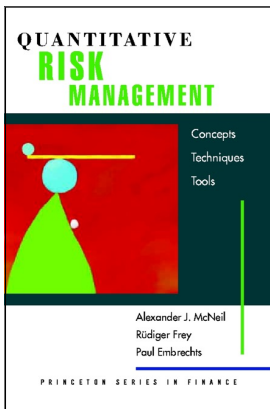
# Quantitative Risk Management

<http://www.qrmtutorial.org>

Last update: 2018-09-26

# Course information

- Website: <http://www.qrmtutorial.org>
- Book: A. J. McNeil, R. Frey, P. Embrechts  
*Quantitative Risk Management* (1st edition: 2005; revised edition: 2015)



# Overview

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# References

- Acharya, B. V., Cooley, V. V., Richardson, M., and Walter, I. (2009), Manufacturing tail risk: A perspective on the financial crisis of 2007–2009, *Foundations and Trends in Finance*, 4(4), 247–325.
- Artzner, P., Delbaen, F., Eber, J. M., and Heath, D. (1999), Coherent measures of risk, *Mathematical Finance*, 9, 203–228.
- Balkema, A. A. and de Haan, L. (1974), Residual life time at great age, *The Annals of Probability*, 2, 792–804.
- Basel Committee on Banking Supervision (2004), Basel II: International convergence of capital measurement and capital standards: A revised framework, Publication No. (107), Bank of International Settlements.
- Bellini, F. and Bignozzi, V. (2013), Elicitable risk measures, Working paper, available at SSRN: <http://ssrn.com/abstract=2334746>.

- Bernard, Carole, Jiang, Xiao, and Wang, Ruodu (2014), Risk aggregation with dependence uncertainty, *Insurance: Mathematics and Economics*, 54, 93–108.
- Berndt, A., Douglas, R., Duffie, D., Ferguson, F., and Schranz, D. (2008), Measuring Default Risk Premia from Default Swap rates and EDF's, Preprint, Tepper School of Business, Carnegie Mellon University.
- Bernstein, S. N. (1928), Sur les fonctions absolument monotones, *Acta Mathematica*, 52, 1–66.
- Black, F. and Scholes, M. (1973), The Pricing of Options and Corporate Liabilities, *Journal of Political Economy*, 81(3), 637–654.
- Brockwell, P. J. and Davis, R. A. (1991), Time Series: Theory and Methods, 2nd, New York: Springer.
- Chavez-Demoulin, V., Embrechts, P., and Hofert, M. (2014), An extreme value approach for modeling operational risk losses depending on covariates, *Journal of Risk and Insurance*, to appear.

- CME SPAN: Standard Portfolio Analysis of Risk (2010), [www.cmegroup.com/](http://www.cmegroup.com/)  
Chicago Mercantile Exchange.
- Cox, J. C., Ingersoll, J. E., and Ross, S. A. (1985), A Theory of the Term Structure of Interest Rates, *Econometrica. Journal of the Econometric Society*, 53(2), 385–407.
- Crosbie, P. J. and Bohn, J. R. (2002), Modeling default risk, Technical document, Moody's/KMV, New York.
- D'Agostino, R. B. and Stephens, M. A. (1986), Goodness-of-fit techniques, Dekker.
- Demarta, S. and McNeil, A. J. (2005), The  $t$  Copula and Related Copulas, *International Statistical Review*, 73(1), 111–129.
- Duffie, D. and Singleton, K. (1999), Modeling term structures of defaultable bonds, *Review of Financial Studies*, 12, 687–720.
- Embrechts, P., Klüppelberg, C., and Mikosch, T. (1997), Modelling Extremal Events for Insurance and Finance, Berlin: Springer.

- Embrechts, P., McNeil, A. J., and Straumann, D. (2002), Correlation and dependency in risk management: properties and pitfalls, *Risk Management: Value at Risk and Beyond*, ed. by M. Dempster, Cambridge: Cambridge University Press, 176–223.
- Embrechts, Paul and Hofert, Marius (2013a), A note on generalized inverses, *Mathematical Methods of Operations Research*, 77(3), 423–432, doi: <http://dx.doi.org/10.1007/s00186-013-0436-7>.
- Embrechts, Paul and Hofert, Marius (2013b), Statistical inference for copulas in high dimensions: A simulation study, *ASTIN Bulletin*, 43(2), 81–95, doi:10.1017/asb.2013.6.
- Fan, Y. and Patton, A.J. (2014), Copulas in econometrics, *Annual Review of Economics*, 6, 179–200.
- Fang, K.-T., Kotz, S., and Ng, K.-W. (1990), Symmetric Multivariate and Related Distributions, London: Chapman & Hall.
- Föllmer, H. and Schied, A. (2002), Convex measures of risk and trading constraints, *Finance and Stochastics*, 6, 429–447.



- Frey, R. and McNeil, A. J. (2001), Modelling dependent defaults, ETH E-Collection, No. 273, ETH Zurich.
- Frey, R., McNeil, A. J., and Nyfeler, M. (2001), Copulas and Credit Models, *Risk*, 14(10), 111–114.
- Frye, J. (2000), Depressing recoveries.
- Genest, C. and Rivest, L. (1993), Statistical inference procedures for bivariate Archimedean copulas, *Journal of the American Statistical Association*, 88, 1034–1043.
- Genest, C., Ghouli, K., and Rivest, L. (1995), A semi-parametric estimation procedure of dependence parameters in multivariate families of distributions, *Biometrika*, 82, 543–552.
- Genest, Christian and Werker, B. J. M. (2002), Conditions for the asymptotic semiparametric efficiency of an omnibus estimator of dependence parameters in copula models, *Distributions with Given Marginals and Statistical Modelling*, ed. by C. M. Cuadras, J. Fortiana, and J. A. Rodríguez-Lallena, Kluwer, Dordrecht, 103–112.

- Glasserman, P. and Li, J. (2005), Importance sampling for portfolio credit risk, *Management Science*, 51, 1643–1656.
- Gnedenko, B. V. (1943), Sur la distribution limite du terme maximum d'une série aléatoire, *Annals of Mathematics*, 44, 423–453.
- Gneiting, T. (2011), Making and Evaluating Point Forecasts, *Journal of the American Statistical Association*, 106(494), 746–762.
- Gregory, J. (2012), Counterparty Credit Risk and Credit Value Adjustment: A Continuing Challenge for Global Financial Markets, Chichester: John Wiley and Sons Ltd.
- Hamilton, R., Varma, S., Ou, S., and Cantor, R. (2005), Default and Recovery Rates of Corporate CBond Issuers, Technical report, Moody's Investor Service.
- Harrison, J. M. and Kreps, D. M. (1979), Martingales and Arbitrage in Multiperiod Securities Markets, *Journal of Economic Theory*, 20, 381–408.

- Harrison, J. M. and Pliska, S. R. (1981), Martingales and Stochastic Integrals in the Theory of Continuous Trading, *Stochastic Processes and their Applications*, 11, 215–260.
- Higham, Nick (2002), Computing the nearest correlation matrix – A problem from finance, *IMA Journal of Numerical Analysis*, 22, 329–343.
- Hofert, Marius and Scherer, Matthias (2011), CDO pricing with nested Archimedean copulas, *Quantitative Finance*, 11(5), 775–787, doi:<http://dx.doi.org/10.1080/14697680903508479>.
- Hofert, Marius, Memartoluie, Amir, Saunders, David, and Wirjanto, Tony (2015), Improved Algorithms for Computing Worst Value-at-Risk: Numerical Challenges and the Adaptive Rearrangement Algorithm.
- Huang, Jing-Zhi, Lanfranconi, M., Patel, N., and Pospisil, L. (2012), Modeling credit correlations: an overview of the Moody's Analytics GCorr Model, tech. rep., Moody's Analytics.

- Iman, R. L. and Conover, W. J. (1982), A distribution-free approach to inducing rank correlation among input variables, *Communications in Statistics – Simulation and Computation*, 11(3), 311–334.
- Jarrow, R. A. and Turnbull, S. M. (1995), Pricing Derivatives on Financial Securities Subject to Credit Risk, *The Journal of Finance*, 50(1), 53–85.
- Jaworski, P., Durante, F., Härdle, W. K., and Rychlik, T., eds. (2010), Copula Theory and Its Applications, vol. 198, Lecture Notes in Statistics – Proceedings, Springer.
- Joe, H. and Xu, J. J. (1996), The Estimation Method of Inference Functions for Margins for Multivariate Models, *Technical Report 166, Department of Statistics, University of British Columbia*.
- Joenssen, D. W. and Vogel, J. (2014), A power study of goodness-of-fit tests for multivariate normality implemented in R, *Journal of Statistical Computation and Simulation*, 84, 1055–1078.
- Karatzas, I. and Shreve, S. E. (1988), Brownian Motion and Stochastic Calculus, Berlin: Springer.

- Kim, G., Silvapulle, M. J., and Silvapulle, P. (2007), Comparison of semiparametric and parametric methods for estimating copulas, *Computational Statistics & Data Analysis*, 51, 2836–2850.
- Kimberling, C. H. (1974), A probabilistic interpretation of complete monotonicity, *Aequationes Mathematicae*, 10, 152–164.
- Kloman, H. F. (1990), Risk management agonists, *Risk Analysis*, 10, 201–205.
- Kolmogorov, A. N. (1933), *Grundbegriffe der Wahrscheinlichkeitsrechnung*, Berlin: Ergebnisse der Mathematik.
- Kou, S. and Peng, X. (2014), On the Measurement of Economic Tail Risk, <http://arxiv.org/abs/1401.4787> (2014-06-09).
- Lando, D. and Skodeberg, T. (2002), Analyzing Rating Transitions and Rating Drift with Continuous Observations, *Journal of Banking and Finance*, 26, 423–444.
- Leadbetter, M. R. (1991), On a basis for Peaks over Threshold modeling, *Statistics and Probability Letters*, 12, 357–362.

- Li, D. X. (2000), On Default Correlation: A Copula Function Approach, *The Journal of Fixed Income*, 9(4), 43–54.
- Li, X., Mikusiński, P., and Taylor, M. D. (2002), Some integration-by-parts formulas involving 2-copulas, *Distributions with Given Marginals and Statistical Modelling*, ed. by C. M. Cuadras, J. Fortiana, and J. A. Rodríguez-Lallena, Kluwer Academic Publishers, 153–159.
- Lindskog, F., McNeil, A. J., and Schmock, U. (2003), Kendall's tau for elliptical distributions, *Credit Risk: Measurement, Evaluation and Management*, ed. by G. Bol et al., Heidelberg: Physica-Verlag (Springer), 149–156.
- Lord Turner (2009), The Turner Review: A regulatory response to the global banking crisis, Financial Services Authority, London.
- Luo, X. and Shevchenko, P. V. (2010), The  $t$  copula with multiple parameters of degrees of freedom: Bivariate characteristics and application to risk management, *Quantitative Finance*, 10(9), 1039–1054.

- Mardia, K. V., Kent, J. T., and Bibby, J. M. (1979), Multivariate Analysis, London: Academic Press.
- Markowitz, H. M. (1952), Portfolio Selection, *The Journal of Finance*, 7, 77–91.
- Maronna, R. A. (1976), Robust M-Estimators of multivariate location and scatter, *The Annals of Statistics*, 4, 51–67.
- Marshall, A. W. and Olkin, I. (1988), Families of multivariate distributions, *Journal of the American Statistical Association*, 83, 834–841.
- Mashal, R. and Zeevi, A. (2002), Beyond correlation: Extreme co-movements between financial assets, Preprint, Columbia Business School.
- McNeil, A. J. and Frey, R. (2000), Estimation of tail-related risk measures for heteroscedastic financial time series: An extreme value approach, *Journal of Empirical Finance*, 7, 271–300.
- McNeil, A. J. and Nešlehová, J. (2009), Multivariate Archimedean copulas,  $d$ -monotone functions and  $\ell_1$ -norm symmetric distributions, *Annals of Statistics*, 37(5b), 3059–3097.

- McNeil, A. J., Frey, R., and Embrechts, P. (2005), *Quantitative Risk Management: Concepts, Techniques and Tools*, Princeton: Princeton University Press.
- McNeil, A. J., Frey, R., and Embrechts, P. (2015), *Quantitative Risk Management: Concepts, Techniques and Tools*, 2nd, Princeton: Princeton University Press.
- Nelson, C. R. and Siegel, A. F. (1987), Parsimonious modeling of yield curves, *Journal of Business*, 60, 473–489.
- Ou, S. (2013), Annual Default Study: Corporate Default and recovery Rates, 1920-2012, Technical document, Moody's Investor Service.
- Patton, A. J. (2006), Modelling asymmetric exchange rate dependence, *International Economic Review*, 47, 527–556.
- Patton, A.J. (2012), A review of copula models for economic time series, *Journal of Multivariate Analysis*, 110, 4–18.
- Petrov, V. V. (1995), *Limit Theorems of Probability Theory*, Oxford: Oxford University Press.



- Pickands, J. (1975), Statistical inference using extreme order statistics, *The Annals of Statistics*, 3, 119–131.
- Press, W. H., Teukolsky, S. A., Vetterling, W. T., and Flannery, B. P. (1992), *Numerical Recipes in C*, Cambridge: Cambridge University Press.
- Ressel, P. (2013), Homogeneous distributions – And a spectral representation of classical mean values and stable tail dependence functions, *Journal of Multivariate Analysis*, 117, 246–256.
- RiskMetrics (1996), RiskMetrics Technical Document, 3rd, J.P. Morgan, New York.
- Scarsini, M. (1984), On measures of concordance, *Stochastica*, 8(3), 201–218.
- Schmitz, V. (2003), *Copulas and Stochastic Processes*, PhD thesis, Rheinisch-Westfälische Technische Hochschule Aachen.
- Schönbucher, P. J. and Schubert, D. (2001), Copula-Dependent Default Risk in Intensity Models, [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=301968](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=301968) (2009-12-30).

- Shreve, S. E. (2008), Don't blame the quants, Available at [www.forbes.com/2008shreve.html](http://www.forbes.com/2008shreve.html).
- Sibuya, M. (1960), Bivariate extreme statistics, *Annals of the Institute of Statistical Mathematics*, 11, 195–210.
- Smith, R. L. (1985), Maximum likelihood estimation in a class of nonregular cases, *Biometrika*, 72, 67–92.
- Smith, R. L. (1987), Estimating Tails of Probability Distributions, *The Annals of Statistics*, 15, 1174–1207.
- Sun, Z., Munves, D., and Hamilton, D. (2012), Public Firm Expected Default Frequency (EDF) Credit Measures: Methodology, Performance and Model Extensions, Technical document, Moody's Analytics.
- Tsay, R. S. and Tiao, G. C. (1984), Consistent estimates of autoregressive parameters and extended sample autocorrelation function for stationary and nonstationary ARMA models, *Journal of the American Statistical Association*, 79, 84–96.

- Wang, Ruodu, Peng, Liang, and Yang, Jingping (2013), Bounds for the sum of dependent risks and worst Value-at-Risk with monotone marginal densities, *Finance and Stochastics*, 17(2), 395–417.
- Weber, S. (2006), Distributions-invariant risk measures, information, and dynamic consistency, *Mathematical Finance*, 16(2), 419–441.
- Ziegel, J. F. (2014), Coherence and elicibility, *Mathematical Finance*, to appear.