

Master's in Financial Engineering
Quantitative Risk and Portfolio Management

www.symmys.com > Teaching > Courses

Spring 2007, Tuesdays 7:10 pm – 9:40 pm, Room 303

Instructor: Attilio Meucci, Lehman Brothers, Inc., New York

The course covers all the aspects of quantitative portfolio management and risk management from the foundations to the most advanced developments.

- Multivariate statistics: multivariate distributions, copulas, location-dispersion ellipsoid, measures of co-dependence
- Estimation techniques: non-parametric, maximum-likelihood under thick tails, shrinkage, robust, Bayesian, extreme value theory
- Market modeling: quest for invariance in different markets, factor models, principal component analysis, FFT projection, delta-gamma & Monte Carlo pricing
- Portfolio evaluation: stochastic dominance, indices of satisfaction, utility, value at risk, expected shortfall, coherent measures
- Allocation frameworks: trading/prospect theory, total return management, benchmark allocation
- Portfolio optimization under estimation risk: Black-Litterman, Bayesian, cone programming and robust optimization

The course consists of theory and applications. The theory follows closely the adopted textbook. The applications are implemented in MATLAB[®] (standard and statistics toolboxes), displayed interactively during the course to support intuition and further analyzed by the students in their homework.

Prerequisites: multivariate calculus, linear algebra, basics of probability.
No knowledge of MATLAB is assumed.

Reading: *Risk and Asset Allocation* – Springer Quantitative Finance

Grading:

- 40% open-book final exam
 - 70% theory (pen & paper)
 - 30% practice (MATLAB)
- 50% home assignments
- 10% class participation

Lecture 1 – 1/16/07: introduction

Contents

- Announcements and course overview
- Introduction to MATLAB
 - Set path and work from command window
 - Generate scripts
 - Generate functions
 - Debug
 - Plot 2D (lines, scatter plots, histograms)
 - Plot 3D (surfaces, histograms)
- Representations of univariate distributions
 - Probability density function
 - Cumulative distribution function
 - Quantile
 - Characteristic function
- Monte Carlo simulations
 - Dirac delta and generalized functions
 - Glivenko-Cantelli theorem
 - Empirical distribution
 - Histograms and pdf
 - Empirical cdf
 - Empirical quantile by interpolation
- Distribution of transformations of random variables
 - Invertible transformations
 - Positive affine transformations
- Summary statistics:
 - Location: mode, median, expected value
 - Scale: modal dispersion, range, variance
 - Higher moments
- Taxonomy of univariate distributions
 - Uniform distribution
 - Normal/Cauchy/ Student t distributions
 - Gamma distribution
 - Lognormal distribution

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer:
Preface, 1.1->1.3, 4.2 p.178-179, B.1, B.2
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 1 – symmys.com

Lecture 2 – 1/23/07: multivariate statistics I

Contents

- Representations of multivariate distributions
 - Probability density function
 - Cumulative distribution function
 - Characteristic function
 - Simulations and empirical distribution
- Copula-marginal factorization
 - Marginal distributions
 - Grades
 - Copula representation via pdf and cdf
 - Copula representation via simulations
 - Co-monotonic random variables
- Conditional distribution
 - pdf representation
 - Bayes' rule
- Dependence and concordance summary statistics
 - Special copulas
 - Schweizer-Wolff measure
 - Kendall tau
 - Spearman rho
- Simulation of generic distributions via copula and quantile

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer:
2.1->2.3, 2.5
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 2 – symmys.com

Lecture 3 – 1/30/07: multivariate statistics II

Contents

- Shape summary statistics
 - Affine equivariance of shape statistics
 - Expected value – covariance
 - Mode – modal dispersion
- Location-dispersion ellipsoid
 - Spectral theorem
 - Statistical interpretation
- Pearson correlation: theory, practice and pitfalls
- Taxonomy of multivariate distributions
 - Normal distribution
 - Cauchy distribution
 - Student t distribution
 - Log-distributions
 - Uniform distribution
 - Wishart distribution

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer:
2.4->2.6, A.1-> A.5
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 3 – symmys.com

Lecture 4 – 2/6/07: market modeling I

Contents

- Special classes of multivariate distributions
 - Order statistics
 - Elliptical distributions
 - Stable distributions
 - Infinitely divisible distributions
- The quest for invariance
 - Equities: log-returns
 - Fixed-income: changes in yield to maturity
 - Derivatives: changes in at-the-money implied volatility

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer: 2.6.8->2.7; 3.1
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com: (!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 4 – symmys.com

Lecture 5 – 2/13/07: market modeling II

Contents

- Projection of invariants to the investment horizon
 - Convolution
 - Fourier transform
 - Analytical projection: characteristic function
 - Numerical projection: FFT
- Pricing of invariants at the investment horizon
 - Analytical: log-distributions for raw securities
 - Numerical: Monte Carlo
 - Approximate: theta-delta/vega-gamma
 - Approximate: carry-duration-convexity

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer: B3, B4, 3.2, 3.3
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com: (!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 5 – symmys.com

Lecture 6 – 2/20/07: market modeling III

Contents

- Dimension reduction, theory:
 - Multivariate market betas
 - Principal component analysis
- Dimension reduction, notable examples
 - Capital Asset Pricing Model
 - Arbitrage Pricing Theory
 - Fama-French factors
- Principal component analysis of the swap market
 - Level-slope-butterfly interpretation of the components
 - Continuum limit: Fourier basis and main frequencies

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer:
A.1->A.5, 3.4, 3.5
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 6 – symmys.com

Lecture 7 – 2/27/07: estimation I

Contents

- Estimators
 - general definitions
 - evaluation: bias, inefficiency, error
- Non-parametric estimators
 - Sample quantile and order statistics.
 - Sample mean/covariance and best-fitting ellipsoid
 - Sample factor loadings (betas) and OLS
- Maximum-likelihood estimators
 - Normal hypothesis: sample estimators
 - Non-normal hypothesis: outlier rejection

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer:
4.1, 4.2, 4.3
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 7 – symmys.com

Lecture 8 – 3/6/07: estimation II

Contents

- Shrinkage estimators
 - Stein mean
 - Ledoit-Wolf covariance
- Robust estimators
 - Assessing robustness: the influence function
 - Huber's "M" robust estimators: location, scatter and betas
 - Outlier detection and high-breakdown estimators
 - Minimum-volume ellipsoid and minimum-covariance determinant
- Missing data: the EM algorithm

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer: 4.4, 4.5, 4.6
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 8 – symmys.com

Lecture 9 – 3/20/07: estimation III

Contents

- Multivariate Bayesian estimation
 - Theoretical background
 - Analytical solutions: Normal-Inverse Wishart model
 - Numerical solutions: Monte Carlo Markov Chains

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer: 7.1->7.4
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 9 – symmys.com

Lecture 10 – 3/27/07: portfolio evaluation I

Contents

- Investor's objectives
 - Total return
 - Benchmark allocation
 - Net profits
- Global evaluation of a portfolio: stochastic dominance
- Summary evaluation of a portfolio: indices of satisfaction
 - Money-equivalence
 - Estimability
 - Sensibility
 - Consistence with stochastic dominance
 - Constancy
 - Positive homogeneity
 - Translation invariance
 - Sub- and super-additivity
 - Co-monotonic additivity
 - Concavity and convexity
 - Risk aversion, risk propensity and risk neutrality

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer:
5.1->5.3
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 10 – symmys.com

Lecture 11 – 4/3/07: portfolio evaluation II

Contents

- Expected utility and certainty-equivalent
- Quantiles and value at risk (VaR)
 - Properties
 - Analytical solutions
 - Numerical approximations
- Extreme value theory (EVT)
- Coherent measures of performance
 - Expected shortfall (ES) and conditional value at risk (CVaR)
 - Spectral measures of performance

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer: 5.4->5.6
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 11 – symmys.com

Lecture 12 – 4/10/07: portfolio optimization I

Contents

- Portfolio optimization theory
 - Investor's inputs: market, investment horizon, objectives and satisfaction
 - Market inputs: distribution of prices at the horizon, transaction costs
- Constrained optimization: computationally tractable problems
 - Linear and quadratic programming
 - Second order and semi-definite cone programming
- Two-step optimization
 - Analytical solutions
 - Numerical solutions

References: (!) = required, (?) = optional

- A. Meucci, *Risk and Asset Allocation* – Springer:
(!): 6.1->6.4, 6.7
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 12 – symmys.com

Lecture 13 – 4/17/07: portfolio optimization II

Contents

- Benchmark vs. total-return portfolio management
 - Mean-variance approximation
 - Analytical solutions in total-return coordinates
 - Analytical solutions in relative-return coordinates:
expected outperformance, tracking error, information ratio
- Pitfalls of the mean-variance approach
- Alternative optimization methods
- Allocations as decisions
 - Opportunity cost
 - Allocation decisions evaluated as estimators

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer:
6.5, 6.6, 8.1
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support materials for Lecture 13 – symmys.com

Lecture 14 – 4/24/07: portfolio optimization III

Contents

- Prior allocation
- Sample-based allocation
 - Error in satisfaction and constraint assessment
 - Leverage of estimation risk
- Bayesian allocation
 - Predictive return allocation
 - Classical-equivalent allocation
- Black-Litterman allocation
 - Views on market parameters
 - Views on the market realizations
- Copula-opinion pooling allocation
- Resampled allocation
- Robust allocation
 - Second-order cone programming problems
 - Semi-definite programming problems
- Robust Bayesian allocation

References: (!) = required, (?) = optional

- (!): A. Meucci, *Risk and Asset Allocation* – Springer:
8.2 -> 9.5
- A. Meucci, *Risk and Asset Allocation, Technical Appendices* – symmys.com:
(!): wherever cited above; (?): otherwise
- (!): Support material for Lecture 14 – symmys.com