NUMERICAL METHODS FOR FINANCE USING R

Instructors: *Dean FANTAZZINI* and *Igor GONCHARENKO*

- **Course Objectives**: The goal of this course is to introduce `R` programming for financial applications, focusing on Market Risk Management, Option Pricing and Portfolio Optimization. The course wants to bridge the gap between theory and practice and the applied aspects of financial models are emphasized throughout the course. The practical part contains many real-world cases for which `R` is an indispensible tool.
- **Prerequisites**: We assume that the students have a background in statistics and econometrics. An introduction to the basic concepts of financial modelling will be provided.
- **Method of Grading**: Each student should take a final written exam.
- **Total teaching hours**: 20 (Dean Fantazzini) + 12 (Igor Goncharenko).
- **Teaching methods**:
  - 8 teaching hours per week (2 meetings), conducted in the computer room;
  - Home assignments for each topic covering both theory and practice (not graded, but for self-study);
  - Teachers' consultations;
  - Self study conducted with the course materials and in a computer room, to solve the home assignments using `R`.
- **Teaching Language**: English
- **Timetable**: February

Course Outline - Dean FANTAZZINI

1. Introduction to R Programming [6 hours]

1.1 R essentials, packages and objects
1.2 Simple statistics, densities and distributions
1.3 Graphics
1.4 Working with time series
1.5 Writing basic R functions and debugging
1.6 Introduction to Optimization methods
1.7 Introduction to Maximum Likelihood estimation and Linear models

References

- W. N. Venables, D. M. Smith and the R Core Team, *An Introduction to R*, Official manual by the R-core team.

- Wurtz D., Lam L., Ellis A., Chalabi Y., *Basic R for Finance*, Rmetrics Association and Finance Online 2010: chapters 1-16.

- Joris Meys, Andrie de Vries, *R for Dummies*, Wiley 2012: chapters 1-14, 16-17.

- R *programming Wikibook*, available at http://en.wikibooks.org/wiki/R_Programming

2. R methods for Market Risk Management [6 hours]

2.1 Risk measures
2.2 Univariate GARCH models
2.3 Multivariate GARCH models
2.4 Value at Risk using GARCH models
2.5 Backtesting VaR estimates

References

- Danielsson, J., *Financial Risk Forecasting*, Wiley Finance, 2011: chapters 1-5, 8.

- McNeil, A., Frey, R., Embrechts, P., *Quantitative Risk Management: Concepts, Techniques, and Tools*, Princeton University Press, 2005: chapters 1-2, 4.

- Ruppert, D. (2010). *Statistics and Data Analysis for Financial Engineering*, Springer-Verlag: chapter 2,4-5, 18-19.

- Alexios Ghalanos , *Introduction to the* ***rugarch*** *package*, R vignette, 2013.

- Alexios Ghalanos , *The* ***rmgarch*** *models: Background and properties*, R vignette, 2013.

3. `R` methods for Option Pricing [4 hours]

3.1 Simulating a Brownian Motion
3.2 Monte Carlo Methods
3.3 Simulation of a Geometric Brownian Motion and Parameters Estimation
3.4 Option Pricing: Analytical Method and Monte Carlo Methods.
3.5 Implied Volatility and the Volatility Smile

References

- Stefano M. Iacus, *Option Pricing and Estimation of Financial Models with R*, Wiley 2011: chapters 4-6.

- Wurtz D., Lam L., Ellis A., Chalabi Y., *Basic R for Finance*, Rmetrics Association and Finance Online 2010: chapters 26-27, 29.

- Gilli M., Maringer D., Schumann E., *Numerical Methods and Optimization in Finance*, Academic press 2011: chapters 8.2.3, 9.3, 15.1 .

4. `R` methods for Portfolio Management [4 hours]

4.1 Introduction to Markowitz portfolio theory
4.2 Mean-Variance portfolio: implementation in `R`
4.3 Markowitz tangency portfolio and Long-only portfolio frontier
4.4 Portfolio management using the `R fPortfolio` package
4.5 Empirical Case study: Dow Jones index

References

- Wurtz D., Chalabi Y., Chen W., Ellis A., *Portfolio Optimization with R/Rmetrics*, Rmetrics Association and Finance Online 2010: chapters 11-20.

- Wurtz D., Lam L., Ellis A., Chalabi Y., *Basic R for Finance*, Rmetrics Association and Finance Online 2010: chapters 30-33.

- Gilli M., Maringer D., Schumann E., *Numerical Methods and Optimization in Finance*, Academic press 2011: chapters 13.1-13.2 .

Course Outline - Igor GONCHARENKO

1. Advanced `R` methods for Market Risk Management [4 hours]

We start with applications of market risk techniques for the computation of haircuts that are used by Equities and Fixed Income desks to structure collateral loans (REPO). Then we show how clearing houses, e.g. LCH, use statistical relationships between various risk factors for delta-risk netting of the diversified portfolio of different financial instruments with the same underlying asset. We discuss how to estimate inputs of such margining system for a portfolio of derivatives that are quoted in different currencies and has nontrivial term structure.

1.1 Computing market risk measures with `'PerformanceAnalytics'` package
1.2 The architecture of the portfolio margin calculator
1.3 Estimating inputs, e.g. scan-ranges and temporal spreads
1.4 Adding cross-currency risk

References

- Tsay R., *An Introduction to Analysis of Financial Data with* `R`, Wiley 2012

- Robert C., Casella R., *Introducing Monte Carlo Methods with* `R`, Springer 2010

- Cowpertwait P., Metcalfe A., *Introductory time series with* `R`, Springer 2009

- Choudhry M., *The REPO Handbook*, Butterworth-Heinemann 2010

2. Advanced `R` methods for Option Pricing and Derivatives Analysis [4 hours]

We show tools that derivatives trading desks use to identify PnL (Profit and Loss) opportunities, to analyze risks of derivatives portfolio, to evaluate collateral due to regulatory requirements, to hedge deltas and gammas. Then we discuss how exotic options, i.e. barrier and asian options, are priced and hedged using the volatility surface approach. Three models for the volatility surface will be considered: local vol, SABR, and Vanna-Volga since the majority of practitioners use one of these models.

2.1 Storing options data in `R`
2.2 Volatility surface construction and prediction
2.3 Interactive 2d PnL plots of options portfolio in R
2.4 FSA rules and regulatory capital
2.5 Strategies neutralizing greeks: Delta, Vega, Gamma, Vanna, Volga
2.6 Pricing with parametrical models: local vol, SABR, and Vanna-Volga

References

- Rebonatto R., *Volatility and correlation*, Wiley 2004: chapters 6, 7, 11 and 12

- Gatheral J., *The volatility surface*, Wiley 2006: chapters 7 and 9

- Sarkar D. *Multivariate Data Visualization with R*, Springer 2008

- *Package 'RQuantLib'*, CRAN, 2013.

- *Package 'quantmod'*, CRAN, 2013.

3. Statistical Arbitrage with R [4 hours]

We analyze cointegration based statistical arbitrage strategy for a basket of liquid stocks. Such strategies require high leverage to be economically attractive. Given a particular cointegration vector, we compute the worst-case scenario daily PnL and we infer the corresponding leverage.

3.1 Getting and storing the stocks data with R
3.2 Vector autoregression with R vars package
3.3 Computing cointegration relationaships with R urca package
3.4 Estimating market risk measures for the statistical arbitrage strategies

References

- Pfaff B., *Analysis of Integrated and Cointegrated Time Series with R*, Springer, 2008

- Varmuza K., Filzmoser P., *Introduction to Multivariate Statistical Analysis with R*, CRC Press, 2008

Table of topics by hours:

No.	Topics titles	Teaching hours
1.	Introduction to R Programming	6
2.	R methods for Market Risk Management	6
3.	R methods for Option Pricing	4
4.	R methods for Portfolio Management	4
5.	Advanced R methods for Market Risk Management	4
6.	Advanced R methods for Option Pricing and Derivatives Analysis	4
7.	Statistical Arbitrage with R	4
	Total:	32