FINANCE AND INSURANCE
https://web.uniroma1.it/memotef/en/finance-and-insurance-finass

Course Syllabus
Financial Optimization and Asset Management
I semester - Fall 2022

Instructor: Federica Ricca (federica.ricca@uniroma1.it)

Office: Room 148, first floor, Corridor B, Faculty of Economics

Office Hours (hours of teaching assistance)**:** Tuesday 12 a.m.

Office Phone: +39 0649766310

Class Hours (day, time, room): Tuesday and Friday 10-12 a.m., DIDALAB – first floor

Course website:
https://web.uniroma1.it/memotef/financial-optimization-and-asset-management-finass-cv-financial-risk-and-data-analysis-lingua

Moodle e-learning webpage:
https://elearning.uniroma1.it/course/view.php?id=13515

Textbooks

[a] G. Cornuéjols, J. Peña, R. Tütüncü, Optimization Methods in Finance, Cambridge University Press, 2018.

[b] P. Rardin, Optimization in Operations Research, Upper Saddle River, Prentice-Hall, 1998 (2017).

[c] F. Cesarone, Computational Finance MATLAB oriented modelling, Giappichelli Editore, 2020

[d] E. J. Elton, M. J. Gruber, Modern Portfolio Theory and investment analysis, John Wiley and Sons, 1995 (2014).

[e] G.L. Thompson, S. Thore, Computational Economics, The Scientific Press 1992.

Additional texts

W.L. Winston, Operations Research, Third Edition Duxbury Press 1997
W.L. Winston e S.C. Albright, Practical Management Science,
2nd Edition, Brooks/Cole Publishing, 2001.
S.A. Zenios, Practical Financial Optimization, Blackwell 2007.

Teacher's handouts The slides of the lectures are published in the **Moodle e-learning webpage** dedicated to the course: https://elearning.uniroma1.it/course/view.php?id=13515

Additional Materials

- Slides used during the classes and the additional materials are available at https://elearning.uniroma1.it/course/view.php?id=13515
- Financial time series (financial database DataStream)
- Matlab functions and scripts for financial optimization modeling and solution are available in Textbook **[c]**
- Campus licence for Matlab and Excel software can be downloaded at:

  https://www.uniroma1.it/it/pagina/software-gratuito (Italian)

  https://www.uniroma1.it/en/pagina/free-software-students (English)

Prerequisites

Students should know and master:
Basic algebra – equalities and inequalities – systems of linear equations – basics of Statistics and probability.

Final Exam

For students following the course's lessons:

- Project: developed in group and discussed collectively with the teacher (the project is assigned at the end of the course and it is valid for one year)
- Individual oral examination

For students who do not follow the course's lessons:

- Individual oral examination

Course Objectives

Students learn how to formulate mathematical models to tackle relevant finance and asset management problems, with a special focus on those related to Portfolio Selection. They are introduced to different quantitative analysis and decision tools, mainly based on Mathematical Programming, Networks and Optimization. They acquire the capacity of using, understanding, and developing computational tools suitable for the efficient solution of the models proposed.

The course is structured into 3 parts:
Part 1. **Optimization models and techniques**
Part 2. **Applications in finance**
Part 3. Computational Finance with Excel and Matlab (if time is enough)

Expected learning objectives and skills

- **Knowledge and understanding.** At the end of the course, students will have a sound knowledge of optimization theory and of the main algorithms to solve optimization problems. They will also know the main optimization models used in finance and particularly in Portfolio Selection and Asset Management.
- **Applying knowledge and understanding.** This course will enable students to address several practical problems in finance and asset management with the aid of quantitative models and with the use of computational tools for their solution. For each specific problem they will know which is the best fitting model and they will be able to evaluate the output solutions also under a multicriteria viewpoint.
- **Making judgements.** On the basis of the knowledge variety of models presented in the course and of the capacity of each of them to capture the essence of a problem, students will develop an attitude to critical thinking and rigorous reasoning, being aware of the relations between models and real problems to which they are applied. They will be able to structure a problem, identifying the fundamental elements that should be included in the model which represents it.
- **Communication skills.** To deal with decision problems via the application of quantitative models it is necessary to know a proper formal language. Students will be asked to discuss models and present the arguments of the course, also in a group collaboration. They will be stimulated by the teacher to write models in their algebraic form and to illustrate them orally. This is important for the student to become familiar with the use of the formal language, but also to reach the capacity of illustrating and explaining the models to every possible interlocutor, possibly using a non-technical language, but however precise and rigorous.
- **Learning skills.** During the course the students will be required to conduct autonomous researches, with possible support from the teacher when necessary, referring to the related literature and reading specific papers published in the scientific journals of the disciplinary field. Students will be subsequently capable to deepen and continue the studies in this field. More generally, they will acquire the capacity of performing bibliographic researches on a specific subject of their interest. This is also useful for the student for the future development of her/his master thesis.

Assignments and Assessment

During the course, students carry out a systematic job of supplementary activities on modelling and solving practical problems. Several different financial problems are formulated as optimization models and solved by using a suitable solver (Excel, Matlab, R, every year depending on the course development and on the students' skills and feedback).

Planning of the weekly course calendar

<table>
<tr><th>Week</th><th>Topics</th></tr>
<tr><td>1.</td><td>Introduction to optimization mathematical modelling: Formal approach for problem modelling and solution – Optimization and Mathematical Programming – Introductory examples – Basic notions and definitions – Practical exercises.

Suggested additional readings:
<table><tr><td>Theory</td><td>Teacher handouts and textbooks [a] Chapter 2 and [b] Chapter 1</td></tr><tr><td>Further readings and applications</td><td></td></tr></table></td></tr>
<tr><td>2.</td><td>Linear Programming financial applications examples: Fund allocation problem – Bond allocation – LP scalar and matrix form – LP equivalent transformations and reference forms – General classes of LP models: Resource allocation – Blending models.

Suggested additional readings:
<table><tr><td>Theory</td><td>Teacher handouts and textbook [a] Chapter 2 and [b] Chapter 4</td></tr><tr><td>Further readings and applications</td><td></td></tr></table></td></tr>
<tr><td>3.</td><td>Geometrical interpretation of a Linear Program and solution: Feasible region shape and optimal points characterization – Practical exercises.

Supplementary Lab activities: Introduction to the Microsoft Excel Solver tool – Solution of a LP – Exercises.

Suggested additional readings:
<table><tr><td>Theory</td><td>Teacher handouts and textbook [a] Chapter 2 and [b] Chapter 2</td></tr><tr><td>Further readings and applications</td><td></td></tr></table></td></tr>
<tr><td>4.</td><td>General classes of LP models: Equivalent systems – Standard Form (SF) and LP equivalent transformation into SF.
Multiperiod Models: Short-term financing problems – Cash-flow matching and BOND Dedicated portfolio selection – Practical exercises.

Suggested additional readings:
<table><tr><td>Theory</td><td>Teacher handouts and textbook [a] Chapter 2 and 3 and textbook [b] Chapter 5</td></tr><tr><td>Further readings and applications</td><td></td></tr></table></td></tr>
<tr><td>5.</td><td>Polyedra and vertices: LP Feasible region – Basic LP Theorems – description of the Simplex Algorithm and Interior point methods search – Examples.

Supplementary Lab activities: Introduction to Matlab. Practical solution of exercises with Excel.

Suggested additional readings:
<table><tr><td>Theory</td><td>Teacher handouts, Textbook [c], Chapter 1</td></tr><tr><td>Further readings and applications</td><td></td></tr></table></td></tr>
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6. **Duality in Linear Programming:** Primal-Dual Canonical pair – Dual model construction – Examples and special cases – Duality theorems – Practical exercises (computing the Dual of an LP).

Suggested additional readings:

Theory	**Teacher handouts and textbook [a] Chapter 2 and [b] Chapter 6**
Further readings and applications	

7. **LP Duality and Sensitivity analysis**: Shadow prices – (Reduced costs) – Example on the use of sensitivity analysis on the short-term cash flow model LP presented in Lect. 6
Supplementary Lab activities: Solution of the exercises assigned in the previous lessons. Upload of the Excel sheets for the solution – Practical exercises (Applying Sensitivity Analysis).

Supplementary Lab activities: Linear Programming with Matlab. Practical solution of exercises with Excel and Sensitivity Report.

Suggested additional readings:

Theory	**Teacher handouts and textbook [a] Chapter 3, Textbook [c], Chapters 1 and 3**
Further readings and applications	

8. **Integer and Mixed Integer Linear Programming:** Knapsack Model and Capital Budgeting Problems – Project Financing Problems. Logic decision variables and constraints – yes/no decision problems – Modeling fixed costs with 0/1 variables – Examples.

Supplementary Lab activities: Integer Programming with Matlab. Practical solution of exercises with Excel and Matlab.

Suggested additional readings:

Theory	**Teacher handouts textbooks [a] Chapter 8 and [b] Chapter 11**
Further readings and applications	

9. **Network models:** definitions and basic notions –The Transportation problem and its applications – Minimum Cost Flow Model (MCF) – MCF applications: transportation problem and Shortest path as MCF
Practical Applications: Financial Networks – Generalized MCF and application to a ALM problem.

Non linear and Quadratic models optimization: definition and matrix form – particular QPs – Global and local optima – Intuition of optimization procedures for LP and NLP in the continuous feasible set – Convex sets, convex and concave functions– Quadratic case.

Suggested additional readings:

Theory	**Teacher handouts textbook [a] Chapter 5 and [b] Chapter 10**
Further readings and applications	**[e] Chapter 21 (Cash management problems)**

10. **Portfolio selection in the risk-return approach:** Markowitz's Modern Portfolio Theory for diversifying risk – Modeling uncertainty for decisions in the risky assets market – Examples – Basic assumptions in portfolio theory, linear prices and mean-variance approach – Efficient Frontier in a market with n assets.

Practical Applications: Presentation and discussion of the Fama's experiment and illustration of Realistic Examples.

Suggested additional readings:

Theory	**Teacher handouts and textbook [a] Chapter 6, Textbook [d] Chapters 4 and 5**
Further readings and applications	

11. **Portfolio selection in the risk-return approach:** Mathematical Programming for Portfolio selection – Markowitz mean-variance models – empirical construction of the EF for a market of n risky assets – Variants of the Markowitz models with side constraints for modelling requirements on portfolio dividends, upper and lower bounds on the individual positions, cardinality, leverage and turnover constraints, transaction costs, buy-in thresholds and roundlot transactions – The Efficient Line and the Sharpe Index – The Sharpe index maximization problem – One Fund Separation Theorem.
Alternative models in the risk-return approach – MaxMin (expected return) models, Expected Portfolio Return Model (EPRM), MAD model**.**

Practical Applications: Presentation and discussion of two real applications with US stocks and bonds, and Domestic and international Stocks.

Supplementary Lab activities: Empirical construction of the EF and of the EL. Practical solution of exercises with Excel and Matlab.

Suggested readings:

Theory	**Textbook [a] Chapter 6, Textbook [d] Chapter 6 , Textbook [c] Chapter 4**
Further readings and Applications	**[1] Mitra et al. (2003)**. A Review of Portfolio Planning: Models and Systems, Brunel University, invited chapter in: Advances in Portfolio Construction and Implementation, Satchell, S.E. and Scowcroft, A.E., (Eds.), Butterworth and Heinemann, Oxford. **[2] Zenios, S.A. (2002)**. Practical Financial Optimization: Decision making for financial engineers, Manuscript, HERMES Centre on Computational Finance and Economics, University of Cyprus, Nicosia, CY.

12. **Index Tracking and Portfolio Diversification optimization models**

Suggested readings:

Theory	**Textbook [a] Chapter 6**
Further readings and Applications	**INDEX TRACKING** **[1] Bruni et al., 2015** – Renato Bruni, Francesco Cesarone, Andrea Scozzari, Fabio Tardella (2015). A linear risk-return model for enhanced indexation in portfolio optimization. OR Spectrum, 37, 735–759. **[2] Scozzari et al., 2013** – Andrea Scozzari, Fabio Tardella, Sandra Paterlini, Thiemo Krink (2013). Exact and heuristic approaches for the index tracking problem with UCITS constraints. Annals of Operations Research, 205, 235–250 **[3] Krink et al., 2009** – Krink, T., Mittnik, S., & Paterlini, S. (2009). Differential evolution and combinatorial search for constrained index tracking. Annals of Operations Research, 172, 153–176. **DIVERSIFICATION** **[1] S. Maillard, T. Roncalli, J. Teiletche (2009)**. On the properties of equally-weighted risk contributions portfolios. **[2] E. Qian (2011)**. Risk parity and diversification. Journal of Investing, 20, 119. **[3] T. Roncalli, 2013** (Book) – Introduction to risk parity and budgeting, CRC Press, 2013. **[4] Y. Choueifaty and Y. Coignard (2008)**. Toward Maximum Diversification. The Journal of Portfolio Management, 35, 40-51.