

# MAFS5310 – Portfolio Optimization with R

## MSc in Financial Mathematics

### Fall 2020-21, HKUST

#### Basic Information

Instructor: Prof. Daniel P. Palomar (<https://www.danielpalomar.com>)

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Website: <https://canvas.ust.hk/courses/32417>

Lecture Time: Tue 19:30 – 22:20

Lecture Venue: Online via Zoom

#### Description

Modern portfolio theory started with Harry Markowitz's 1952 seminal paper "Portfolio Selection," for which he would later receive the Nobel prize in 1990. He put forth the idea that risk-averse investors should optimize their portfolio based on a combination of two objectives: expected return and risk. Until today, that idea has remained central in portfolio optimization. However, the vanilla Markowitz portfolio formulation does not seem to behave as expected in practice and most practitioners tend to avoid it.

During the past half century, researchers and practitioners have reconsidered the Markowitz portfolio formulation and have proposed countless of improvements and alternative such as robust optimization methods, alternative measures of risk (e.g., CVaR or ES), regularization via sparsity, improved estimators of the covariance matrix via random matrix theory, robust estimators for heavy tails, factor models, mean models, volatility clustering models, risk-parity formulations, etc.

This course will explore the Markowitz portfolio optimization in its many variations and extensions, with special emphasis on R programming. Each week will be devoted to a specific topic, during which the theory will be first presented, followed by an exposition of a practical implementation based on R programming.

#### Textbooks

- Yiyong Feng and Daniel P. Palomar, *A Signal Processing Perspective on Financial Engineering*. Foundations and Trends® in Signal Processing, Now Publishers, 2016.  
[\[https://palomar.home.ece.ust.hk/papers/2016/Feng&Palomar-FnT2016.pdf\]](https://palomar.home.ece.ust.hk/papers/2016/Feng&Palomar-FnT2016.pdf)
- S. Boyd and L. Vandenberghe. *Convex Optimization*. Cambridge University Press, 2004.  
[\[https://web.stanford.edu/~boyd/cvxbook/\]](https://web.stanford.edu/~boyd/cvxbook/)
- G. Cornuejols and R. Tutuncu, *Optimization Methods in Finance*. Cambridge Univ. Press, 2007.
- F. J. Fabozzi, P. N. Kolm, D. A. Pachamanova, and S. M. Focardi, *Robust Portfolio Optimization and Management*. Wiley, 2007.

#### Prerequisites:

Good knowledge of linear algebra and some programming knowledge in R (or similar). Willingness to spend countless of hours programming in R.

#### Grading:

|                                 |     |
|---------------------------------|-----|
| Homework:                       | 25% |
| Class participation (video on): | 10% |
| Weekly portfolio game (in R):   | 40% |
| Final lightening presentation:  | 25% |

## Course Schedule

| Date   | Week | Topic   |
|--------|------|---|
| 8-Sep  | 1    | Theory: Introduction to convex optimization           |
|        |      | Practice: R for finance primer                        |
| 15-Sep | 2    | Theory: Convex optimization problems                  |
|        |      | Practice: Solvers in R                                |
| 22-Sep | 3    | Portfolio optimization                                |
|        |      | (cont'd)  |
| 29-Sep | 4    | Backtesting portfolios                                |
|        |      | Data cleaning   |
| 6-Oct  | 5    | Prior information: Shrinkage and Black-Litterman      |
|        |      | (cont'd) [Factor models for asset returns?]           |
| 13-Oct | 6    | Robust estimators under heavy tails and outliers      |
|        |      | (cont'd)  |
| 20-Oct | 7    | Robust portfolio optimization                         |
|        |      | (cont'd)  |
| 27-Oct | 8    | Portfolio optimization with alternative risk measures |
|        |      | (cont'd)  |
| 3-Nov  | 9    | Risk parity portfolio                                 |
|        |      | (cont'd)  |
| 10-Nov | 10   | Index tracking of financial markets                   |
|        |      | (cont'd)  |
| 17-Nov | 11   | Time series modeling of financial data                |
|        |      | (cont'd)  |
| 24-Nov | 12   | Theory: Pairs trading                                 |
|        |      | Practice: Pairs trading with R                        |
| 1-Dec  | 13   | Project presentations by students                     |

|  |       |                                  |
|--|-------|----------------------------------|
|  | extra | Factor models for asset returns? |
|  |       | Theory: Pairs trading            |
|  |       | Practice: Pairs trading with R   |