WINTER SCHOOL IN DIGITILIZATION, VISUALIZATION AND OPTIMIZATION
Topics in data science and optimization methods for large asset markets

Instructor:

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Course pre-requisites:

- Basic knowledge of programming language R or other languages,
- Basic knowledge of optimization principles for finite dimensional optimization problems,
- Interest in applications of quantitative modelling, data-science and various optimization methods to finance,
- Interest in exploring key properties of selected financial research databases.

Material: Self-contained lecture notes and teaching material will be provided, covering fundamental concepts and ideas necessary to understand and apply selected data-science and optimization methods to key finance research questions for large asset markets. Relevant selected articles in the domain of asset pricing and portfolio optimization for large asset markets will be discussed and implemented. During the winter school, students will have full access to an integrated data science and computational platform, on which they will directly implement the introduced models and approaches on real financial data from established research databases.

Course description: The course is an introduction to recent advances in data science and optimization methods for large asset markets. We will start from a systematic theory for studying portfolio optimization and asset pricing problems in large asset markets, which relies on the extended notion of a stochastic discount factor (SDF) that allows for non zero pricing errors on a subset of assets. In this setting, many pricing and portfolio problems with investment constraints can be understood with a unifying approach. We will then consider estimation of optimal portfolios and SDFs under various relevant constraints for pricing errors and portfolio weights, such as, e.g., sparse pricing error or portfolio weight constrains induced by Lasso, Elastic Net or related regularizations. In parallel, we will consider in detail implementation of the various models considered on real financial data, by means of open-source libraries for convex optimization. Here, selected topics related to (i) portfolio choice with a misspecified factor model and (ii) high-dimensional characteristics selections will also be investigated.

Grading: Grading will be based on group work and group presentations of relevant topics covered by selected recent papers in the literature. Bonus points will be given to students showing evidence of having independently implemented selected aspects of models introduced in the course.

Teaching philosophy: The course aims to provide students in a workshop-like style with key skills and competences allowing them:

"to soundly understand key methodological aspects and to reproduce with own implementations"

stylized empirical evidence from recent practically-relevant research papers in finance, based on selected data science and optimization methods for large asset markets. More broadly, the course provides students with useful experience, intuition and implementation skills that are typically gained after structuring and addressing a research project with a substantial data-analytic and optimization component. Lectures provide methodological background and empirical context that students need to deepen, both with their reading of the selected material to the course and with their empirical-implementation work in groups. The implementation and empirical work for the course is supported by an integrated data science and computational platform, on which students will be able to directly implement the introduced models and optimization approaches on real financial data from established research databases.

Selected contents:

1. Stochastic discount factor (SDF) pricing and optimal portfolios in large asset markets:
   (a) SDFs, SDF–projections and large asset markets,
   (b) SDF–projections, Fenchel duality and optimal portfolios,
   (c) Estimation of SDFs and optimal portfolios.
2. Modelling pricing error and portfolio weight constraints:
   (a) Positivity, short-sale and leverage constraints,
   (b) Lasso, Ridge and related penalizations,
   (c) A systematic penalization approach based on Moreau (1962) envelopes.
3. The Arbitrage Pricing Theory (APT) and misspecification:
   (a) Factor models and the APT,
   (b) Misspecification and pricing error constraints,
   (c) Optimal portfolios and APT–consistent SDFs.
4. Asset characteristics, expected returns and portfolio choice:
   (a) Regularization and selection of asset characteristics,
   (b) Nonparametric characteristics modelling,
   (c) SDFs with nonparametric characteristics dependence.

Selected reading material:

1. Stochastic discount factor (SDF) pricing and optimal portfolios in large asset markets:
   (a) Own lecture notes.
   (b) S. Korsaye, A. Quaini and F. Trojani (2018). Smart SDFs, working paper.
2. Modelling pricing error and portfolio weight constraints:
   (a) Own lecture notes.
   (b) S. Korsaye, A. Quaini and F. Trojani (2018). Smart SDFs, working paper.
   (c) E. G. Luttmer (1996). Asset pricing in economies with frictions. Econometrica, 1439–1467.
   (d) V. De Miguel, A. Martin-Utrera, F. J. Nogales, and R. Uppal (2017). A portfolio perspective on the multitude of firm characteristics, working paper.
   (e) J.-J. Moreau (1962). Fonctions convexes duales et points proximaux dans un espace hilbertien. Comptes Rendus de l'Académie des Sciences, pages 2897–2899.
   (f) R. Tibshirani. Regression shrinkage and selection via the lasso (1996). Journal of the Royal Statistical Society. Series B, 267–288.
   (g) H. Zou and T. Hastie (2005). Regularization and variable selection via the elastic net. Journal of the Royal Statistical Society: Series B, 67(2):301–320.
3. The Arbitrage Pricing Theory (APT) and misspecification:
   (a) Own lecture notes.
   (b) S. Korsaye, A. Quaini and F. Trojani (2018). Smart SDFs, working paper.
   (c) P. Gagliardini, E. Ossola, and O. Scaillet (2016). Time-Varying Risk Premium in Large Cross-Sectional Equity Data Sets. Econometrica, Volume 84, Issue 3, 985–1046.

(d) R. Uppal and P. Zaffaroni (2016). Portfolio choice with model misspecification: a foundation for alpha and beta portfolios, working paper.

(e) R. Uppal, P. Zaffaroni, and I. Zviadadze (2018). Beyond the bound: Pricing assets with misspecified stochastic discount factors, working paper.

4. Asset characteristics, expected returns and portfolio choice:

(a) Own lecture notes.

(b) S. Korsaye, A. Quaini and F. Trojani (2018). Smart SDFs, working paper.

(c) C. Harvey, Y. Liu and H. Zhu, 2016. ...and the cross-section of expected returns. Review of Financial Studies, vol. 29, issue 1, 5-68.

(d) S. Nagel, S. Kozak, and S. Santosh (2018). Shrinking the cross-section. Journal of Financial Economics.

(e) J. Freiberger, A. Neuhier and M. Weber (2016). Dissecting characteristics nonparametrically, Working Paper.

(f) V. De Miguel, A. Martin-Utrera, F. J. Nogales, and R. Uppal (2017). A portfolio perspective on the multitude of firm characteristics, working paper.