Workshop

on

Optimization in Finance

Center for International Mathematics

Thematic term on Optimization

July 5-8, 2005
School of Economics, University of Coimbra
Coimbra, Portugal

http://www.mat.uc.pt/tt2005/of

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Scope: Optimization models and methods are playing an increasingly important role in financial decision making. Many problems in quantitative finance, originated from asset allocation, risk management, derivative pricing, and model fitting, are now routinely and efficiently solved using modern optimization techniques. This workshop will bring together researchers in the rapidly growing field of financial optimization and intends to provide a forum for innovative models and methods on new topics, novel approaches to well-known problems, success stories, and computational studies in this exciting field. Participants are encouraged to present and discuss their recent work and new, possibly controversial, approaches are particularly welcome.

The targeted audience for this workshop includes graduate students and faculty members working in applied mathematics, operations research, and economics, who have been interested in mathematical finance or plan to do so. The workshop will also be attractive for those doing quantitative modeling in the financial market.

A one-day short-course, intended for optimization researchers interested in quantitative finance as well as finance researchers and practitioners interested in optimization models and methods, will precede the scientific program of the workshop. Invited and contributed presentations will be scheduled during the remaining three days.

Organizers

Ana Margarida Monteiro (Univ. Coimbra, Portugal)
Reha H. Tütüncü (Carnegie Mellon Univ., USA)
Luís Nunes Vicente (Univ. Coimbra, Portugal)

Sponsors

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Grupo de Estudos Monetários e Financeiros

Other Events

Summer School on Geometric and Algebraic Approaches for Integer Programming
Faculty of Science, University of Lisbon, July 11-15, 2005
`http://www.mat.uc.pt/tt2005/ss`

Workshop on Optimization in Medicine
IBILI, University of Coimbra, July 20-22, 2005
`http://www.mat.uc.pt/tt2005/om`

Workshop on PDE Constrained Optimization
Tomar, July 26-29, 2005
`http://www.mat.uc.pt/tt2005/pde`

PROGRAM AT GLANCE

Tuesday 5	
9:00-9:45	Registration
9:45-10:00	Opening Remarks
10:00-12:15	Tutorial T1
12:15-14:00	Lunch
14:00-16:15	Tutorial T2
17:30	Visit to Old University
Wednesday 6	
9:00-9:45	Invited Speaker I1
9:45-10:15	Coffee Break
10:15-12:15	Sessions OS1, S1
12:15-14:00	Lunch
14:00–15:30	Invited Speakers I2, I3
15:30-16:00	Coffee Break
16:00-18:00	Sessions OS2, S2
Thursday 7	
9:00-9:45	Invited Speaker I4
9:45-10:15	Coffee Break
10:15-12:15	Sessions OS3, S3
12:15-14:00	Lunch
14:00-15:30	Sessions OS4, S4
15:30-16:00	Coffee Break
16:00-18:00	Sessions OS5, S5
19:30	Conference Dinner
Friday 8	
9:30-10:30	Sessions S6, S7
10:30-11:00	Coffee Break
11:00-12:30	Invited Speakers I5, I6
12:30-14:00	Lunch
14:00-15:30	Sessions OS6, S8
17:30	Visit to Roman Ruins

Tuesday 5

9:00-9:45 **Registration** – Room Gonçalves da Silva

9:45-10:00 **Opening Remarks** – Auditorium

Tutorial T1 – Auditorium

10:00-12:15 **Reha H. Tütüncü**, Carnegie Mellon Univ., USA
Robust optimization in finance

12:15-14:00 **Lunch**

Tutorial T2 – Auditorium

14:00-16:15 **Stefano Herzel**, Univ. Perugia, Italy
Optimization problems in pricing and hedging options

17:30 **Visit to Old University**

Wednesday 6

Invited Speaker I1 – Auditorium

9:00-9:45 **John Birge**, Univ. Chicago, USA
Portfolio optimization with consumption and trading constraints

9:45-10:15 **Coffee Break**

Robust Optimization in Finance I – OS1 – Auditorium

Organizer: **Mustafa Pınar**, Bilkent Univ., Turkey

10:15-10:45 **Alper Atamtürk**, Univ. California, Berkeley, USA
Nonconvex robust portfolio optimization

10:45-11:15 **Emre Erdogan**, Columbia Univ., USA
Robust portfolio management

11:15-11:45 **Denis Zuev**, Univ. Oxford, UK
Robust portfolio optimisation using maximisation of min eigenvalue methodology

11:45-12:15 **Mustafa Pınar**, Bilkent Univ., Turkey
Robust scenario optimization based on downside-risk measure for multi-period portfolio selection

Option Pricing – S1 – Room Keynes

10:15-10:45 **Alejandro A. Chacur**, Univ. Concepción, Chile
Study and analysis of real option techniques in the valuation of investment projects

10:45-11:15 **Roberto Ferulano**, Univ. Perugia, Italy
Enhanced Monte-Carlo methods for American options

11:15-11:45 **Uwe Wystup**, Business School Finance Management, Germany
On the cost of delayed fixing announcements and its impact on FX exotic options

12:15-14:00 **Lunch**

Invited Speakers I2, I3 – Auditorium

14:00-14:45 **Stanislav Uryasev**, Univ. Florida, USA
Pricing options in incomplete market

14:45-15:30 **Nizar Touzi**, CREST, France
Hedging under gamma constraints, second order BSDE's, and fully non-linear PDE's

15:30-16:00 **Coffee Break**

Optimization in the Financial Practice – OS2 – Auditorium

Organizer: **Reha H. Tütüncü**, Carnegie Mellon Univ., USA

16:00-16:45 **Arun Verma**, Bloomberg, USA
Global optimization of VaR (Value-at-Risk) using continuation methods

16:45-17:30 **Attílio Meucci**, Lehman Brothers, Inc., USA
Robust bayesian allocation

Portfolio Selection – S2 – Room Keynes

16:00-16:30 **Oleksandr Romanko**, McMaster Univ., Canada
Parametric analysis in convex quadratic optimization and its applications to portfolio selection models

16:30-17:00 **Marius Radulescu**, Romanian Academy, Romania
Portfolio selection models with complementarity constraints

17:00-17:30 **Diogo Júdice**, Univ. Warwick, UK
A fractional programming portfolio selection model for the stock market

17:30-18:00 **Victor DeMiguel**, London Business School, UK
How inefficient are simple asset-allocation strategies?

Thursday 7

Invited Speaker I4 – Auditorium

9:00-9:45 **Terry Rockafellar**, Univ. Washington, USA
Risk measures and safeguarding in optimization under uncertainty

9:45-10:15 **Coffee Break**

Optimal Control in Finance – OS3 – Auditorium

Organizer: **Huyen Pham**, Univ. Paris 7, France

10:15-10:45 **Bruno Bouchard**, LPMA, Univ. Paris 6, France
Explicit characterization of the super-replication strategy in financial markets with partial transaction costs

10:45-11:15 **Abel Cadenillas**, Univ. Alberta, Canada
Classical and impulse stochastic control for the optimization of the risk and dividend policies of a financial firm

11:15-11:45 **Andrew Lim**, Univ. California, Berkeley, USA
Alternative formulations of the robust portfolio selection problem

11:45-12:15 **Paolo Guasoni**, Boston Univ., USA
Optimal long term investment and the utility growth rate

Robust Optimization in Finance II – S3 – Room Keynes

10:15-10:45 **Jan H. Maruhn**, Univ. Trier, Germany
Adding robustness to static hedge portfolios for barrier options

10:45-11:15 **Katrin Schöttle**, Tech. Univ. Munich, Germany
Benefits and costs of robust portfolio optimization

11:15-11:45 **Ralf Werner**, Allianz GRC, Germany
Efficient approximation of robust portfolio optimization problems

12:15-14:00 **Lunch**

Stochastic Optimization in Finance I – OS4 – Room Keynes

Organizer: **Andrea Consiglio**, Univ. Palermo, Italy

14:00-14:30 **Marida Bertocchi**, Univ. Bergamo, Italy
Bond portfolio management via stochastic programming

14:30-15:00 **Luís Seco**, Univ. Toronto, Canada
Portfolio optimization under regime switching: Applications to hedge fund portfolio management

15:00-15:30 **Georg Pflug**, Univ. Vienna, Austria
Risk contributions in diversified portfolios

Hedging and Valuation Methods – S4 – Room Gonçalves da Silva

14:00-14:30 **Paresh Date**, Brunel Univ., UK
Valuation of cash flows under stochastic interest rate: A linear algebraic approach

14:30-15:00 **Arnaud Porchet**, Univ. Paris Dauphine, France
Valuation of a production asset subject to production constraints

15:00-15:30 **Alexei Gaivoronsky**, Norwegian Univ., Norway
Stochastic programming problems for risk budgeting

15:30-16:00 **Coffee Break**

Conic Optimization in Finance – OS5 – Room Keynes

Organizer: **Luís Zuluaga**, Univ. New Brunswick, Canada

16:00-16:30 **Tomás Prieto-Rumeau**, Univ. Nac. Educación Distancia, Spain
Pricing exotic options with semidefinite programming

16:30-17:00 **Karthik Natarajan**, National Univ. Singapore, Singapore
Persistency and its applications in finance

17:00-17:30 **Luís Zuluaga**, Univ. New Brunswick, Canada
Optimal semi-parametric bounds for European rainbow options

Stochastic Dominance and Approximation – S5 – Room Gonçalves da Silva

16:00-16:30 **Michal Cervinka**, Charles Univ., Czech Republic
On comparison of second order stochastic dominance tests

16:30-17:00 **Petr Chovanec**, Charles Univ., Czech Republic
Stochastic dominance and CVaR in portfolio selection problem

17:00-17:30 **Nikolas Topaloglou**, Univ. Genève, Switzerland
Testing for stochastic dominance efficiency

17:30-18:00 **Jean-Sebastien Roy**, EDF, France
Temporal difference learning with kernels

19:30 **Conference Dinner** – Quinta das Lágrimas

Friday 8

Duality Methods in Finance – S6 – Room Keynes

9:30-10:00 **Sara Biagini**, Univ. Perugia, Italy
A unifying framework for utility maximization problems

10:00-10:30 **Daniel Gabay**, EHESS, France
Alternative interpretations of convex duality in financial economics

Calibration and Forecasting – S7 – Room Gonçalves da Silva

9:30-10:00 **Richard Hawkes**, Brunel Univ., UK
The inference of optimal timescales in forecasting actual volatility

10:00-10:30 **Kenneth O. Kortanek**, Univ. Pittsburgh, USA
Nonstochastic uncertainty modeling for extraction and prediction problems in finance

10:30-11:00 **Coffee Break**

Invited Speakers I5, I6 – Auditorium

11:00-11:45 **John Mulvey**, Princeton Univ., USA
Optimizing a multi-strategy hedge fund

11:45-12:30 **Stavros Zenios**, Univ. Cyprus, Cyprus
Financial products with guarantees: Applications, models and internet-based services

12:30-14:00 **Lunch**

Stochastic Optimization in Finance II – OS6 – Keynes

Organizer: **Andrea Consiglio**, Univ. Palermo, Italy

14:00-14:30 **Hercules Vladimirou**, Univ. Cyprus, Cyprus
A stochastic programming framework for managing international portfolios

14:30-15:00 **Kourosh Rasmussen**, Tech. Univ. Denmark, Denmark
Mortgage loan portfolio optimization using mixed integer multi stage stochastic programming with scenario reduction

15:00-15:30 **Andrea Consiglio**, Univ. Palermo, Italy
Evaluation of insurance products with guarantee: A stochastic programming approach

Arbitrage Pricing Methods – S8 – Room Gonçalves da Silva

14:00-14:30 **Pedro Júdice**, JP Morgan Chase, UK
Foundations and applications of good-deal pricing I: Single-period market models

14:30-15:00 **Gino Favero**, Univ. Bocconi, Italy
Long and short-term arbitrages: A comment on an example by Pham and Touzi

17:30 **Visit to Roman Ruins**

Titles and Abstracts – Tutorials

Optimization problems in pricing and hedging options

Stefano Herzel

The purpose of this tutorial is to illustrate the most important concepts of the arbitrage pricing theory to an audience whose expertise is mostly focused in the field of optimization. The fundamental results on hedging and pricing of contingent claims will be derived through the use of basic tools of duality theory. An overview of the most significant applications of optimization's techniques to some option pricing problems will also be given.

Robust optimization in finance

Reha H. Tütüncü

Many optimization problems are formulated using parameters whose true values are not known with certainty. Robust optimization refers to a modeling strategy for such problems that intends to obtain a solution that is guaranteed to perform adequately for all or most possible realizations of these uncertain parameters. During the last decade, an intensive study of robust formulations for many classes of optimization problems using various uncertainty structures have led to many successful algorithms and applications. We will review some of these results and pay special attention to current debates on the different interpretations of robustness such as robustness in constraints vs. objective function, absolute vs. relative robustness, adjustable robustness, etc.

Optimization formulations of problems from financial mathematics often involve parameters such as returns, interest rates, and volatilities whose values will be realized in the future and therefore are uncertain. Or, these parameters may represent statistical quantities (means, covariances, etc.) associated with random events whose true distributions are unobservable. Robust optimization provides an ideal setting for addressing such uncertainties in a conservative fashion. We will review some recent applications of robust optimization approach to portfolio selection, risk management, as well as pricing and hedging of derivative securities.

Titles and Abstracts – Invited Talks

Portfolio optimization with consumption and trading constraints

John Birge

Practical portfolio management often includes a variety of constraints surrounding the consumption of resources and liquidity in certain asset classes. In isolation, each of these forms of constraints may have relatively little impact on portfolio allocations, but their combined effect can be substantial. This talk will describe various approaches to including these constraints and will present results on their joint effects, especially in terms of investments in alternative asset classes.

Optimizing a multi-strategy hedge fund

John Mulvey

Hedge fund managers have much greater flexibility to invest in novel investments and strategies than traditional portfolio managers. Our objective is to develop a modeling language, by which we can efficiently analyze/optimize a portfolio of hedge fund investment strategies. The primary focus is multi-stage stochastic programs. To illustrate the approach, we show the advantages of a multi-strategy fund as compared with the typical fund-of-hedge-funds.
Joint with: A.J. Thompson and Cenk Ural

Risk measures and safeguarding in optimization under uncertainty

Terry Rockafellar

Coping with the uncertainties in future outcomes is a fundamental theme of optimization in a stochastic environment. It enters in the treatment of constraints as well as the treatment of objectives.

In the field of stochastic programming, which has grown from the traditions of linear and quadratic programming, constraints on future outcomes have commonly been relaxed by penalty expressions, unless they can be satisfied almost surely through recourse actions. Probabilistic constraints, requiring that a condition only to be satisfied up to a given probability, have sometimes utilized instead, but with the drawback that convexity and even continuity in a problem formulation can be

lost, except in special circumstances. Objectives have usually taken the form of maximizing expected utility or minimizing an expected cost which may come in part from constraint penalties. Some extensions involving information and entropy have also been explored.

In financial optimization, where uncertainties are likewise unavoidable, approaches other than stochastic programming have prevailed. Although traditional portfolio theory was focused on minimizing variance of return subject to a constraint on expected return, other schemes have more recently gained popularity. An important example is constraints and objectives based on the notion of value-at-risk, which relates closely to probabilistic constraints and unfortunately, therefore, suffers from similar mathematical shortcomings. Value-at-Risk suffers even from financial inconsistencies, which have led to the axiomatic development of "coherent risk measures", including the robust alternative called conditional value-at-risk.

Hedging under gamma constraints, second order BSDE's, and fully non-linear PDE's

Nizar Touzi

We provide a quasi-explicit solution to the super-replication problem with gamma constraints. In particular, the upper bound constraint on the gamma implies that the optimal strategy consists in hedging a conveniently face-lifted payoff function, while the lower bound induces an optimal stopping problem.

Motivated by this problem, we introduce the notion of second order backward stochastic differential equations for which we prove existence and uniqueness under some conditions. This result provides an extension of the Feynman-Kac representation theorem to the case of parabolic fully non-linear PDE's.

Pricing options in incomplete market

Stanislav Uryasev

The paper considers a regression approach to pricing options in incomplete markets. The algorithm replicates an option by a portfolio consisting of an underlying security and a risk-free bond. We applied the linear regression framework and quadratic programming with linear constraints (input = sample paths of underlying security; output = table of option prices as function of time and price of the underlying security). Risk neutral processes or probabilities are not needed in this framework. We populated the model with historical prices of the underlying security ("massaged" to the present volatility).

We evaluated numerical performance of the algorithm with several real life data sets: options on S&P500, on natural gas futures, and on crude oil futures.
Joint with: Sergey Sarykalin and Valeriy Ryabchenko

Financial products with guarantees: Applications, models and internet-based services

Stavros Zenios

Endowments with a minimum guaranteed rate of return appear in insurance policies, pension plans and social security plans. In several cases, especially in the insurance industry, such endowments also participate in the business and receive bonuses from the firm's asset portfolio. In this paper we develop a scenario based stochastic optimization model for asset and liability management of participating insurance policies with minimum guarantees. The model allows the analysis of the tradeoffs facing an insurance firm in structuring its policies as well as the choices in covering their cost. The model is applied to the analysis of policies offered by insurance firms in Italy and the UK. While the optimized model results are in general agreement with current industry practices, inefficiencies are still identified and potential improvements are suggested.

The modeling tools developed for the management of insurance policies are also used to develop a web-based system for individual investors. Investors goals and risk profiles are addressed in an integrated fashion. The requirements for real-time modeling by the average investor must be reflected in the model, and this issue will be discussed as well. The practical experience with this model will be discussed.

Titles and Abstracts – Talks

Nonconvex robust portfolio optimization

Alper Atamtürk

We give a robust portfolio optimization model with linear constraints in the presence of fixed and variable transaction costs. We describe valid inequalities to approximate the convex hull of solutions and present preliminary computational results with the model.

Joint with: Vishnu Narayanan

Bond portfolio management via stochastic programming

Marida Bertocchi

Stochastic programming is a tool to support bond portfolio management decisions. For a successful application of the stochastic programming methodology, one must choose an adequate model, assess its parameters generate sensible input scenarios or scenario tree, solve the scenario-based problem using an optimization software and validate the results. Formulation of two-stage and three-stage models for bond portfolio optimization are discussed and computational results displayed. Comparisons of monthly and quarterly time discretizations and for various topologies of the input scenario trees are presented. Black-Derman-Toy binomial lattice calibrated from market data is used to generate scenarios and scenario reduction and scenario construction are applied using GAMS. The contamination technique is exploited to quantify the impact of including additional (stress or out-of-sample) scenarios and/or additional stages to an already selected scenario tree.

A unifying framework for utility maximization problems

Sara Biagini

Expected utility maximization in continuous-time stochastic incomplete markets is a very well known problem that received a great impulse in the middle of the Eighties when the "duality approach" to the resolution was first employed. In the most general semimartingale model for the underlying process X, the problem we address takes the following form:

$$\sup_{H \in \mathcal{H}} E[u(x + (H \cdot X)_T)] \tag{1}$$

where

1. u is the utility function of the agent, which is assumed to be a concave function, strictly increasing and differentiable over its proper domain;

2. x is the initial endowment of the agent, T is the time horizon;

3. $\mathcal{H}$ is a proper class of admissible integrands, which represent the allowed trading strategies;

4. $(H \cdot X)_T$ is the terminal wealth of the investor when following strategy H.

Up to now the current literature is somehow split in two main branches, which rely on two different applications of the duality.

The first methodology is the Kramkov-Schachermayer's approach, which is suitable when the proper domain of u is $\mathcal{R}_+$ (i.e. power or log-like utilities) and X is a general semimartingale, or when the proper domain is $\mathcal{R}$ but X is locally bounded (Schachermayer, Ann. Appl. Prob., 2001). The set $\mathcal{H}$ of strategies here employed is the classical set $\mathcal{H}^1$ of strategies with bounded from below wealth.

The second is Frittelli's approach, which was first used to solve problem (1) when the proper domain of u is the entire real line (exp-like utilities) and X locally bounded (i.e. with the usual set of strategies $\mathcal{H}^1$, which is non trivial when X is locally bounded). However, we have recently shown (BF2004 "Utility Maximization in Incomplete Markets for Unbounded Processes", Fin. Stoch., in press) that this method can be used also when X is a general, not necessarily locally bounded, semimartingale. This extension relies on a careful analysis of the proper set of strategies $\mathcal{H}$ that are allowed in the trading. In fact, the traditional set of strategies $\mathcal{H}^1$ may reduce to the null strategy when X is non-locally bounded (just to fix the ideas, think of such an X as a Compound Poisson with unbounded jump size). So the maximization problem on this set turns out to be trivial. To model the situation in which the investor is willing to take more risk to really increase her expected utility in a very risky market, we enlarged the set of allowed strategies by admitting unbounded losses. These losses have to be compatible with the utility function u.

Following the second approach and the ideas contained in BF2004, we show how these two apparently different branches can be seen as particular cases of a single, unifying framework. In addition, we are now able to cover a more general situation that the one exposed in BF2004 since we require a weaker notion of compatibility between the losses of the enlarged set of strategies $\mathcal{H}$ and the utility function.

Joint with: M. Frittelli

Explicit characterization of the super-replication strategy in financial markets with partial transaction costs

Bruno Bouchard

We consider a multivariate financial market with transaction costs and study the problem of finding the minimal initial capital needed to hedge, without risk,

European-type contingent claims. The model is similar to the one considered in Bouchard and Touzi (2000), except that some of the assets can be exchanged freely, i.e. without paying transaction costs. In this context, we generalize the result of the above paper and prove that the value of this stochastic control problem is given by the cost of the cheapest hedging strategy in which the number of non-freely exchangeable assets is kept constant over time.

Classical and impulse stochastic control for the optimization of the risk and dividend policies of a financial firm

Abel Cadenillas

This paper deals with the dividend optimization problem for a financial or an insurance entity which can control its business activities, simultaneously reducing the risk and potential profits. It also controls the timing and the amount of dividends paid out to the shareholders. The objective of the corporation is to maximize the expected total discounted dividends paid out until the time of bankruptcy. Due to the presence of a fixed transaction cost, the resulting mathematical problem becomes a mixed classical-impulse stochastic control problem. The analytical part of the solution to this problem is reduced to quasi-variational inequalities for a second order nonlinear differential equation. We solve this problem explicitly and construct the value function together with the optimal policy. We also compute the expected time between dividend payments under the optimal policy.

Joint with: Tahir Choulli, Michael Taksar, and Lei Zhang

On comparison of second order stochastic dominance tests

Michal Cervinka

This contribution compares second-order stochastic dominance (SSD) efficiency tests under diversification — an asset is SSD efficient if there exists no convex combination of other assets that it dominates in SSD sense. In the literature, there are only two tests for SSD efficiency under diversification. One approach proposed in Kopa et al. (2005) is based on Ogryczak et al. (2002) results on relation between SSD and conditional value-at-risk, and the other, introduced in Post (2003), uses a direct approach and DEA ideas. Although Kopa et al. (2005) approach is computationally more difficult, it takes into account also scenarios, not only historical data.

This paper answers the question whether this computational disadvantages pays off. For that purpose, we use data from Prague Stock Exchange.

Joint with: P. Chovanec

Study and analysis of real option techniques in the valuation of investment projects

Alejandro A. Chacur

This investigation analyzes a new approach to economically evaluate investment projects, based on Real Options Theory. The main difference between Real Options and traditional methods, such as NPV, is that the former aims to consider Management Flexibility as a source of strategic value for the project itself.

To undertake this investigation, a complete review of bibliography was performed, in order to develop a theoretical framework of analysis upon the traditional methods of project economic evaluation, as well as the Real Options Theory and its major valuing methods. This previous study suggests that the traditional methods are not able to capture the degree of flexibility of a project, showing clear evidence of weakness in strategic decisions. On the other hand, the Options valuation techniques, early used in Capital Budgeting, have been successfully applied on the evaluation of investment projects, since it considers financial aspects in conjunction with strategic ones.

In fact, a project can be seen as a collection of Real Options (such as Option to Defer, Abandon, Contract, Expand and Switch use) and its value is calculated by adding to the traditional NPV, the value of flexibility in the project, as an Option Premium. As result, a new Expanded NPV is obtained.

In this work, we present the application of Real Options in the economic evaluation of investment decisions. As case of study, we considered the project "Implementation of Geographical Information System (GIS), as a way of cartographic control, in Forestal Mininco S.A plantations". This project has already been studied by Julio Becker, by focusing on traditional valuation methods. This results were compared with the ones obtained with Real Options theory, using the Log Transformed Binomial Method.

The results show that the value of the project, calculated upon Real Options differs greatly from the one supported on the traditional approach. Also, the numeric value that was obtained is quite different from the algebraic sum of the individual options if they were estimated separately.

In conclusion, the proposed methodology shows itself as a powerful tool to allow a better decision making process in highly uncertain and volatile scenarios, in which the value of flexibility is key to justify strategic investment decisions.

Joint with: Ignacio Garrido

Stochastic dominance and CVaR in portfolio selection problem

Petr Chovanec

Our contribution deals with portfolio selection problem using second-order stochastic dominance (SSD). As was shown in Ogryczak et al. (2002) SSD corresponds to conditional value-at-risk (CVaR), and applying this result we intro-

duce new sufficient and necessary conditions for portfolio to be dominated or non-dominated — whether there exists convex combination of another assets that dominates our portfolio in SSD sense. Because of the complexity of this problem, we also introduce new algorithm based on scenario-approach for finding dominated assets in portfolio. The algorithm uses the special properties of CVaR for discrete probabilistic distributions and conditions introduced in this paper. In the end, we examine the algorithm in praxis, deriving its computational time for different number of scenarios and number of assets. To this end, we use data from the Prague Stock Exchange.

Joint with: M. Kopa

Evaluation of insurance products with guarantee: A stochastic programming approach

Andrea Consiglio

Insurance policies with guarantee can be modeled as a fixed income bond coupled with an implicit option sold to the policyholders. Policies with a final bonus provision are characterized by a call option which is exercised if the underlying portfolio of assets outperform a given benchmark. Policies with a minimum guarantee rate implicitly embed a put option which is exercised when the rate of return of the assets falls below the contractual rate.

The pricing of these implicit options is of vital importance for the insurance industry. Risk management, strategic asset allocation, and product design depend on the correct evaluation of the options sold. Also regulators are interested in such issues since they have to be aware of the possible scenarios that the overall industry will face with. Pricing techniques based on the Black & Scholes paradigm are often used, however, the hypotheses underneath this model are rarely meet: non-tradeability of the liabilities, regulatory and market constraints are arguments which are pushing investigators to look at models developed for real options and, in general, in case of market incompleteness.

Our objective is to use a stochastic programming approach to determine the fair price of the hidden options embedded in policy contracts. In this context, we compare the results obtained with a model based on the utility invariant principle, and a model based on the hedging principle. We also provide extensive numerical experiment to describe the behavior of the insurance policies for different setting of the key parameters (participation rate, minimum guarantee rate, etc.), market and regulatory constraints.

Valuation of cash flows under stochastic interest rate: A linear algebraic approach

Paresh Date

A new approach is presented to value a series of cash flows under a stochastic interest rate setting. Given the dynamics of a short rate process and the expected values of future payments, we derive a uniformly convergent approximation of the risk-neutral expected present value of cash flows. This approximation is based on reformulating the present value problem as a problem of inverting a matrix with random entries and then using techniques from linear algebra to expand the resulting matrix inverse. The convergence results hold under fairly realistic conditions and are independent on the specific choice of short rate model. We demonstrate the applicability of the proposed methodology by pricing defaultable coupon-bearing bonds.

Joint with: R. Mamon and C. Wang

How inefficient are simple asset-allocation strategies?

Victor DeMiguel

In this paper, we wish to evaluate the performance of simple asset-allocation strategies such as allocating $1/N$ to each of the N assets available. To do this, we compare the out-of-sample performance of such simple allocation rules to about ten models of optimal asset-allocation (including both static and dynamic models) for nine data sets. We devote particular emphasis to models the literature has proposed to handle issues related to parameter uncertainty, estimation, and model error. We find that the simple "$1/N$" asset-allocation rule is far from inefficient. In fact, it typically has a higher out-of sample Sharpe ratio, a higher certainty equivalent value, and a lower turnover than optimal asset allocation policies. The intuition for the good performance of the $1/N$ policy is that the loss from naïve rather than optimal diversification is smaller than the loss arising from the estimation error in the parameters needed to implement optimal asset allocation rules. Simulations show that the performance of optimal strategies relative to the $1/N$ rule improves with the length of the estimation window, which reduces estimation error. Moreover, we have observed that the estimation window length necessary for the optimal strategies to outperform the $1/N$ strategy is larger whenever: (a) the idiosyncratic risk is smaller or (b) the number of assets is larger.

Robust portfolio management

Emre Erdogan

In this paper we present robust models for index tracking and active portfolio management, — two basic strategies adopted by fund managers. Our models allow

one to impose additional side constraints such as bounds on the portfolio holdings, beta-constraints, limits on cash exposure, etc. Portfolios are computed by solving second-order cone programs.

We report on the performance of our robust strategies in tests on data from 1994-2003. We find that our robust strategy is able to track the S&P500 index with a significantly smaller number of assets than a non-robust mean-variance index tracking strategy and that our robust active portfolio management strategy significantly outperforms the S&P500 index.

Joint with: Donald Goldfarb and Garud Iyengar

Long and short-term arbitrages: A comment on an example by Pham and Touzi

Gino Favero

When bid-ask spreads are introduced in a market model, the absence of arbitrage opportunities does not propagate by backward induction. We show that this is due to the fact that absence of arbitrage in frictionless markets naturally corresponds to absence of convenient super-hedgings (called effectiveness by some authors) in a market with frictions. Besides characterizing markets which do not allow convenient super-hedgings, we also characterize arbitrage-free markets with frictions and provide an intuitive way to spot at a glance arbitrages and convenient super-hedgings. In particular, our results clarify a well known example by H. Pham and N. Touzi.

Joint with: Erio Castagnoli

Enhanced Monte-Carlo methods for American options

Roberto Ferulano

It's well known that there is not a closed form for pricing American Options. An approximate analytical formula was proposed by Barone-Adesi and Whaley (1987), but usually the binomial trees or the finite difference are used to solve the problem. Recently Longstaff-Schwartz (2001) proposed a simple simulation-based method. To obtain the continuation value at each step, Longstaff-Schwartz implement a least square algorithm on the cross sectional values. So the method can be simply extended to more factors, i.e. to more dimensions. The financial series show some features, as volatility clustering, that are not well modeled by a Brownian Geometric Motion. Stentoft (2005) extended the Longstaff-Schwartz's work to an underlying following a GARCH model. To improve the pricing convergence, and reduce the variance we use the Heston-Nandi's analytical approximation (2000) for pricing European options as control variable.

Alternative interpretations of convex duality in financial economics

Daniel Gabay

In this paper we apply the sup-convolution approach introduced by Rockafellar (1970) to some financial situations: in particular, we focus on portfolio optimization, equilibrium theory and risk measures. For these problems, solutions have already been proposed using tools from classical duality theory (see e.g. Karatzas et al. 1987, Cvitanic and Karatzas 1995, Follmer and Schied 2001). Our aim is to present a unified approach by using the sup-convolution operation and its conjugate (which is simply the sum of the conjugates of its components), thus providing very direct proofs and renewed interpretations. Moreover, we obtain additional insights about more recent problems like model calibration (Cont and Gabay 2005), portfolio optimization (Grasselli 2004) and derivative design (Barrieu and El Karoui 2004).

Joint with: Martino Grasselli

Stochastic programming problems for risk budgeting

Alexei Gaivoronski

Risk Budgeting is an important trend in risk management of complex portfolios. Typically, portfolio of assets of an agent like insurance company or a pension fund consists of large variety of diverse assets which are managed according to different principles. For example, a bulk of portfolio may be invested in a few index funds, while a smaller, but significant portion may be allocated to traders pursuing different active investment strategies. Such portfolio consists from complex assets which not only have different risk profiles, but are exposed to risk of substantially different nature. Statistical properties of these risk types can be known with different levels of uncertainty, and, moreover, the levels of risk aversion of financial actors towards these risk types can differ. Traditional risk management tools like Markowitz model may be insufficient in such situation because they tend to treat all risk types from a uniform perspective. Risk budgeting explicitly recognizes different nature of different types of risk and controls them separately within the general risk management framework. In this paper we present stochastic optimization models related to risk budgeting, study their properties and provide some examples.

Joint with: Sergiy Krylov

Optimal long term investment and the utility growth rate

Paolo Guasoni

We study the problem of utility maximization in an incomplete market with a riskless asset and a risky asset. The price of the risky asset is driven by a diffusion

with coefficients depending on a stochastic factor partially correlated with the asset price. This framework is a general version of the ICAPM and includes models with stochastic volatility and time-varying expected returns.

We introduce a general approach for obtaining explicit asymptotics for expected utilities for long horizons, and define the related concepts of expected utility growth rate and equivalent Sharp ratio, which play a role similar to that of the certainty equivalent in static models.

The methodology proposed relies on the Donsker-Varadhan theory of large deviations for continuous-time Markov processes, and reduces the calculation of the utility growth rate to the solution of two one-dimensional variational problems.

We conclude showing explicit solutions for some models, and discussing their comparative statics.

The inference of optimal timescales in forecasting actual volatility

Richard Hawkes

In this work, high-frequency equity price data is used to compute realized volatility over regular fixed intervals. The actual volatility is then given as a hidden state in a stochastic process with realized volatility as the observable series. Quasi-maximum likelihood is used along with Kalman filter to estimate the parameters of the model governing the dynamics of the volatility. The quality of the model is then analyzed in terms of mean square prediction errors in forecasting future volatility and in terms of standard errors in the parameters. Forecasting is then carried out over several timescales corresponding to the length of the interval over which realized volatility is computed. The optimal timescale is then infered based on theoretical considerations and empirical results. This work contributes in a significant way in analysing the forecasting performance of stochastic volatility models.

A fractional programming portfolio selection model for the stock market

Diogo Júdice

In this talk a fractional programming portfolio selection model is introduced. The objective function of the associated optimization problem is a quotient between the expected return and a weighted variance of stocks returns, where the weights consist of stock prices. The problem also contains linear restrictions and a convex quadratic restriction that forces a limit on the variance. This model has some interesting properties as an optimization problem, namely there exists a unique global maximum that is exactly the unique stationary point of the objective function on the convex set defined by the constraints. A computational study involving stocks from the S&P100 Index is also included and shows the practical relevance of this portfolio selection model.

Foundations and applications of good-deal pricing I: single-period market models

Pedro Júdice

Several authors have recently introduced bounds on option prices based on the notion that the market should not allow "good-deals". This is a weaker requirement than the absence of arbitrages, so it yields tighter bounds than the well known arbitrage-based bounds. We develop the convex analysis of "good-deal" bounds in a discrete space framework, thereby unifying and extending the recent literature on this topic. Our extension includes: (a) important properties that the bounds should follow; (b) the relationship between equilibrium bounds and super-sub replication (c) extension of the results to markets with frictions such as transaction costs and short-sales constraints. By unifying all the good-deal bound literature, we are able to provide new and important properties common to all the "good-deal" approaches. The mathematical heart of the matter is the convex analysis for the single-period case, where the "good-deals" form a cone and the admissible pricing kernels lie in a suitably-defined dual cone.

Nonstochastic uncertainty modeling for extraction and prediction problems in finance

Kenneth O. Kortanek

A class of models is presented that has its origins related to Norbert Wiener's theory of prediction and filtering and to modeling approaches that have a long history in the Russian literature. An underlying law of motion of a financial instrument is modeled as a linear differential equation under uncertainty with perturbations for the financial instrument generating a time series, and several variations are presented as analogs of applicable stochastic models. The uncertainty is described in terms of known feasible sets for varying parameters whose values are otherwise unknown and where a finite set of observed data points are taken directly as inputs into the system. This talk reviews the systems analysis for the joint dynamical system-geometric programming modeling approach and presents numerical results for the following financial modeling applications: (1) extracting the spot rate curve from Government Bills, Notes, & Bonds using a Vasicek-model analog and (2), tracking a financial data series such as the German DAX stock index using a Dothan-model analog.

Alternative formulations of the robust portfolio selection problem

Andrew Lim

In this talk, we present an alternative approach to finding robust portfolios which differs from the typical "worst case" methodology that is popular in the

literature. We show how the solution to this problem can be obtained in the context of continuous time problems (including jumps), and discuss properties of the resulting robust portfolio.

Joint with: George Shanthikumar and Thaisiri Watewai

Adding robustness to static hedge portfolios for barrier options

Jan H. Maruhn

Due to the difficulties associated with dynamic hedging of barrier options, research has focussed on the development of static hedge portfolios consisting of a set of standard options. The derivation of these static strategies usually depends on the parameters of the financial market model under consideration. If the model parameters are subject to change, the hedge portfolio might deteriorate rapidly. During the talk, we will present a robust optimization approach reducing the sensitivity of the hedge with respect to parameters. As numerical results for real-world examples show, the resulting robust hedge portfolio offers protection for a broad range of model parameters and is only marginally more expensive than its non-robust counterpart.

Robust Bayesian allocation

Attílio Meucci

Using the Bayesian posterior distribution of the market parameters we determine self-adjusting uncertainty regions, which take the investor's prior into account, for the robust mean-variance problem. Under the standard normal-inverse-Wishart conjugate assumption for the market, the ensuing robust Bayesian mean-variance efficient frontier simplifies to a parsimonious set. This set is parametrized by the exposure to overall risk, which includes market risk, estimation risk for the expected values and estimation risk for the covariances.

Persistency and its applications in discrete choice theory

Karthik Natarajan

A mathematical notion of persistency in optimization problems has recently been introduced. Under uncertain data, this is the probability that a decision variable takes a particular value in an optimal solution. In this talk, we discuss some implications of the notion of persistency in discrete choice theory. The approach of identifying persistency is based on techniques of conic programming.

Risk contributions in diversified portfolios

Georg Pflug

We give a definition of the contribution to the total risk of a portfolio, which is due to one particular portfolio item or one portfolio category. Since risk measures are typically nonadditive, we use a "local" notion, which turns out to be relevant in portfolio optimization, since it is related to the Karush-Kuhn-Tucker conditions. In particular, optimal portfolios are characterized by the fact that the relative risk contribution of all items is equal. Moreover, we discuss the notion of RAROC (risk adjusted return on capital) and relate it to the notion of risk contributions.

As a practical example, we show how the relative return and risk contributions of a portfolio can be visualized. These visualizations allow the decision maker to identify portfolio items, whose relative weights should be increased or decreased to fulfill a certain risk/return objective.

Robust scenario optimization based on downside-risk measure for multi-period portfolio selection

Mustafa Pinar

We develop and test multistage portfolio selection models maximizing expected end-of-horizon return while minimizing one-sided deviation from a target return level. The trade-off between two objectives is controlled by means of a non-negative parameter as in Markowitz Mean-Variance portfolio theory. We use a piecewise-linear penalty function, leading to linear programming models and ensuring optimality of subsequent stage decisions. We adopt a simulated market model to randomly generate scenarios approximating the market stochasticity. We report results of rolling horizon simulation with two variants of the proposed models depending on the inclusion of transaction costs, and under different simulated stock market conditions. We compare our results with the usual expected return-based stochastic programming models. The results indicate that the robust investment policies are indeed quite stable in the face of market risk while ensuring expected return levels quite similar to the competing expected-return maximizing stochastic programming model at the expense of solving larger linear programs.

Valuation of a production asset subject to production constraints

Arnaud Porchet

We study the valuation problem of a production asset in a financial market, in presence of production constraints. We use the utility indifference approach to define such a value. We provide a characterization in terms of the solution of a reected back-ward stochastic differential equations system. We then show that this

price coincides with the Black-Scholes price when there are no constraints and a complete market. We finally give a numerical scheme to compute the value of the physical asset.

Pricing exotic options with semidefinite programming

Tomás Prieto-Rumeau

We present a new methodology for the numerical pricing of a class of exotic derivatives such as European, Asian, Parisian or barrier options when the underlying asset price dynamics are modeled by a geometric Brownian motion or a number of mean-reverting processes of interest.

This methodology identifies derivative prices with infinite-dimensional linear programming problems involving the moments of appropriate measures, which are then relaxed to semi-definite programs indexed by the number of moments considered.

This method provides monotone sequences of both upper and lower bounds, which, in most cases, are shown to be convergent. Numerical investigation shows that very good results are obtained with only a small number of moments.

Portfolio selection models with complementarity constraints

Marius Radulescu

In this paper we extend Markowitz's portfolio selection model to include transaction costs in the presence of initial holdings for the investor. Our approach is new. Our aim is to obtain an optimal portfolio which has a minimum risk or a maximum return. The portfolio selection models are mathematical programming problems with complementarity constraints. For the case of linear transaction costs we give several heuristic algorithms for solving the models and we show that our models are equivalent to mathematical programming problems with nonsmooth constraints.

Joint with: Sorin Radulescu and Constanta Radulescu

Mortgage loan portfolio optimization using mixed integer multi stage stochastic programming with scenario reduction

Kourosh Rasmussen

The Danish mortgage loan system is among the most complex of its kind in the world. Purchase of most properties in Denmark is financed either by issuing fixed-rate callable mortgage bonds or through issuing non-callable short or medium-term bullet bonds. Such loans may be refinanced at the market rate on an ongoing basis. The complexity of the mortgage loan system makes it a non-trivial task to decide on an initial choice of mortgage loan portfolio and on finding a continuing

plan to readjust the portfolio optimally. We develop a mixed integer stochastic programming model for the Danish mortgagor problem and extend the model to reflect the choices of a mortgagor as well as his attitude towards interest rate and wealth risk. The models are difficult to solve for more than 10 stages. We suggest a scenario reduction scheme which results in near optimal solutions for problems up to 30 stages. Our results show that the standard Danish mortgagor should hold a more diversified portfolio of mortgage loans, and that he should rebalance the portfolio more frequently.

Parametric analysis in convex quadratic optimization and its applications to portfolio selection models

Oleksandr Romanko

We present an Interior Point Method and optimal partition based technique, and provide a polynomial time algorithm for conducting sensitivity and parametric analysis of Convex Quadratic Optimization problems. A general case of simultaneous perturbation in the coefficient vector of the linear term of the objective function and in the right-hand side vector of the constraints is considered. We will discuss the implementation issues for the outlined algorithm. A well-known application of parametric quadratic optimization is the classical mean-variance portfolio selection problem. We also illustrate applications of parametric analysis to other portfolio selection models as well as extensions of the mean-variance model.

Joint with: Alireza Ghaffari Hadigheh and Tamas Terlaky

Temporal difference learning with kernels

Jean-Sebastien Roy

To overcome the curse of dimensionality usually encountered in dynamic programming problems with high-dimensional state spaces, most approaches so far have proposed to approximate the value function as a linear combination of a predefined finite functional basis, therefore giving up optimality. We introduce an alternative approach, based on functional gradient descent and using an infinite kernel basis, that preserve optimality under very light conditions while being implementable in practice. We proceed to illustrate a temporal difference scheme adapted to this approach, on Bermudean option pricing.

Joint with: Kengy Barty and Cyrille Strugarek

Benefits and costs of robust portfolio optimization

Katrin Schöttle

Although being very famous among practitioners in asset management, classical Markowitz optimization is not extensively used for deriving optimal asset allocations. This is mostly due to severe limitations on the stability of the optimal portfolios with respect to the input data, especially with respect to estimated expected returns. One possibility to avoid this shortcoming and to achieve more robust solutions of optimization problems is the robust counterpart approach as introduced by Ben-Tal and Nemirovski. Certainly, robust solutions cannot be obtained for free, hence after shortly introducing the general approach, the main part of the talk will deal with the unavoidable costs of this method. We will show that a trade-off between stability and optimality (i.e. performance) has to be made. Considerations of model and estimation risk yield an optimal trade-off and thus the optimal degree of robustification. We illustrate the effectiveness of our approach on a real-world example.

Portfolio optimization under regime switching: Applications to hedge fund portfolio management

Luís Seco

In this talk we consider a portfolio optimization problem where the underlying asset returns are distributed as a mixture of two multivariate Gaussians; these two Gaussians may be associated with "distresse" and "tranquil" market regimes. In this context, the Sharpe ratio needs to be replaced by other non-linear objective functions which, in the case of many underlying assets, lead to optimization problems which cannot be easily solved with standard techniques. We obtain a geometric characterization of efficient portfolios, which reduces the complexity of the portfolio optimization problem.

Testing for stochastic dominance efficiency

Nikolas Topaloglou

We consider consistent tests for stochastic dominance at any order of a given portfolio with respect to all possible portfolios constructed from a set of assets. We propose and justify approaches based on simulation and the block bootstrap to achieve valid inference in a time series setting. We also suggest estimators of efficiency lines up to which we may assert that stochastic dominance efficiency is achieved. The test statistics and the estimators are computed using mixed integer programming.

Global optimization of VaR (Value-at-Risk) portfolios using continuation methods

Arun Verma

Value at Risk is defined as the maximum loss of a portfolio given a future time horizon within high confidence or probability (typical values used are 95% or 99%). In our work VaR is computed using Monte Carlo simulations and has the following properties:

1. VaR is a non-coherent measure of risk; in particular, it is not sub-additive thus violating one of the requirements of a coherent risk measure.
2. VaR also happens to be a non-convex (multiple local minima, potentially a lot).
3. VaR is a piece-wise non-linear function and thus a non-differentiable function of the independent variables, which are the weights of different securities in a portfolio.
4. The number of linear pieces is proportional to number of scenarios.

The above properties make search for a global minimum of VaR a very difficult problem, in fact an NP-hard problem. We outline efficient algorithms for this hard problems using continuation methods for global minimum search. The results show that optimal VaR is within 1% of global minimum if found and as efficient as finding a solution to a convex conditional-VaR minimization problem.

Joint with: Thomas Coleman

A stochastic programming framework for managing international portfolios

Hercules Vladimirou

We present a stochastic programming framework for managing portfolios of stock and bond indices denominated in multiple currencies. Internationally diversified portfolios broaden the scope for diversification, but are exposed to market risks and currency risks. The international portfolio selection problem and the risk hedging decisions are typically considered separately in practice and in the literature. We take a holistic view of the problem and employ multistage stochastic programming models that address risk management issues in an integrated manner. The models determine not only the capital allocation in each market, but also the selection of specific securities within each market, as well as the use of appropriate instruments for hedging the two main sources of risk. We explore alternative risk hedging strategies. We consider options on stock indices as means for controlling the market risk. For currency risk, we consider either forward currency contracts or currency options as risk hedging instruments. Thus, several interrelated decisions

are addressed in a common framework. The incorporation of options in stochastic optimization models for portfolio management is a novel contribution. Uncertainty in asset returns and exchange rates is represented by means of discrete distributions (scenario sets). Empirical evidence indicates that these random variables exhibit asymmetric distributions with fat tails. Hence, we employ a moment-matching scenario generation procedure that captures asymmetry and excess kurtosis in the distributions of the random variables, as well as their correlations. For internal consistency of the optimization models, the options must be priced consistently with the postulated scenario sets for the underlying securities, while at the same time satisfying fundamental economic principles (i.e., no-arbitrage conditions). To this end, we adapt appropriate procedures for pricing the options consistently with the scenario sets for the underlyings. Through extensive computational experiments, both in static as well as in dynamic settings we demonstrate (a) the benefits of international diversification, (b) the impact of alternative hedging strategies — including options — to control the main risk exposures, (c) the relative performance of alternative risk hedging strategies and alternative model forms. We find that additional benefits are gained as an increasingly integrated view towards total risk management is taken, i.e., as the constituent risks are jointly controlled through appropriate means.

Joint with: Nikolas Topaloglou and Stavros Zenios

Efficient approximation of robust portfolio optimization problems

Ralf Werner

In the last years, a few authors have applied the robust counterpart approach of Ben-Tal and Nemirovski to mean-variance portfolio optimization. Most approaches rely on the ability to express the resulting semi-infinite robust counterpart in an appropriate cone formulation (Goldfarb) or switch to simpler uncertainty sets (Bertsimas). Another way of tackling the robust formulation was done recently by means of saddle-point programming. We will show how a general robust counterpart of a conic problem with an uncertainty set with rather complicated structure can be approximated by a sequence of standard conic problems. The approximation, which basically relies on the cascading algorithm developed by Kocvara for robust material optimization, is compared to the existing approaches. We illustrate our method on two robust formulations of the Markowitz portfolio problem with two realistic uncertainty sets used in practical implementations by a German asset managing company.

On the cost of delayed fixing announcements and its impact on FX exotic options

Uwe Wystup

In Foreign Exchange Markets vanilla and barrier options are traded frequently. The market standard is a cutoff time of 10 am in New York for the strike of vanillas and a knock-out event based on a continuously observed barrier. However, many clients, particularly from Italy, prefer the cutoff and knock-out event to be based on the fixing published by the European Central Bank on the Reuters Page ECB37. These barrier options are called discretely observed barrier options. While these options can be priced in several models by various techniques, the ECB source of the fixing causes two problems. First of all, it is not tradable, and secondly it is published with a delay of about 15-20 minutes. We examine here the effect of these problems on the hedge of these options and consequently suggest a cost based on the additional uncertainty encountered.

Joint with: Christoph Becker

Robust portfolio optimisation using maximisation of min eigenvalue methodology

Denis Zuev

This work deals with the discussion of the problems with the standard Markovitz model faced when measurement errors make the covariance matrix singular (almost singular) and hence produce not well diversified unstable portfolios. This problem can be addressed by choosing the covariance matrix with the maximal min eigenvalue among the set of possible covariance matrices. We will be looking at the stability of the corresponding portfolio and hence will be trying to track the portfolio index in the most efficient way.

Optimal semi-parametric bounds for European rainbow options

Luís Zuluaga

We consider the problem of computing the best upper and lower semi-parametric bounds on the expected payoff of a European "rainbow" option; that is, an option whose payoff depends on the price of various underlying asset prices. In practice, these bounds are used to obtain information about option prices under incomplete market conditions, or to approximate options prices that are difficult to compute exactly. We show how conic optimization techniques can be used to either prove the optimality or improve the best known semi-parametric bounds for European options on the maximum of several assets. In addition, we show that these same techniques can be applied to a wide variety of European rainbow options.

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