# Stieltjes/CentER/MRI/STAR

# 9th Winter School on Mathematical Finance

Special Topics:

Numerical methods

Illiquid markets

**January 18 – 20, 2010**
**CongresHotel De Werelt, Lunteren**

Sponsored by NWO and ESF

# Stieltjes/CentER/MRI/STAR Winter School on Mathematical Finance

In recent years, the mathematical theory associated with financial risk management and the pricing of contingent claims has been a highly active field of research. The area has established itself as one of the most vigorously growing branches of applied mathematics. Model-based analysis of contracts and portfolios has become a standard in the finance industry, and the number of academic institutions offering curricula in financial mathematics is increasing rapidly. In this context, the winter school on Mathematical Finance that will take place January 18–20, 2010 in Lunteren aims at providing a meeting place for participants both from industry and from academia. The program provides ample opportunity for discussion.

The special topics of the 9th winter school are *Numerical methods* and *Illiquid markets*. These are the subjects of minicourses that will be taught by two distinguished speakers: Professor Peter Forsyth (Cheriton School of Computer Science, University of Waterloo) and Professor Alexander Schied (Universität Mannheim). Additionally there will be three one-hour lectures by Professors Pauline Barrieu (London School of Economics), Mark Davis (Imperial College, London) and Peter Tankov (Ecole Polytechnique, Palaiseau). Thirty-minute lectures on recent research work in the Netherlands will be presented by Dion Bongaerts (Universiteit van Amsterdam), Alexander van Haastrecht (Universiteit van Amsterdam), Vincent Leijdekker (Universiteit van Amsterdam and ABN AMRO) and Mitja Stadje (Eurandom, Eindhoven).

## Auspices and sponsoring

The winter school takes place under the auspices of three research schools, to wit:

- Center for Economic Research (CentER)
- Mathematics Research Institute (MRI)
- Thomas Stieltjes Institute for Mathematics.

CentER is the research school of the Faculty of Economics and Business Administration of Tilburg University. The mathematics departments of the universities of Groningen, Nijmegen, Twente, and Utrecht cooperate in MRI, while the Stieltjes Institute involves mathematics groups at the two universities in Amsterdam and at the universities in Delft, Eindhoven, Leiden, Rotterdam, and Tilburg. The winter school is supported financially by the three research schools, by the Netherlands Organization for Scientific Research (NWO) and by the research program AMaMeF (Advanced Mathematical Methods for Finance) of the European Science Foundation (ESF). The winter school is also supported by the newly created Dutch research cluster STAR (Stochastics — Theoretical and Applied Research).

Administrative assistance is provided by the Korteweg–De Vries Institute for Mathematics of the Universiteit van Amsterdam.

## Organizers

The winter school is organized by:

Hans Schumacher (Department of Econometrics and Operations Research, Tilburg University; tel. 013-4662050, e-mail `jms@uvt.nl`)

Peter Spreij (Korteweg–De Vries Institute for Mathematics, Universiteit van Amsterdam; tel. 020-5256070, e-mail `spreij@uva.nl`).

## Program outline

The program starts with registration and coffee on Monday, January 18, from 10:30 to 11:30, and ends on Wednesday, January 20, at 16:00. The following events are planned:

### Minicourses

Peter Forsyth
*Numerical methods for Hamilton-Jacobi-Bellman equations in finance*

Alexander Schied
*Market impact models and optimal execution*

### Special invited lectures

Pauline Barrieu
*Robust asset allocation under model uncertainty*

Mark Davis
*Risk-sensitive asset management with jump-diffusion price processes*

Peter Tankov
*Discrete hedging in exponential Lévy models*

### Short contributions

Dion Bongaerts
*Corporate bond liquidity and the credit spread puzzle*

Alexander van Haastrecht
*Valuation of guaranteed annuity options using a stochastic volatility model for equity prices*

Vincent Leijdekker
*Sample-path large deviations in credit risk*

Mitja Stadje
*Extending time-consistent risk measures from discrete time to continuous time: a convergence approach*

## Schedule of lectures

| | Monday<br>January 18 | Tuesday<br>January 19 | Wednesday<br>January 20 |
|---|---|---|---|
| 09:00 - 10:00 | | Schied | Schied |
| 10:30 - 11:30 | | Schied | Schied |
| 11:30 - 12:30 | Schied | Forsyth | Forsyth |
| 14:00 - 15:00 | | | Forsyth |
| 15:00 - 16:00 | Forsyth | Forsyth | Davis |
| 16:00 - 17:00 | Tankov | Barrieu | |
| 17:30 - 18:00 | Bongaerts | Van Haastrecht | |
| 18:00 - 18:30 | Leijdekker | Stadje | |

## Web page

Please see `www.mathfin.nl` for the latest information about the winter school.

## Venue

The winter school will take place at Congreshotel De Werelt, Westhofflaan 2, Lunteren, tel. 0318-484641, fax 0318-482924. Located in the heart of the Veluwe forest, De Werelt is one of the top accommodations in the Netherlands in terms of attractiveness of surroundings. Access by car or by public transportation is easy. By train, the village of Lunteren can be reached in twenty minutes from Amersfoort, and in ten minutes from Ede-Wageningen. It takes about fifteen minutes to walk from the railway station in Lunteren to the conference center (see directions below). If you come by car, ANWB signs in Lunteren will guide you to the venue. It is also possible to take a taxi from the taxi stand at railway station Ede-Wageningen. To get a taxi in Lunteren, call 0318-484555. For further details please see `www.congrescentrum.com/engels/index.htm`.

Directions from the railway station: leaving the station, turn right across the pebble-covered parking lot. Turn left into the forest (Boslaan). At the crossroads, turn right into Molenweg. The first turn left is Westhofflaan.

# Abstracts

## Minicourse on Numerical methods

Peter Forsyth (University of Waterloo)

*Numerical methods for Hamilton-Jacobi-Bellman equations in finance*

Many problems in finance can be posed as non-linear Hamilton Jacobi Bellman (HJB) Partial Integro Differential Equations (PIDEs). Examples of such problems include: dynamic asset allocation for pension plans, optimal operation of natural gas storage facilities, optimal execution of trades, and pricing of variable annuity products (e.g. Guaranteed Minimum Withdrawal Benefit). This course will discuss general numerical methods for solving the HJB PDEs which arise from these types of problems. After an introductory lecture, we will give an example where seemingly reasonable methods do not converge to the correct (viscosity) solution of a nonlinear HJB equation. A set of general guidelines is then established which will ensure convergence of the numerical method to the viscosity solution. Emphasis will be placed on methods which are straightforward to implement. We then illustrate these techniques on some of the problems mentioned above.

Lecture 1: Examples of HJB equations, viscosity solutions
Lecture 2: Sufficient conditions for convergence to the viscosity solution
Lecture 3: Pension plan asset allocation, passport options
Lecture 4: Guaranteed minimum withdrawal benefit (GMWB) variable annuity
Lecture 5: Gas storage

## Minicourse on Market impact models

Alexander Schied (Universität Mannheim)

*Market impact models and optimal execution*

We consider mathematical problems arising in illiquid markets or, more specifically, when trading asset positions that are large enough to move the underlying asset price. In dealing with this situation, we first need a suitable modeling framework. We will thus discuss several model classes proposed in the literature. It turns out that requiring that these models are free of arbitrage opportunities in the usual sense may not be enough, and we illustrate this fact by several examples. We therefore discuss additional requirements that should be met by any viable market impact model. The problem of model viability is actually closely related to finding strategies that unwind or acquire large asset positions in an optimal way. This problem is known as the optimal execution problem. We give an overview over some of the results that are known to date. We conclude by discussing the situation in which there are several market participants: a seller who needs to unwind a large asset position and a group of informed arbitrageurs trying to make a profit out of this.

## Special invited lectures

Pauline Barrieu (London School of Economics)

*Robust asset allocation under model uncertainty*

In the present paper, we propose a robust decision methodology, when there is some ambiguity concerning the potential future scenarii about decision variables, such as financial asset dynamics. The decision maker considers several prior models for those scenarii and displays an ambiguity aversion against them. We have developed a two step ambiguity robust methodology, that offers the advantage to be more tractable and easier to implement than the various approaches proposed in the literature. This methodology decomposes the ambiguity adjustment into a model specific ambiguity adjustment as well as a relative ambiguity adjustment for each of the considered models. The optimal solutions inferred by each prior are transformed through a generic absolute ambiguity function. Then, the transformed solutions are together mixed through a measure that reflects the relative ambiguity aversion of the decision maker for the different priors considered. This methodology is then illustrated through empirical study of asset allocation. Based on a joint work with Sandrine Tobelem.

Mark Davis (Imperial College, London)

*Risk-sensitive asset management with jump-diffusion price processes*

Risk-sensitive asset management (RSAM) is in some sense 'dynamic Markowitz' — a trade-off between risk and return in a fully dynamic setting. In earlier work we studied a problem in which asset prices follow jump-diffusions where the mean rates of return are functions of an exogenous 'factor' process $X_t$ which was supposed to be a diffusion (i.e. continuous paths). We showed that RSAM reduces to a stochastic control problem for a diffusion process, for which the Bellman equation has a classical solution. Here we consider the general case where $X_t$ also has jumps. Then the associated stochastic control problem is one of controlled jump-diffusions. We show that the value function is a viscosity solution of the associated Bellman PIDE and derive smoothness properties of the solution. (Joint work with Sebastien Lleo.)

Peter Tankov (Ecole Polytechnique, Palaiseau)

*Discrete hedging in exponential Lévy models*

Most authors who studied the problem of option hedging in incomplete markets, focused on finding the strategies which minimize the residual hedging error. However, the resulting strategies are usually unrealistic because they require continuous trading. In practice, the portfolios are readjusted at discrete dates, which leads to a 'hedging error of the second type', due to the difference between the optimal portfolio and its discretized version. In this talk, we review some recent results on the structure of this discretization error in the context of exponential Lévy models. We discuss the rates of convergence of the error to zero when the number of trading dates increases, under different strategies and pay-off profiles, and show how this convergence can be improved with a suitable choice of readjustment dates.

## Short contributions

Dion Bongaerts (Universiteit van Amsterdam)

*Corporate bond liquidity and the credit spread puzzle*

This paper explores the role of expected liquidity and liquidity risk in the pricing of corporate bonds. In particular, we investigate to which extent liquidity can help to explain the credit spread puzzle. For our analysis, we use the TRACE data on an intra-day frequency. Since these data do not contain bid-ask-spreads, we estimate them latently using a Gibbs sampler in a similar spirit as in Hasbrouck (forthcoming). We find a significant premium on expected liquidity, but little evidence for liquidity risk. The liquidity premium goes a long way in explaining the credit spread puzzle.

Alexander van Haastrecht (Universiteit van Amsterdam)

*Valuation of guaranteed annuity options using a stochastic volatility model for equity prices*

Guaranteed Annuity Options are options providing the right to convert a policy-holder's accumulated funds to a life annuity at a fixed rate when the policy matures. These options were a common feature in UK retirement savings contracts issued in the 1970's and 1980's when interest rates were high, but caused problems for insurers as the interest rates began to fall in the 1990's. Currently, these options are frequently sold in the U.S. and Japan as part of variable annuity products. The last decade the literature on pricing and risk management of these options evolved. Until now, for pricing these options generally a geometric Brownian motion for equity prices is assumed. However, given the long maturities of the insurance contracts a stochastic volatility model for equity prices would be more suitable. In this paper closed form expressions are derived for prices of guaranteed annuity options assuming stochastic volatility for equity prices and either a 1-factor or 2-factor Gaussian interest rate model. The results indicate that the impact of ignoring stochastic volatility can be significant.

Vincent Leijdekker (Universiteit van Amsterdam, ABN AMRO)

*Sample-path large deviations in credit risk*

The event of large losses plays an important role in a portfolio credit risk. As these large losses are typically rare, and portfolios usually consist of a large number of positions, large deviation theory is the natural tool to analyze the tail asymptotics of the probabilities involved. We first derive a sample-path large deviation principle (LDP) for the portfolios loss process, which enables the computation of the logarithmic decay rate of the probabilities of interest. In addition, we derive exact asymptotic results for a number of specific rare-event probabilities, such as the probability of the loss process exceeding some given function.

Mitja Stadje (Eurandom)

*Extending time-consistent risk measures from discrete time to continuous time: a convergence approach*

The main aim of this talk is to present an approach to the transition from risk measures in discrete time to their counterparts in continuous time. After a general introduction to risk assessment in mathematical finance, it is shown that a large class of risk measures in continuous time can be obtained as limits of time-consistent risk measures in a discrete setting. The discrete-time risk measures are constructed from properly rescaled ('tilted') one-period risk measures, using a d-dimensional random walk converging to a Brownian Motion. Under suitable conditions (covering the classical one-period risk measures) we obtain convergence of the discrete risk measures to the solution of a backward stochastic differential equation, defining a risk measure in continuous time, whose driver can then be viewed as the continuous-time analogue of the discrete driver characterizing the one-period risk. We derive the limiting drivers for the semi-deviation risk measure, Average Value at Risk, and the Gini risk measure in closed form.

# Registration

To register for the winter school, please use the electronic registration form that is available at the web page of the winter school (see `www.mathfin.nl` or `www.science.uva.nl/~spreij/stieltjes/winterschool.html`). Alternatively, you may complete the registration form on the last page and return it to ms. E. Wallet, Korteweg–De Vries Institute for Mathematics, PO Box 94248, 1090GE Amsterdam.

The registration fee includes accommodation (single room) for the nights of January 18 and 19, all meals starting with lunch on Monday up to and including lunch on Wednesday, and tea and coffee during breaks. Payment can be made by transferral to account 7388994 of Winter School Amsterdam, Secretariaat Korteweg–De Vries Instituut, Amsterdam. For international money transfers please use the bank codes IBAN: NL27 INGB 0007388994 and BIC: INGBNL2A. The fee schedule is as follows:

| | early registration (before December 1) | late registration (after December 1) |
|---|---|---|
| standard | 1600 euro | 1900 euro |
| full-time university staff | 340 euro | 390 euro |

Inquiries concerning fees for partial attendance may be directed to ms. Wallet at the address given below. Registration will be valid after full payment has been received. Refunds can be given only for cancellations received before January 1, 2010.

Accommodation at the venue is limited. Therefore, reservations will be treated on a first-come-first-served basis with priority for full arrangements. Participants who cannot be lodged at the venue will be accommodated in a hotel nearby. Transportation from the hotel to the venue and vice versa will be taken care of by the organization.

# Further information

For further information regarding the scientific program, please contact one of the members of the organizing committee. For information concerning registration please contact:

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**9th Winter School on Mathematical Finance**

**Lunteren, January 18–20, 2010**

# Registration Form

Last name: _____

First name: _____

Affiliation: _____

Address: _____

_____

_____

_____

Telephone: _____

Fax: _____

Email address: _____

Date: _____

Signature: _____

Please return the completed form *before January 1, 2010* to:

ms. E. Wallet
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PO Box 94248
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*Registration is valid only after full payment has been received following the fee schedule.*