NWO/STAR/PWN

19th Winter School on Mathematical Finance

Special topics:

Dealing with Market Frictions

Hedging in Markets with Price Impact

January 20–22, 2020
Congrescentrum De Werelt, Lunteren

Sponsored by NWO, STAR, PWN, and FWO

NWO/STAR/PWN
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 has increased rapidly. In this context, the winter school on Mathematical Finance that will take place on January 20–22, 2020 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 19th winter school are *Dealing with Market Frictions*, and *Hedging in Markets with Price Impact*. These are the subjects of minicourses that will be taught by two distinguished speakers: Professors Peter Bank (Technische Universität Berlin) and Bruno Bouchard (Université Paris-Dauphine). Additionally there will be three one-hour special invited lectures by Professors René Aïd (Université Paris-Dauphine), Martin Keller-Ressel (Technische Universität Dresden) and Vladimir Piterbarg (NatWest Markets). Thirty-minute lectures on recent research work in the Netherlands will be presented by Arnoud den Boer (University of Amsterdam), Guusje Delsing (Rabobank and University of Amsterdam), Lingwei Kong (University of Amsterdam) and Sofie Reyners (KU Leuven).

Auspices, sponsoring and grants

The Winter School takes place under the auspices of the mathematics cluster STAR and of PWN. The stochastics groups of the mathematics departments of the universities in The Netherlands cooperate in STAR. PWN (Platform Wiskunde Nederland) is a national organization that aims to strengthen the position of mathematics in The Netherlands in all its aspects. The winter school is supported financially by STAR, PWN, by the Netherlands Organization for Scientific Research (NWO) and by the Research Foundation - Flanders (FWO). Administrative assistance is provided by the Korteweg–De Vries Institute for Mathematics of the University of Amsterdam.

The FWO WOG research network Stochastic Modelling with applications in financial markets has made available a limited number of grants for young researchers (PhD students and postdocs) associated to the network to be used as a waiver of the registration fee for the winter school. For those researchers the grants completely cover the registration fee. For other young researchers a limited number of grants of € 250 each is available as a reduction on the registration fee for the winter school. Priority will be given to grant applications from PhD students whose supervisor is a member of the network, but others are invited to apply as well. Applications for the grant can be sent by email to both Michel Vellekoop and Peter Spreij (make sure that both are addressed). Applications are required to contain a brief motivation why the grant should be beneficial for the research of the applicant, a brief motivation why the applicant has a specific need for the grant, a (link to) a CV of the applicant and the name of her/his principal supervisor. Applications should be submitted before the deadline, November 20, 2019.

Organizers

The winter school is organized by:

Michel Vellekoop (Faculty Economics and Business, University of Amsterdam; tel. +31 20 5254210, e-mail m.h.vellekoop@uva.nl)

Peter Spreij (Korteweg–De Vries Institute for Mathematics, University of Amsterdam and IMAPP, Radboud University; tel. +31 20 5256070, e-mail spreij@uva.nl).

Program outline

The program starts with registration and coffee on Monday, January 21, from 10:30 to 11:30, and ends on Wednesday, January 23, at 16:00. The following events are planned:

Minicourses

Peter Bank
Dealing with market frictions: some challenges for stochastic analysis and optimal control

Bruno Bouchard
Hedging in market models with linear price impact

Special invited lectures

René Aïd
Optimal electricity demand response contracting with responsiveness incentives

Martin Keller-Ressel
Total positivity and the shape of the yield curve

Vladimir Piterbarg
The classical optimal investment problem: modern models and deep learning

Short contributions

Arnoud den Boer
Dynamic pricing and learning

Guusje Delsing
Capital reserve management for a multi-dimensional risk model

Lingwei Kong
Hansen-Jagannathan distance in the presence of weak (proxy) factors

Sofie Reyners
Machine learning for derivative pricing: Gaussian processes vs. gradient boosting

Website

https://staff.fnwi.uva.nl/p.j.c.spreij/winterschool/winterschool.html

Schedule of lectures

	Monday January 20	Tuesday January 21	Wednesday January 22
09:00 - 10:00		Bank	Bank
10:30 - 11:30		Bank	Bank
11:30 - 12:30	Bank	Bouchard	Bouchard
14:00 - 15:00			Bouchard
15:00 - 16:00	Bouchard	Bouchard	Aïd
16:00 - 17:00	Piterbarg	Keller-Ressel	
17:30 - 18:00	Delsing	den Boer	
18:00 - 18:30	Kong	Reyners	

Venue

The winter school will take place at Congrescentrum De Werelt, Westhofflaan 2, Lunteren, tel. +31-(0)318-484641, fax +31-(0)318-482924. 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 +31-(0)318-484555. For further details please see https://dewerelt.nl/en/ (under ABOUT US).

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 Dealing with Market Frictions

Peter Bank (Technische Universität Berlin)

Dealing with market frictions: some challenges for stochastic analysis and optimal control

Frictions in financial markets have proven a wonderful source for mathematical challenges at the interfaces of Finance, Optimal Control, and Stochastic Analysis. This course will present some tractable models which have been proposed in the literature on optimal trading when markets are not perfectly elastic to demand shocks. We will show how linear-quadratic optimization emerges naturally from asymptotic expansions and discuss how solutions to such problems can be interpreted concisely in practical terms. The tractability of these models also allows for a multi-agent Nash equilibrium analysis which sheds some light on price formation in dealer markets. More refined models of liquidity with transient impact lead to singular control problems for which we develop some tools from convex duality theory. Our discussion will include a number of open questions and challenges left unanswered by my works with Yan Dolinsky, Moritz Voss, Mete Soner, and David Besslich that will serve as the basic references for this course.

Minicourse on Hedging in Markets with Price Impact

Bruno Bouchard (Université Paris-Dauphine)

Hedging in market models with linear price impact

We will study a class of financial market models in which prices are affected by trading strategies, in a seemingly linear way. This creates both market impact and illiquidity costs. We shall consider two situations: 1. The option is un-covered, meaning that the premium is paid in cash and the amount of cash and stocks to be delivered at maturity are fixed by the payoff; 2. The option is covered, meaning that the premium is paid and the payoff is delivered in cash and stocks (at their current market price) with proportions decided by the trader. In both cases, we shall show how stochastic target techniques allow one to derive pricing PDEs, and that, under additional smoothness conditions, these PDEs allow us to derive perfect hedging strategies. In case 1., the equation is semi-linear, it is fully non-linear in case 2. This shows that: a. the impact of having to jump to certain deltas at initiation and at maturity has a strong impact on the nature of the hedging strategy; b. although these markets exhibit frictions, perfect hedging is still possible (up to a face-lifting in case 2.). We will go further in the case of covered options and show some asymptotic results for asymptotically small market impact, which allows to construct approximate hedging strategies based on the traditional Black and Scholes delta hedging policy. We shall also prove a dual formulation in this case, reducing the search for a hedging strategy to the resolution of an optimal control in standard Mayer form.

Special invited lectures

René Aïd (Université Paris-Dauphine)

Optimal electricity demand response contracting with responsiveness incentives

Despite the success of demand response programs in retail electricity markets in reducing average consumption, the random responsiveness of consumers to price event makes their efficiency questionnable to achieve the flexibility needed for electric systems with a large share of renewable energy. The variance of consumers' responses depreciates the value of these mechanisms and makes them poorly reliable. This paper aims at designing demand response contracts which allow to act on both the average consumption and its variance. The interaction between a risk–averse producer and a risk–averse consumer is modelled as a Principal-Agent problem, thus accounting for the moral hazard underlying demand response contracts. The producer, facing the limited flexibility of production, pays an appropriate incentive compensation in order to encourage the consumer to reduce his average consumption and to enhance his responsiveness. We provide a closed–form solution for the optimal contract in the case of constant marginal costs of energy and volatility for the producer and constant marginal value of energy for the consumer. We show that the optimal contract has a rebate form where the initial condition of the consumption serves as a baseline. Further, the consumer cannot manipulate the baseline at his own advantage. The first–best price for energy is a convex combination of the marginal cost and the marginal value of energy where the weights are given by the risk-aversion ratio, and the first–best price for volatility is the risk-aversion ratio times the marginal cost of volatility. The second–best price for energy and volatility do not share this simple structure. They are non–linear and non–constant in time. The price for energy is lower (resp. higher) than the marginal cost of energy during peak–load (resp. off–peak) periods. We illustrate the potential benefit issued from the implementation of an incentive mechanism on the responsiveness of the consumer by calibrating our model with publicly available data. We predict a significant increase of responsiveness under our optimal contract and a significant increase of the producer satisfaction. Joint work with Dylan Possamaï (Columbia University) and Nizar Touzi (Ecole Polytechnique).

Martin Keller-Ressel (Technische Universität Dresden)

Total positivity and the shape of the yield curve

The term structure of interest rates - summarized in the form of the yield or forward curve - is one of the most fundamental economic indicators. Its shape encodes important information on the preferences for short- vs. long-term investments, the desire for liquidity and on expectations of central bank decisions and the general economic outlook. It is therefore a natural question - to be asked of any mathematical model of the term structure - which shapes of yield and forward curves the model is able to (re-)produce. For one-dimensional affine models, such as the Vašíček and the Cox-Ingersoll-Ross model, it has been known for some time that only normal, inverse and humped curves can be produced. In this talk, we provide for the first time a systematic classification of term structure shapes beyond the one-dimensional case and discuss the classification of yield and forward curve shapes in the two-dimensional Vašíček model. As expected, several additional shapes, such as a dipped curve, become attainable in the two-factor model. Our main mathematical tool is the theory of total positivity (pioneered by Schönberg,

Gantmacher, Krein and Karlin in the last century), a theory linked to the variation-diminishing properties of certain matrices, function systems and integral kernels. We explain how total positivity can be applied to the shape analysis of the term structure in case of the two-factor Vašíček model and discuss possible applications to other multi-factor interest rate models as well.

Vladimir Piterbarg (NatWest Markets)

The classical optimal investment problem: modern models and deep learning

We revisit the classical Merton optimal allocation problem and consider it through the lens of modern local and stochastic volatility models. We demonstrate that the adjustments to the myopic Merton ratio can be largely deduced from observed option prices. Furthermore, we investigate how deep learning techniques could help us determine a model-free optimal investment strategy.

Short contributions

Arnoud den Boer (University of Amsterdam)

Dynamic pricing and learning

For sellers of (online) services or commodities, efficiently learning optimal selling prices from accumulating sales data is an important challenge. This problem has received lots of research attention in the last decade, both from the operations research and computer science community. In this talk I will describe a few important and intriguing recent results.

Guusje Delsing (University of Amsterdam)

Capital reserve management for a multi-dimensional risk model

Firms should keep capital to offer sufficient protection against the risks they are facing. In the insurance context methods have been developed to determine the minimum capital level required, but less so in the context of firms with multiple business lines including allocation. This research focuses on the calculation of finite-time ruin probabilities and capital reserves for a multi-dimensional risk model. The individual reserves of these lines of business are modelled by means of a Cramér-Lundberg model with constant incoming premiums and outgoing claims that arrive according to a Poisson process. To allow for dependence between business lines we introduce a common (latent) environmental factor. This environmental factor impacts the claim inter-occurrence times as well as the claim sizes. Considering a fixed environmental process over time, we present a novel Bayesian approach to calibrate the latent environmental state distribution based on observations concerning the claim processes. We then allow for the distribution of individual claims to change over time by using a Markov environmental process. For the latter, we present two approximations for the finite-time multivariate survival/ruin probabilities: a diffusion approximation and a single-switch approximation. Finally, we point out how to determine the (allocated) optimal initial capital of the different business lines under specific constraints on the ruin/survival probability of subsets of business lines. This research has been performed together with Erik Winands, Michel Mandjes and Peter Spreij.

Lingwei Kong (University of Amsterdam)

Hansen-Jagannathan distance in the presence of weak (proxy) factors

We analyse the Hansen-Jagannathan (HJ) distance statistic in a GMM framework and show its misbehaviour in the presence of weak/useless (proxy) factors. We provide a new test procedure for the specification test based on the HJ distance which is robust against the presence of weak (proxy) factors. We also show the conventional test procedure tends to over-reject correct model specification and our test procedure leads to size-correct results. Our simulation exercises support our theory.

Sofie Reyners (KU Leuven)

Machine learning for derivative pricing: Gaussian processes vs. gradient boosting

In the derivatives world, daily zillion computations need to be done. Since financial models and instruments have become more and more complex, this is not always trivial and one often has to rely on time-consuming numerical techniques. We show how machine learning algorithms can be used for speeding up classical computations, by deploying either Gaussian process regression (GPR) models or gradient boosting machine (GBM) models. The price we have to pay for this extra speed is some loss of accuracy, which is often very acceptable from a practical point of view. In this talk, we focus on speeding up advanced pricing methods for structured products. We compare the pricing performance and behavior of GPR and GBM models. Finally, we show how Greek profiles can be computed in an efficient and smooth way.

Reference

Jan De Spiegeleer, Dilip B. Madan, Sofie Reyners & Wim Schoutens (2018), Machine learning for quantitative finance: fast derivative pricing, hedging and fitting, *Quantitative Finance*, **18:10**, 1635–1643.

Registration procedure

To register for the winter school, please use the electronic registration form that is available at the web page of the winter school (see https://staff.fnwi.uva.nl/p.j.c.spreij/winterschool/winterschool.html). Registration, payment included, uses the ticket shop Paydro.

The fee schedule is as follows:

	early registration (before December 1)	late registration (after December 1)
industry professional	€1195	€1350
full-time academic	€395	€445

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, 2020.

Please note that PhD students and postdocs which receive an FWO WOG grant should also register at the website, to ensure accommodation. They should use the discount code (will be sent) in the registration process.

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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