Università degli Studi di Padova

Dipartimento Matematica

10th General AMaMeF Conference

Department of Mathematics “Tullio Levi - Civita”
University of Padova, Italy
22–25 June 2021

Advanced Mathematical Methods for Finance

Contents

1 General overview

Welcome to the 10th General AMaMeF Conference!

AMaMeF is a network of researchers active in the field of mathematical finance. AMaMeF provides platforms of knowledge exchange at the frontiers of research, facilitates the interaction between young and experienced researchers, and promotes the growth of expert education in mathematical finance. Our agenda is centered around knowledge sharing with focus on methods from probability, stochastic analysis, deterministic and stochastic control theory, the theory of differential equations, functional analysis, mathematical statistics, numerical analysis and simulation. The activities of AMaMeF are directed by the acting board, chaired by Prof. Robert Stelzer (University of Ulm).

The General AMaMeF Conference represents the most important event organised by AMaMeF, taking place in a roughly two-yearly schedule. The 10th General AMaMeF conference is hosted by the Department of Mathematics "Tullio Levi-Civita" of the University of Padova. During the last year, the Covid-19 pandemic has deeply impacted on our lives, from a personal as well as an academic viewpoint. Unfortunately, the current restrictions prevent the organisation of meetings in the traditional in-person format. For this reason, the 10th General AMaMeF will take place as a virtual event.

The program consists of 8 plenary lectures, 9 invited thematic sessions and 27 contributed sessions, for a total of 117 talks addressing a full range of topics in mathematical finance and related fields, both theoretical and applied. Due to the large volume of submissions received, we regret to not having been able to accept all the contributions.

We are thankful to the Department of Mathematics of the University of Padova and to the Interdepartmental Centre "Giorgio Levi Cases" for Energy Economics and Technology for generous financial support. Most importantly, we want to express our gratitude to all speakers and participants of the conference, for making this event scientifically engaging despite the virtual format.

The organising committee,

G. Callegaro, C. Fontana, M. Grasselli, W.J. Runggaldier, T. Vargiolu

Plenary speakers:

- Beatrice ACCIAIO (ETH Zurich, Switzerland)
- Clémence ALASSEUR (Electricité de France, France)
- Elisa ALOS (University Pompeu Fabra, Spain)
- Michalis ANTHROPELOS (University of Piraeus, Greece)
- Francois DELARUE (University of Nice Sophia-Antipolis, France)
- Marcel NUTZ (Columbia University, USA)
- Frank RIEDEL (Bielefeld University, Germany)
- Emanuela ROSAZZA GIANIN (University of Milano-Bicocca, Italy)

Invited sessions:

- Economics of climate risk
  (organisers: Pauline Barrieu and Johanna Ziegel)
- Green energy and finance: new problems, mathematical models and solutions
  (organisers: Giorgia Callegaro and Robert Stelzer)
- Equilibrium models in mathematical finance
  (organiser: Claudio Fontana)
- Mean-field games and McKean-Vlasov equations
  (organisers: Erhan Bayraktar and Martin Larsson)
- Market microstructure
  (organisers: Johannes Muhle-Karbe and Eyal Neuman)
- Recent advances in volatility modelling
  (organisers: Martino Grasselli and Mathieu Rosenbaum)
- Risk-sharing and principal-agent models
  (organiser: Mihail Zervos)
- Stochastic control: new developments and directions
  (organisers: Giulia Di Nunno and Mihail Zervos)
- Optimization and hedging in market with memory
  (organiser: Giulia Di Nunno)

2 Committees

Scientific Commitee:

- Erhan BAYRAKTAR (University of Michigan)
- Giorgia CALLEGARO (University of Padova)
- Giulia DI NUNNO (University of Oslo)
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- Tiziano VARGIOLU (University of Padova)

Tuesday, 22 June 2021

ZOOM LINK: https://unipd.zoom.us/s/87282326618

9.00 - 9.30	**WELCOME ADDRESSES (B. Chiarellotto, M. Grasselli, A. Bertucco, R. Stelzer) - VIRTUAL ROOM A**		
9.30 - 10.30	**PLENARY TALK 1 - E. Rosazza Gianin - Capital allocation rules: new perspectives in a static and dynamic setting - MAIN ROOM**		
10.30 - 11.00	***break***		
11.00 - 12.30	**INVITED SESSION 1 - MAIN ROOM Economics of climate risk (organizer: P. Barrieu and J. Ziegel)**	**CONTRIBUTED SESSION 1 - VIRTUAL ROOM B Interest rate and term structure modelling**	**CONTRIBUTED SESSION 2 - VIRTUAL ROOM C Insurance mathematics**
11.00 - 11.30	J. Hinz - Variables reduction in sequential resource allocation problems	D. Hainaut - Lévy interest rate models with a long memory	C. Ceci - Optimal reinsurance and investment under common shock dependence between the financial and the actuarial market
11.30 - 12.00	G. Marangoni - An integrated multi-objective appraisal of mitigation and climate engineering under uncertainty	J. Hölzermann - Term structure modeling under volatility uncertainty	T. Schmidt - Arbitrage in insurance
12.00 - 12.30	B. Sinclair-Desgagné - Climate policy under model uncertainty	S. Lavagnini - Accuracy of deep learning in calibrating HJM forward curves	Y. Havrylenko - Decrease of capital guarantees in life insurance products: can reinsurance stop it?
12.30 - 14.00	***break***		
14.00 - 15.00	**PLENARY TALK 2 - C. Alasseur - MFG model with a long-lived penalty at random jump times: application to demand side management for electricity contracts - MAIN ROOM**		
15.00 - 16.30	**INVITED SESSION 2 - MAIN ROOM Green energy and finance: new problems, mathematical models and solutions (organizers: G. Callegaro and R. Stelzer)**	**CONTRIBUTED SESSION 3 - VIRTUAL ROOM B Mean field games and their applications**	**CONTRIBUTED SESSION 4 - VIRTUAL ROOM C Risk measures I**
15.00 - 15.30	S. Glas - Application-oriented model reduction techniques	F. Djete - Mean field game of mutual holding	E. Mastrogiacomo - Optimization of coherent multivariate risk measures
15.30 - 16.00	C. Sgarra - A Barndorff-Nielsen and Shephard model with leverage in Hilbert space for commodity forward markets	S. Rigger - Propagation of minimality in the supercooled Stefan problem	A. Ince - Risk contributions of lambda quantiles
16.00 - 16.30	A. Veraart - High-frequency estimation of the Levy-driven graph Ornstein-Uhlenbeck process with applications to wind capacity factor measurements	G. Dos Reis - Forward utility and market adjustments in relative investment-consumption games of many players	G. Canna - Haezendonck-Goovaerts capital allocation rules
16.30 - 17.00	***break***		
17.00 - 18.30	**CONTRIBUTED SESSION 5 - MAIN ROOM Energy markets**	**CONTRIBUTED SESSION 6 - VIRTUAL ROOM B Stochastic games and their applications**	**CONTRIBUTED SESSION 7 - VIRTUAL ROOM C Risk measures II**
17.00 - 17.30	A. Kemper - The market price of risk for electricity swaps	A. Bovo - A zero-sum game between a stopper and a controller	A. Doldi - Conditional systemic risk measures
17.30 - 18.00	A. Awerkin - Optimal installation of renewable electricity sources	H. Dong - Rogue traders	C. De Vecchi - How does correlation impact Value-at-Risk bounds?
18.00 - 18.30	C. Milbradt - A cross-border market model with limited transmission capacities	E. Savku- Stochastic differential games via dynamic programming principle with regimes	A. Perchiazzo - Implied Value-at-Risk and model-free simulation

Wednesday, 23 June 2021

ZOOM LINK: https://unipd.zoom.us/s/81232092271

9.00 - 10.00	**PLENARY TALK 3 - F. Riedel - Frank Knight's legacy: the economics of uncertainty and risk - MAIN ROOM**		
10.00 - 10.30	***break***		
10.30 - 12.00	**INVITED SESSION 3 - MAIN ROOM Equilibrium models in mathematical finance (organizer: C. Fontana)**	**CONTRIBUTED SESSION 8 - VIRTUAL ROOM B Volatility estimation and forecasting**	**CONTRIBUTED SESSION 9 - VIRTUAL ROOM C Optimal stopping problems**
10.30 - 11.00	A. Danilova - On pricing rules and optimal strategies in general Kyle-Back models	G. Toscano - Rate-efficient asymptotic normality of the Fourier estimator of the leverage process	L. Stettner - Long run risk sensitive impulse control problems
11.00 - 11.30	P. Guasoni - Incomplete-market equilibrium with heterogeneous preferences and business cycles	C. Chong - Mixed semimartingales: estimating volatility in the presence of fractional noise	Y. Zou - Monte Carlo methods for optimal stopping under parameter uncertainty in multidimensional models
11.30 - 12.00	M. Herdegen - Equilibrium asset pricing with transaction costs	M. Garcin - Forecasting with fractional Brownian motion: a financial perspective	C. Herrera - Optimal stopping via randomized neural networks
12.00 - 14.00	***break***		
14.00 - 15.00	**PLENARY TALK 4 - F. Delarue - Exploration noise for learning linear-quadratic mean field games - MAIN ROOM**		
15.00 - 16.30	**INVITED SESSION 4 - MAIN ROOM MFGs and McKean - Vlasov equations (organizers: E. Bayraktar and M. Larsson)**	**CONTRIBUTED SESSION 10 - VIRTUAL ROOM B Liquidity and optimal execution**	**CONTRIBUTED SESSION 11 - VIRTUAL ROOM C Credit risk and XVA**
15.00 - 15.30	A. Cohen - Markovian equilibria in ergodic and discounted many-player and mean-field games	M. Di Giacinto - Execution under price impact with inventory cost: a heterogeneous characteristic timescales approach	A. Hertbertsson - Saddlepoint approximations for credit portfolios with stochastic recoveries: central clearing, risk management and pricing
15.30 - 16.00	A. Sojmark - Contagious McKean-Vlasov systems under heterogenous interactions	M. Urusov - Optimal trade execution in an order book model with stochastic liquidity parameters	P. Semeraro - Model risk in credit risk
16.00 - 16.30	Y. Zhang - Mean field contest with singularity	J. Ackermann - Càdlàg semimartingale strategies for optimal trade execution in stochastic order book models	A. Gnoatto - A unified approach to xVA with CSA discounting and initial margin
16.30 - 17.00	***break***		
17.00 - 18.30	**INVITED SESSION 5 - MAIN ROOM Market microstructure (organizers: J. Muhle-Karbe and E. Neuman)**	**CONTRIBUTED SESSION 12 - VIRTUAL ROOM B Affine processes**	**CONTRIBUTED SESSION 13 - VIRTUAL ROOM C Asset allocation**
17.00 - 17.30	U. Horst - The microstructure of stochastic volatility models with self-exciting jump dynamics	R. Frey - Markov modulated affine processes and applications in finance	M. Zhao - Mean-variance option portfolio and their performances
17.30 - 18.00	F. Lillo - Instabilities in multi-asset and multi-agent market impact games	J. He - A Kalman particle filter for online parameter estimation with applications to affine models	F. Rotondi - On time-consistent multi-horizon portfolio allocation
18.00 - 18.30	I. Rosu - Dynamic adverse selection and liquidity	S. Karbach - An affine stochastic volatility model in Hilbert spaces with state-dependent jumps	J. Jerome - Infinite horizon stochastic differential utility

Thursday, 24 June 2021

ZOOM LINK: https://unipd.zoom.us/s/82655567199

9.00 - 10.00	**PLENARY TALK 5 - B. Acciaio - Model-independence in a fixed-income market via weak optimal transport - MAIN ROOM**		
10.00 - 10.30	*break*		
10.30 - 12.00	**INVITED SESSION 6 - MAIN ROOM Recent advances in volatility modelling (organizers: M. Grasselli and M. Rosenbaum)**	**CONTRIBUTED SESSION 14 - VIRTUAL ROOM B Arbitrage theory**	**CONTRIBUTED SESSION 15 - VIRTUAL ROOM C Robust finance I**
10.30 - 11.00	E. Abi Jaber - Quadratic Gaussian models: analytic expressions for pricing and portfolio allocation	A. Mazzon - Optional projection under equivalent local martingale measures	F.B. Liebrich - Model uncertainty: a reverse approach
11.00 - 11.30	S. De Marco - On the implied and local volatility surfaces generated by rough volatility	A. Molitor - Semimartingale price systems in models with transaction costs beyond efficient friction	A. Papapantoleon - Model-free bounds for multi-asset options using option-implied information and their exact computation
11.30 - 12.00	B. Horvath - Insights from deep hedging under rough volatility	N. Khan - Mean-ρ portfolio selection and ρ-arbitrage for coherent risk measures	A. Rygiel - Semi-static hedging under volatility uncertainty
12.00 - 14.00	*break*		
14.00 - 15.00	**PLENARY TALK 6 - M. Nutz - Entropic optimal transport - MAIN ROOM**		
15.00 - 16.30	**INVITED SESSION 7 - MAIN ROOM Risk-sharing and principal-agent models (organizer: M. Zervos)**	**CONTRIBUTED SESSION 16 - VIRTUAL ROOM B Stochastic volatility I**	**CONTRIBUTED SESSION 17 - VIRTUAL ROOM C Robust finance II**
15.00 - 15.30	D. Possamai - Moral hazard for time-inconsistent agents and BSVIEs	A. Pallavicini - A general framework for a joint calibration of VIX and VXX options	K. Ugurlu - Terminal wealth maximization under drift uncertainty
15.30 - 16.00	S. Villeneuve - Agency problems, long memory and linear contracts	Z. Zuric - Joint SPX and VIX calibration with neural SDEs	D. Prömel - A cadlag rough path foundation for robust finance
16.00 - 16.30	E. Hubert - Epidemic control through incentives, lockdown, and testing: the government's perspective	I. Raffaelli - Revisiting the implied remaining variance framework of Carr and Sun (2014): locally consistent dynamics and sandwiched martingales	J. Wiesel - Data driven robustness and sensitivity analysis
16.30 - 17.00	*break*		
17.00 - 18.30	**CONTRIBUTED SESSION 18 - MAIN ROOM Systemic risk**	**CONTRIBUTED SESSION 19 - VIRTUAL ROOM B Stochastic volatility II**	**CONTRIBUTED SESSION 20 - VIRTUAL ROOM C Numerical methods I**
17.00 - 17.30	Y. Zhang - A macroprudential view on portfolio compression and rebalancing	G. Pagès - Stationary Heston model: calibration and pricing of exotics using product recursive quantization	F. Krach - Neural jump ordinary differential equations: consistent continuous-time prediction and filtering
17.30 - 18.00	R. Pang - Assessing and mitigating fire sales risk under partial information	S. Scotti - The alpha-Heston stochastic volatility model	A. Picarelli - Deep XVA solver: a neural network based counterparty credit risk management framework
18.00 - 18.30	X. Cui - Impact of systemic risk regulation on optimal policies and asset prices	G. Szulda - CBI-time-changed processes for multi-currency modeling	M. Gaudenzi - Utility indifference pricing methods for incomplete markets

Friday, 25 June 2021

ZOOM LINK: https://unipd.zoom.us/s/83142174414

9.00 - 10.00	**PLENARY TALK 7 - E. Alos - The asymptotic expansion of the regular discretization error of Itô integrals (and applications to variance swaps) - MAIN ROOM**		
10.00 - 10.30	***break***		
10.30 - 12.00	**INVITED SESSION 8 - MAIN ROOM Stochastic control: new developments and directions (organizer: G. Di Nunno and M. Zervos)**	**CONTRIBUTED SESSION 21 - VIRTUAL ROOM B Signature processes**	**CONTRIBUTED SESSION 22 - VIRTUAL ROOM C Rough volatility models**
10.30 - 11.00	G. Ferrari - Two-sided singular control of an inventory with unknown demand trend	G. Gazzani - Universal signature-based models: theory and calibration	S. Pulido - American options in the rough Heston model
11.00 - 11.30	A. Sulem - Mean-field BSDEs with jumps and global risk measures	S. Svaluto-Ferro - Universality of affine and polynomial processes and application to signature processes	A. Pannier - Large and moderate deviations for stochastic Volterra systems
11.30 - 12.00	H. Cao - Bridging stochastic analysis and GANs (and beyond)	C. Liu - Adapted topologies and higher rank signatures	J. Pospisil - Robustness and sensitivity analyses for rough Volterra stochastic volatility models
12.00 - 14.00	***break***		
14.00 - 15.00	**PLENARY TALK 8 - M. Anthropelos - Strategic informed traders and risk averse market makers - MAIN ROOM**		
15.00 - 16.30	**INVITED SESSION 9 - MAIN ROOM Optimization and hedging in markets with memory (organizer: G. Di Nunno)**	**CONTRIBUTED SESSION 23 - VIRTUAL ROOM B Stochastic optimal control I**	**CONTRIBUTED SESSION 24 - VIRTUAL ROOM C Numerical methods II**
15.00 - 15.30	T. Sottinen - Conditional-mean hedging in Gaussian long-memory models with transaction costs	A. Milazzo - Dynamic programming principle for singular control with discretionary stopping problems	M. Gardini - A bivariate Normal Inverse Gaussian process with stochastic delay: efficient simulations and applications to energy markets
15.30 - 16.00	J. Teichmann - Representation of path functionals and non-parametric drift estimation	A. Calvia - On a class of partially observed systems arising in singular optimal control	L. Gonzato - Efficient quasi-Bayesian estimation of affine option pricing models using risk-neutral cumulants
16.00 - 16.30	G. Di Nunno - Optimal portfolios in markets with memory	S. Federico - Taming the spread of an epidemic by lockdown policies	D. Shkel - Barrier option pricing with trading and non-trading hours
16.30 - 17.00	***break***		
17.00 - 18.30	**CONTRIBUTED SESSION 25 - MAIN ROOM Stochastic volatility III**	**CONTRIBUTED SESSION 26 - VIRTUAL ROOM B Stochastic optimal control II**	**CONTRIBUTED SESSION 27 - VIRTUAL ROOM C Cryptocurrencies**
17.00 - 17.30	A. Yurchenko-Titarenko - Stochastic volatility modelling via sandwiched processes with Volterra noise	O. Shelley - Transaction tax in a general equilibrium model	M. Patacca - Regime switches and commonalities of the cryptocurrencies asset class
17.30 - 18.00	L.P.D. Garces - A numerical approach to pricing exchange options under stochastic volatility and jump-diffusion dynamics	M. Tarsia - Subgame-perfect equilibrium strategies in state-constrained recursive stochastic control problems	N. Sirotko-Sibirskaya - Deep reinforcement learning-based portfolio management for the cryptocurrency market
18.00 - 18.30		M. Giordano - Optimal control in affine advertising models with memory	
18.30 - 19.00	**CONFERENCE CLOSING - VIRTUAL ROOM A**		

4 Abstracts

Eduardo Abi Jaber (Université Paris 1 Panthéon-Sorbonne, France)

Quadratic Gaussian models: analytic expressions for pricing and portfolio allocation

Stochastic models based on Gaussian processes, like fractional Brownian motion, are able to reproduce important stylized facts of financial markets such as rich autocorrelation structures, persistence and roughness of sample paths. This is made possible by virtue of the flexibility introduced in the choice of the covariance function of the Gaussian process. The price to pay is that, in general, such models are no longer Markovian nor semimartingales, which limits their practical use. We derive explicit analytic expressions for Fourier-Laplace transforms of quadratic functionals of Gaussian processes. Such analytic expression can be approximated by closed form matrix expressions stemming from Wishart distributions. We highlight the applicability of such result in the context of rough volatility modeling: (i) fast pricing and calibration in the (rough) fractional Stein-Stein model; (ii) explicit solutions for the Markowitz portfolio allocation problem in a multivariate rough Stein-Stein model. Based on joint works with Enzo Miller and Huyên Pham.

Beatrice Acciaio (ETH Zurich, Switzerland)

Model-independence in a fixed-income market via weak optimal transport

In this talk I will consider model-independent pricing problems in a stochastic interest rates framework. In this case the usual tools from classical Optimal Transport and Skorokhod embedding cannot be applied. I will show how some pricing problems in a fixed-income market can be reformulated as Weak Optimal Transport problems as introduced by Gozlan et al. (2017). This allows us to establish a first robust super-replication result in such a framework, and leads to a characterization of extremal pricing models. This talk is based on joint work with M. Beiglboeck and G. Pammer.

Julia Ackermann (University of Gießen, Germany)

Càdlàg semimartingale strategies for optimal trade execution in stochastic order book models

We analyze an optimal trade execution problem in a financial market with stochastic liquidity. To this end we set up a limit order book model in continuous time where both order book depth and resilience may evolve randomly in time. We allow for trading in both directions and for càdlàg semimartingales as execution strategies. We find that, under appropriate assumptions, the minimal execution costs are characterized by a quadratic BSDE. We further identify conditions under which an optimal execution strategy exists and investigate qualitative aspects of optimal strategies such as appearance of strategies with infinite variation or existence of block trades. These are purely continuous-time effects and therefore cannot be studied in the framework of [1]. This talk is based on [2].

References: [1] Julia Ackermann, Thomas Kruse, Mikhail Urusov. Optimal trade execution in an order book model with stochastic liquidity parameters, arXiv:2006.05843

[2] Julia Ackermann, Thomas Kruse, Mikhail Urusov. Càdlàg semimartingale strategies for optimal trade execution in stochastic order book models, arXiv:2006.05863

Clémence Alasseur (EDF, France)

MFG model with a long-lived penalty at random jump times: application to demand side management for electricity contracts

We consider an energy system with n consumers who are linked by a Demand Side Management (DSM) contract, i.e. they agreed to diminish, at random times, their aggregated power consumption by a predefined volume during a predefined duration. Their failure to deliver the service is penalised via the difference between the sum of the n power consumptions and the contracted target. We are led to analyse a non-zero sum stochastic game with n players, where the interaction takes place through a cost which involves a delay induced by the duration included in the DSM contract. When $n \to \infty$, we obtain a Mean-Field Game (MFG) with random jump time penalty and interaction on the control. We prove a stochastic maximum principle in this context, which allows to compare the MFG solution to the optimal strategy of a central planner. In a linear quadratic setting we obtain an semi-explicit solution through a system of decoupled forward-backward stochastic differential equations with jumps, involving a Riccati Backward SDE with jumps. We show that it provides an approximate Nash equilibrium for the original n-player game for n large. Finally, we propose a numerical algorithm to compute the MFG equilibrium and present several numerical experiments. Based on joint works with Luciano Campi, Roxana Dumitrescu and Jia Zeng.

Elisa Alós (University Pompeu Fabra, Spain)

The asymptotic expansion of the regular discretization error of Itô integrals (and applications to variance swaps)

In this talk, we present an Edgeworth-type refinement of the central limit theorem for the discretization error of Itô integrals. Toward this end, we introduce a new approach, based on the anticipating Itô formula. This alternative technique allows us to compute explicitly the terms of the corresponding expansion formula. As an application, we study the difference between continuously and discretely monitored variance swap payoffs under stochastic volatility models. A short introduction to Malliavin calculus is given at the beginning of the talk. This is joint work with Masaaki Fukasawa.

Michalis Anthropelos (University of Piraeus, Greece)

Strategic informed traders and risk averse market makers

We consider a quote-driven financial market, where all trades are executed through market makers (MMs). MMs (assumed risk averse) exploit their market power by quoting bid and ask prices taking into account the demand schedules submitted by traders (an informed trader and a mass of uniformed ones). We introduce a novel strategic behavior for the informed trader, who submits her demand schedule based, not only on her private signal, but also on the way MMs quote prices. We show that informed trader?s strategic behavior results in lower trading volume, but also lower equilibrium bid-ask spread. The effect becomes more intense when informed trader?s risk tolerance and asymmetric information increase. Interestingly enough, an imperfect competition among two informed traders would reduce the bid-ask spread even further, (regardless of the side of the trade they stand). This is a joint working paper with my PhD student Mr. Vasileios Nastoulis.

Andrea Bovo (University of Leeds, United Kingdom)

A zero-sum game between a stopper and a controller

We consider a zero-sum game associated with a payoff which depends on a controlled d-dimensional stochastic process. This game is played between two players, where one player is trying to maximise the payoff using a stopping time as terminal time of the game, and one is trying to minimise it using a pair control which affects the dynamic of the process. The payoff is defined as the expectation of a terminal cost and the integral of a running cost and an action cost. The value function of the following zero-sum game, which is equal for both orders of supremum and infimum, is related to a variational inequality with two constraints - an obstacle constraint and a gradient constraint. The solution of the variational inequality is found through the limit function of a sequence of solutions of penalised problems. Uniform properties of these solutions are proved with both probabilistic and analytic approaches. Moreover, we guess an optimal strategy for the stopper. On the other hand, we guess that an optimal strategy for the controller cannot be defined and only a nearly optimal strategy can be found, cause the singular control class is allowed.

Alessandro Calvia (LUISS University, Italy)

On a class of partially observed systems arising in singular optimal control

Partially observed systems model phenomena that appear in various disciplines, such as engineering, economics, and finance, where some quantity of interest, described by a stochastic process called signal, is not directly measurable or observable. The signal process affects another quantity, the observed process, through which one can obtain probabilistic estimates of the state of the unobserved signal. The estimate that one seeks is provided by the filtering process, defined as the conditional distribution of the signal at each time $t \geq 0$, given the observation available at time t. This estimate is required, for instance, in optimal control problems with partial observation, where an agent (or controller) aims at optimizing some functional, depending on the stochastic processes previously introduced, by means of a control process. In continuous time, these problems have been deeply studied in the literature. However, to the best of our knowledge, a particularly relevant case for applications has not yet received proper attention: the singular control case. Indeed, few papers study singular control problems for partially observed systems and they do so only in the case where the control process acts on the observation. Instead, the case where the control acts on the signal process is more delicate, from a technical point of view, and requires a careful novel analysis. In this talk, we will introduce a class of singular control problems with partial information, underline their relevance in applications (e.g., pollution control, inventory management), and provide the explicit filtering equation (i.e., the SPDE satisfied by the filtering process), together with a uniqueness result. These results lay the ground to solve the corresponding singular optimal control problem under partial observation. This is joint work with Giorgio Ferrari, Bielefeld University.

Gabriele Canna (University of Milano Bicocca, Italy)

Haezendonck-Goovaerts capital allocation rules

This paper deals with the problem of capital allocation for a peculiar class of risk measures, namely the Haezendonck-Goovaerts (HG) ones (Bellini and Rosazza Gianin (2008)). To this aim, we generalize the capital allocation rule (CAR) introduced by Xun et al. (2019) for Orlicz risk premia (Haezendonck and Goovaerts (1982)) as well as for HG risk measures, using an approach based on Orlicz quantiles (Bellini and Rosazza Gianin (2012)). We therefore study the properties of different CARs for HG risk measures in the quantile-based setting. Finally, we provide robust versions of the introduced CARs, considering ambiguity both over the probabilistic model and over the Young function, following the scheme of Bellini et al. (2018).

Haoyang Cao (Alan Turing Institute, United Kingdom)

Bridging stochastic analysis and GANs (and beyond)

Generative adversarial networks (GANs) have enjoyed tremendous success in image generation and processing, and have recently attracted growing interests in many other fields of applications including mathematical finance. In this talk we will start from analyzing the connection between GANs and mean field games (MFGs) as well as optimal transport (OT). We will first show a conceptual connection between GANs and MFGs: MFGs have the structure of GANs, and GANs are MFGs under the Pareto Optimality criterion. Interpreting MFGs as GANs, on one hand, will enable a GANs-based algorithm (MFGANs) to solve MFGs: one neural network (NN) for the backward Hamilton-Jacobi-Bellman (HJB) equation and one NN for the Fokker-Planck (FP) equation, with the two NNs trained in an adversarial way. Viewing GANs as MFGs, on the other hand, will reveal a new and probabilistic aspect of GANs. This new perspective, moreover, will lead to an analytical connection between GANs and Optimal Transport (OT) problems, and sufficient conditions for the minimax games of GANs to be reformulated in the framework of OT. Building up from the probabilistic views of GANs, we will then establish the approximation of GANs training via stochastic differential equations and demonstrate the convergence of GANs training via invariant measures of SDEs under proper conditions. This stochastic analysis for GANs training can serve as an analytical tool to study its evolution and stability. If time permits, we will also touch upon a natural connection between stochastic analysis and another popular machine learning problem - the inverse reinforcement learning (IRL) problem. We will show how the entropy regularized stochastic control could help us understand the identifiability issue in IRL.

Claudia Ceci (Università di Chieti-Pescara, Italy)

Optimal reinsurance and investment under common shock dependence between the financial and the actuarial market

We study the optimal proportional reinsurance and investment strategy for an insurance company which experiences both ordinary and catastrophic claims and wishes to maximize the expected exponential utility of its terminal wealth. We propose a model where the insurance framework is affected by environmental factors, and aggregate claims and stock prices are subject to common shocks, i.e. drastic events such as earthquakes, extreme weather conditions, or even pandemics, that have an immediate impact on the financial market and simultaneously induce insurance claims. Using the classical stochastic control approach based on the Hamilton-Jacobi-Bellman equation, we provide a verification result for the value function via classical solutions to two backward partial differential equations and characterize the optimal strategy. Finally, we discuss the effect of the common shock dependence via a comparison analysis.

Carsten Chong (Columbia University, USA)

Mixed semimartingales: estimating volatility in the presence of fractional noise

In this talk, we consider the problem of estimating volatility at high frequency when the observable price process follows what we call a mixed semimartingale: that is, an Ito semimartingale, contaminated by a continuous-time process that locally resembles fractional Brownian motion. The motivation behind this model is threefold: (a) to provide a framework for market microstructure noise in continuous time; (b) to explain the different rates of divergence for different assets found in volatility signature plots; and (c) to match the observation that the noise variance shrinks as the sampling frequency increases. After introducing the model, we discuss estimation of the Hurst parameter of the noise and its consequences for deriving consistent and asymptotically normal estimators for integrated volatility. Our estimators will be evaluated in a simulation study and applied to transaction and quote data of selected assets.

Asaf Cohen (University of Michigan, United States)

Markovian equilibria in ergodic and discounted many-player and mean-field games

We consider both ergodic and discounted symmetric stochastic games with weak interactions between many players. Time is continuous and the number of states is finite. In addition, we consider also the respective mean-field games. We construct the Nash-equilibrium finite-difference systems of equations and the master equations, and show that the discounted equations converge to the ergodic ones. Finally, we study the convergence problem from the many-player games to the mean-field games. (Joint work with Ethan Zell)

Xuecan Cui (Southwestern University of Finance and Economics, China)

Impact of systemic risk regulation on optimal policies and asset prices

Although a few systemic risk management approaches have been proposed in the literature and implemented in the industry, such as stress tests based scenarios, the impact of such regulations remains unclear. In this paper, we present a theoretical framework to study the impact of systemic risk management on financial institutions' optimal policies and asset prices in equilibrium. Specifically, we study the impact of the Conditional VaR (CoVaR) and Systemic Expected Shortfall (SES) constraints and illustrate the potential adverse effects of conditional risk measures given the market is under stress. We find that a proper choice of the SES constraint, especially using information under risk neutral probability, may effectively reduce these effects.

Albina Danilova (London School of Economics and Political Science, United Kingdom)

On pricing rules and optimal strategies in general Kyle-Back models

The folk result in Kyle-Back models states that the value function of the insider remains unchanged when her admissible strategies are restricted to absolutely continuous ones. In this talk I will show that, for a large class of pricing rules used in current literature, the value function of the insider can be finite when her strategies are restricted to be absolutely continuous and infinite when this restriction is not imposed. This implies that the folk result doesn't hold for those pricing rules and that they are not consistent with equilibrium. I will derive the necessary conditions for a pricing rule to be consistent with equilibrium and prove that, when a pricing rule satisfies these necessary conditions, the insider's optimal strategy is absolutely continuous, thus obtaining the classical result in a more general setting. This, furthermore, allows to justify the standard assumption of absolute continuity of insider's strategies since one can construct a pricing rule satisfying the derived necessary conditions that yield the same price process as the pricing rules employed in the modern literature when insider's strategies are absolutely continuous.

François Delarue (University of Nice, France)

Exploration noise for learning linear-quadratic mean field games

he general purpose of the talk is to show that common noise may help for learning equilibria in some mean-field games. I will provide a short review of the impact of a common noise in the analysis of mean-field games. In particular, I will recall some recent results about existence and uniqueness of equilibria under the action of the common noise. Next, I will explain the main idea: Using the noise to explore the space of solutions when learning an equilibrium. In order to do so, I will restrict myself to a mean field game with a linear quadratic structure. In this case, I will show how common noise may help for the convergence of the so-called fictitious play. I will conclude with some numerical examples. The talk is based on a recent work, with A. Vasileadis (PhD, Nice).

Stefano De Marco (École Polytechnique, France)

On the implied and local volatility surfaces generated by rough volatility

Several asymptotic results for the implied volatility generated by a rough volatility model have been obtained in recent years (notably in the small-maturity regime), providing a better understanding of the shapes of the volatility surface induced by such models, and supporting their calibration power to SP500 option data. Rough volatility models also generate a local volatility surface, via the Markovian projection of the stochastic volatility (equivalently, via Dupire's formula applied to the model's option price surface). We complement the existing results with the asymptotic behavior of the local volatility surface generated by a class of rough stochastic volatility models encompassing rough Bergomi. Notably, we observe that the celebrated "1/2 skew rule" linking the short-term at-the-money (ATM) skew of the implied volatility to the short-term ATM skew of the local volatility, a consequence of the celebrated "harmonic mean formula" of [Berestycki, Busca, and Florent, QF 2002], is replaced by a new rule: the ratio of the implied volatility and local volatility ATM skews tends to the constant $1/(H+3/2)$ (as opposed to the constant $1/2$), where H is the regularity index of the underlying instantaneous volatility process. Joint work with Florian Bourgey, Peter Friz, and Paolo Pigato.

Corrado De Vecchi (Vrije Universiteit Brussels, Belgium)

How does correlation impact Value-at-Risk bounds?

Some aggregation formulas that are used in the insurance and financial industry implicitly assume that the knowledge of marginal distributions and of some measure of dependence (e.g., the average correlation) leads to an appropriate estimation of the Value-at-Risk (VaR). We challenge this idea by investigating under which conditions the unconstrained VaR bounds (which are the maximum and minimum VaR for the sum when only the knowledge on the marginal distributions of the components is assumed) coincide with the VaR bounds when in addition one has information on some measure of dependence (e.g., Pearson correlation, Spearman's rho or Kendall's tau). We show that correlation has typically no effect on the highest possible VaR whereas it can impact the lowest possible VaR. To reduce the VaR upper bound, we show that additional tail information is needed. Additional results for TVaR and Range VaR supplements the study.

Marina Di Giacinto (Università degli studi di Cassino e del Lazio Meridionale, Italy)
Execution under price impact with inventory cost: a heterogeneous characteristic timescales approach

The classical Almgren-Chriss model of price impact is generalized in this article to accommodate nonlinear execution price path by adding an extra feature that models the market makers' contributions to the transaction price by aggregated Ornstein-Uhlenbeck processes. During execution of a meta order, market makers are assumed to mean revert their inventories to certain preassigned capacities as a reaction. Upon the termination of the execution, market makers revert their capacities back to zero. The expected price path post a TWAP (time weighted average price) execution thus reverts to a price level higher than price prior to the TWAP execution. The execution problem faced by investor is recast as a possibly infinite dimensional stochastic control problem, which in general is neither Markovian nor semimartingale. However, since the problem remains linear-quadratic, we are able to derive a system of Riccati equations that characterizes the optimal value process and the associated optimal trading strategy. Numerical examples are presented to illustrate the implementation of the resulting optimal execution strategy under the proposed model.

Giulia Di Nunno (University of Oslo, Norway)
Optimal portfolios in markets with memory

We study a classical portfolio optimization problem in a market model with memory in the form of Volterra dynamics and stochastic volatility modulated by the time change in the Lévy noises. We present necessary and sufficient criteria to identify the optimal portfolio and, in the case of linear type dynamics in the market model, we achieve some explicit formulations. The presentation is based on joint work with Michele Giordano.

Mao Fabrice Djete (Ecole Polytechnique, France)
Mean field game of mutual holding

In this presentation, we will talk about a new class of mean field game that we will call mean field game of mutual holding. We will begin by introducing this model which can be seen as a natural expected limit from a N-agents game where each agent can hold part of the assets of other agents. The induced mean field dynamics appear naturally in a form which is not covered by standard McKean-Vlasov stochastic differential equations. In the absence of common noise, we will present results of the study of this mean field game model. Our main result provides existence of an explicit equilibrium of the mean field game of mutual holding, defined by a bang-bang control consisting in holding those competitors with non-negative drift coefficient of their dynamic value. Our analysis requires to prove an existence result for our new class of mean field SDE with the additional feature that the diffusion coefficient is irregular. If there is enough time, we will bring up the case with common noise which presents many additional difficulties.

Alessandro Doldi (Università di Milano, Italy)

Conditional systemic risk measures

We investigate to which extent the relevant features of (static) systemic risk measures can be extended to a conditional setting. After providing a general dual representation result, we analyze in greater detail Conditional Shortfall Systemic Risk Measures. In the particular case of exponential preferences, we provide explicit formulas that also allow us to show a time consistency property. Finally, we provide an interpretation of the allocations associated to Conditional Shortfall Systemic Risk Measures as suitably defined equilibria. Conceptually, the generalization from static to conditional systemic risk measures can be achieved in a natural way, even though the proofs become more technical than in the unconditional framework.

Huayuan Dong (Dublin City University, Ireland)

Rogue traders

Investing on behalf of a firm, a trader can commit fraud that with high probability remains undetected and generates small gains, feigning personal skill, but that with low probability will bankrupt the firm, offsetting ostensible gains. Honesty requires enough skin in the game: If two traders with isoelastic preferences operate in continuous-time and one of them is honest, the other is honest as long as the respective fraction of capital is above an endogenous fraud threshold that depends on the trader's preferences and skill. If both traders can cheat, they reach a Nash equilibrium in which the fraud threshold of each of them is lower than if the other one were honest. More skill, higher risk aversion, longer horizons, and greater volatility all lead to honesty on a wider range of capital allocations between the traders.

Gonçalo Dos Reis (University of Edinburgh, United Kingdom)

Forward utility and market adjustments in relative investment-consumption games of many players

We study a portfolio management problem featuring many-player and mean-field competition, investment and consumption, and relative performance concerns under the forward performance processes (FPP) framework. We focus on agents using power (CRRA) type FPPs for their investment-consumption optimization problem an under common noise Merton market model and we solve both the many-player and mean-field game providing closed-form expressions for the solutions where the limit of the former yields the latter. In our case, the FPP framework yields a continuum of solutions for the consumption component as indexed to a market parameter we coin "market consumption intensity". The parameter permits the agent to set a preference for their consumption going forward in time that, in the competition case, reflects a common market behaviour. We show the FPP framework, under both competition and no-competition, allows the agent to disentangle his risk-tolerance and elasticity of intertemporal substitution (EIS) just like Epstein-Zin preferences under a recursive utility framework and unlike the classical utility theory one. This, in turn, allows a finer analysis on the agent's consumption "income" and "substitution" regimes, and, of independent interest, motivates a new strand of economics research on EIS under the FPP framework. We find that competition rescales the agent's perception of consumption in a non-trivial manner in addition to a time-dependent "elasticity of conformity" of the agent to the market's consumption intensity.

Salvatore Federico (University of Genova, Italy)
Taming the spread of an epidemic by lockdown policies

We study the problem of a policymaker who aims at taming the spread of an epidemic while minimizing its associated social costs. The main feature of our model lies in the fact that the disease?s transmission rate is a diffusive stochastic process whose trend can be adjusted via costly confinement policies. We provide a complete theoretical analysis, as well as numerical experiments illustrating the structure of the optimal lockdown policy. In all our experiments the latter is characterized by three distinct periods: the epidemic is first let to freely evolve, then vigorously tamed, and finally a less stringent containment should be adopted. Moreover, the optimal containment policy is such that the product "reproduction number x percentage of susceptible" is kept after a certain date strictly below the critical level of one, although the reproduction number is let to oscillate above one in the last more relaxed phase of lockdown. Finally, an increase in the fluctuations of the transmission rate is shown to give rise to an earlier beginning of the optimal lockdown policy, which is also diluted over a longer period of time.

Giorgio Ferrari (University of Bielefeld, Germany)
Two-sided singular control of an inventory with unknown demand trend

In this talk we discuss the problem of optimally managing an inventory with unknown demand trend. By considering an extension under partial observation of the celebrated paper by J.M. Harrison and M.I. Taksar (Math. Oper. Res., 1983), our formulation leads to a stochastic control problem in which a Brownian motion with non-observable drift can be singularly controlled in both an upward and downward direction. We first derive the equivalent separated problem under full information with state-space components given by the Brownian motion and the filtering estimate of its unknown drift, and we then completely solve the latter. Our approach uses the transition amongst three different but equivalent problem formulations, links between two-dimensional bounded-variation stochastic control problems and games of optimal stopping, and probabilistic methods in combination with refined viscosity theory arguments. We show substantial regularity of (a transformed version of) the value function, we construct an optimal control rule, and we show that the free boundaries delineating (transformed) action and inaction regions are bounded globally Lipschitz continuous functions. This is based on a joint work with Salvatore Federico and Neofytos Rodosthenous.

Rudiger Frey (Vienna University of Economics and Business, Austria)
Markov modulated affine processes and applications in finance

In this talk we discuss the theory of conditionally affine processes with Markov modulated coefficients and we sketch several financial applications. These processes are attractive modelling tools since they substentially extend the modelling possibilities as opposed to pure affine processes, while largely preserving the tractability of the latter model class. We develop the general theory of these process using an approach via martingale problems and discuss issues such as existence, moment conditions and the form of the affine transform. Extending existing results we deal with the case where the generator of the modulating pocess is an unbounded operator (as in the case of diffusuion processes). Moreover, we discuss several financial applications. We study in particular the pricing of defaultable bonds with negative dependence between the default intensity of the issuer and the default-free short rate.

Len Patrick Dominic Garces (University of South Australia, Australia)

A numerical approach to pricing exchange options under stochastic volatility and jump-diffusion dynamics

We price European and American exchange options when the underlying asset prices are modelled as Merton (1976) jump-diffusion process with a common Heston (1993) stochastic volatility process. Pricing is performed under an equivalent martingale measure obtained by taking the second asset yield process as the numeraire, as suggested by the put-call transformation technique suggested by Bjerskund and Stensland (1993). Under this equivalent martingale measure, we derive the exchange option pricing integro-partial differential equations (IPDEs) and investigate the early exercise boundary of the American exchange option. We then discuss a numerical solution of the IPDEs using the method of lines (MOL) its implementation using computing software. Our analytical and numerical investigation shows that the near-maturity behavior of the early exercise boundary of the American exchange option is significantly influenced by the dividend yields and the presence of jumps in the underlying asset prices. Furthermore, with the numerical results generated by the MOL, we are able to show that key jump and stochastic volatility parameters significantly affect the early exercise boundary and exchange option prices. Our numerical analysis also verifies that the MOL performs more efficiently, compared to other finite difference methods or simulation approaches for American options, since the MOL integrates the computation of option prices, greeks, and the early exercise boundary and does so with the least error.

Matthieu Garcin (ESILV, France)

Forecasting with fractional Brownian motion: a financial perspective

The fractional Brownian motion (fBm) extends the standard Brownian motion by introducing some dependence between non-overlapping increments. Consequently, if one considers for example that log-prices follow an fBm, one can exploit the non-Markovian nature of the fBm to forecast future states of the process and make statistical arbitrages. We provide new insights into forecasting an fBm, by proposing theoretical formulas for accuracy metrics relevant to a systematic trader, from the hit ratio to the expected gain and risk. In addition, we answer some key questions about optimizing trading strategies in the fBm framework: Which lagged increments of the fBm, observed in discrete time, are to be considered? If the predicted increment is close to zero, up to which threshold should one make an investment decision? We also propose empirical applications on high-frequency FX rates, as well as on realized volatility series, exploring the rough volatility concept in a forecasting perspective.

Matteo Gardini (University of Genova, Italy)

A bivariate Normal Inverse Gaussian process with stochastic delay: efficient simulations and applications to energy markets

Using the concept of self-decomposable subordinators introduced in Gardini et al. (2020), we build a new bivariate Normal Inverse Gaussian process that can capture stochastic delays. In addition, we also develop a novel path simulation scheme that relies on the mathematical connection between self-decomposable Inverse Gaussian laws and Levy-driven Ornstein-Uhlenbeck processes with Inverse Gaussian stationary distribution. We show that our approach provides an improvement to the existing simulation scheme detailed in Zhang and Zhang (2008), because it does not rely on an acceptance-rejection method. Eventually, these results are applied to the modelling of energy markets and to the pricing of spread options using the proposed Monte Carlo scheme and Fourier techniques.

Marcellino Gaudenzi (University of Udine, Italy)

Utility indifference pricing methods for incomplete markets

We propose a method to determine optimal strategies for investment in markets which are incomplete. To generate approximations for such problems in continuous time, we define a sequence of models in discrete time with a finite state space and a restricted class of utility functions for which the exact optimal strategy can be found. With our technique the optimization involves a sequence of binary choices instead of the search over real numbers that is required for every possible value of the state when finite difference schemes for the Hamilton-Jacobi-Bellman equations in continuous time are used. The method provides a very efficient calculation scheme which generates the exact solutions for our discrete time approximations. We use the theory of viscosity solutions to give conditions which guarantee that a sequence of such approximations for a given problem in continuous time converges to the correct limit. We show in a number of examples how the method can be used to find indifference prices in incomplete markets, for example when volatility is stochastic or there are other untradeable risk factors.

Guido Gazzani (University of Vienna, Austria)

Universal signature-based models: theory and calibration

Universal classes of dynamic processes based on neural networks and signature methods have recently entered the area of stochastic modeling and Mathematical Finance. This has opened the door to robust and more data-driven model selection mechanisms, while first principles like no arbitrage still apply. Here we focus on signature SDEs whose characteristics are linear functions of a primary underlying process, which can range from a (market-inferred) Brownian motion to a general multidimensional tractable stochastic process. The framework is universal in the sense that any classical model can be approximated arbitrarily well and that the model characteristics can be learned from all sources of available data by simple methods. Indeed, we derive formulas for the expected signature in terms of the expected signature of the primary underlying process. These formulas enter directly in the calibration procedure to option prices, while time series data calibration just reduces to a simple regression. The talk is based on a joint work with Christa Cuchiero and Sara Svaluto-Ferro.

Michele Giordano (University of Oslo, Norway)

Optimal control in affine advertising models with memory

We study a class of optimal control problems for linear Volterra integral equations arising in the theory of optimal advertising. Our goal is to find

$$\hat{J}(X(0), u) := \sup_{u \in L^2([0,T]\times\Omega)} \mathbb{E}\left[-\int_0^T a_1 u^2(s) ds + a_2 X^u(T) \right], \tag{1}$$

where the forward dynamics is given by

$$X^u(t) = X(0) + \int_0^t K(t-s)\Big(\alpha u(s) - \beta X^u(s)\Big) ds + \sigma \int_0^t K(t-s) dW(s), \tag{2}$$

where we consider a general h-Hölder continuous kernel ($h \in (0,1)$).

Being the setting non-Markovian, it is complicated to solve this optimization problem by means of a *dynamic programming principle* (DPP) approach and one usually has to resort to some maximum principle techniques.

Nevertheless, we propose a *Hamilton-Jacobi-Bellman* (HJB) approach to solve the above optimization problem exploiting an *infinite dimensional lift* that can be regarded as a generalization of the ones presented in [2-3]. This method allows us to recover some Markov properties for the problem (1)-(2) by considering an infinite-dimensional Hilbert space optimization problem equivalent to the original one. The current work stems out from [3], where the lift is performed only for kernels that can be regarded as Laplace transforms of measures, and from [1-2], where the hypothesis on the kernel required to perform the lift are quite strict.

Our approach is as follows: first, we formulate a finite-dimensional approximation of the problem (1)-(2), then we lift such approximated problem to a Hilbert space and use an infinite-dimensional DPP to solve it. Lastly, we show that the optimal control of the approximated problem $\hat{u}_\varepsilon$ is suboptimal for (1)-(2).

We also explicitly solve the HJB equations for the approximated problem, provide a numerical scheme for computing $\hat{u}_\varepsilon$, and present simulations for the problem (1)-(2) with the kernel $K(t) = t^h$, $h \in (0, 1/2)$.

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Silke Glas (Cornell University, United States)

Application-oriented model reduction techniques

Numerical methods have gained significant importance in the last decades for real-world applications in e.g., finance, engineering and medicine. The underlying equations are typically nonlinear and thus often do not possess a closed-form solution. Therefore, numerical methods are used to approximate those application-oriented problems, in which several have a parametric form. The arising discrete problems often are solved in a high-dimensional space and thus result in long computing times for each parameter. To lower the costs for each parameter, we derive an efficient low-dimensional model. The quality of linear reduced models can be quantified by the Kolmogorov-N-width, which is the best achievable error for linear approximations of fixed dimension N. For problems with a fast-decaying Kolmogorov-N-width, e.g., elliptic problems, linear subspace models are sufficient to achieve a reduced model with high accuracy. Nevertheless, for problems with slowly decaying Kolmogorov-N-width such as advection dominated problems, linear models might yield inaccurate results. In this talk, we consider new efficient model reduction techniques for problems yielding slow decaying Kolmogorov-N-width, which conserve the properties of the high-dimensional problem. We show stability for the reduced problem and provide numerical results for a transport problem.

Alessandro Gnoatto (Università di Verona, Italy)

A unified approach to xVA with CSA discounting and initial margin

In this paper we extend the existing literature on xVA along three directions. First, we enhance current BSDE-based xVA frameworks to include initial margin in presence of defaults. Next, we solve the consistency problem that arises when the front-office desk of the bank uses trade-specific discount curves (CSA discounting) which differ from the discount rate adopted by the xVA desk. Finally, we clarify the impact of aggregation of several subportfolios of trades on the xVA-valuation of the resulting global portfolio and study related non-linearity effects.

Luca Gonzato (University of Vienna, Austria)

Efficient quasi-Bayesian estimation of affine option pricing models using risk-neutral cumulants

We propose a general, accurate and fast econometric approach for the estimation of affine option pricing models. The algorithm belongs to the class of Laplace-Type Estimation (LTE) techniques and exploits Sequential Monte Carlo (SMC) methods. We employ closed-form risk-neutral cumulants to marginalize latent states and we address parameter estimation by designing a density tempered SMC sampler. We test our algorithm by estimating an option pricing model that allows for co-jumps between price and volatility, and stochastic jump intensity using both simulated and real data. We exploit the high accuracy of our estimates for derivative pricing under parameter ambiguity and for portfolio management purposes.

Paolo Guasoni (Dublin City University, Ireland)

Incomplete-market equilibrium with heterogeneous preferences and business cycles

We solve a general equilibrium model of an incomplete market with heterogeneous preferences, identifying first-order and second-order effects. Several long-lived agents with different absolute risk-aversion and discount rates make consumption and investment decisions, borrowing from and lending to each other, and trading a stock that pays a dividend whose growth rate has random fluctuations over time. For small fluctuations, the first-order equilibrium implies no trading in stocks, the existence of a representative agent, predictability of returns, and multi-factor asset pricing, and that agents use a few public signals for consumption, borrowing, and lending. At the second-order, agents trade stocks and no representative agent exist, as both the interest rate and asset prices depend on the dispersion of agents' preferences.

Donatien Hainaut (LIDAM-ISBA, Université Catholique de Louvain, Belgium)

Lévy interest rate models with a long memory

This article proposes an interest rate model ruled by mean reverting Lévy processes with a sub-exponential memory of their sample path. This feature is achieved by considering an Ornstein- Uhlenbeck process in which the exponential decaying kernel is replaced by a Mittag-Leffler function. Based on a representation in term of an infinite dimensional Markov processes, we present the main characteristics of bonds and short-term rates in this setting. Their dynamics under risk neutral and forward measures are studied. Finally, bond options are valued with a discretization scheme and a discrete Fourier's transform.

Yevhen Havrylenko (TU Munich, Germany)

Decrease of capital guarantees in life insurance products: can reinsurance stop it?

In this work, we analyze the potential of reinsurance for reversing the current trend of decreasing capital guarantees in life insurance products. Providing an insurer with an opportunity to shift part of the financial risk to a reinsurer, we solve analytically the insurer's dynamic investment-reinsurance optimization problem under simultaneous Value-at-Risk and no-short-selling constraints. Market conditions for which reinsurance is optimal in the management of life insurance product with capital guarantees are presented. We also introduce the concept of guarantee-equivalent utility gain and use it to compare life insurance products with and without reinsurance. Our numerical studies indicate that the optimally managed reinsurance allows the insurer to offer significantly higher capital guarantees to clients without any loss in the insurer's expected utility. We also established that the longer the investment horizon and the less risk-averse the insurer, the more prominent the reinsurance benefit.

Jian He (University of Amsterdam, Netherlands)

A Kalman particle filter for online parameter estimation with applications to affine models

In this paper we address the problem of estimating the posterior distribution of the static parameters of a continuous-time state space model with discrete-time observations by an algorithm that combines the Kalman filter and a particle filter. The proposed algorithm is semi-recursive and has a two layer structure, in which the outer layer provides the estimation of the posterior distribution of the unknown parameters and the inner layer provides the estimation of the posterior distribution of the state variables. This algorithm has a similar structure as the so-called recursive nested particle filter, but unlike the latter filter, in which both layers use a particle filter, our algorithm introduces a dynamic kernel to sample the parameter particles in the outer layer to obtain a higher convergence speed. Moreover, this algorithm also implements the Kalman filter in the inner layer to reduce the computational time. This algorithm can also be used to estimate the parameters that suddenly change value. We prove that, for a state space model with a certain structure, the estimated posterior distribution of the unknown parameters and the state variables converge to the actual distribution. We present numerical results of the implementation of this algorithm, in particularly we implement this algorithm for affine interest models, possibly with stochastic volatility, although the algorithm can be applied to a much broader class of models.

Alexander Herbertsson (University of Gothenburg, Sweden)

Saddlepoint approximations for credit portfolios with stochastic recoveries: central clearing, risk management and pricing

We study saddlepoint approximations for intensity based credit portfolios with stochastic recoveries in conditional independent homogeneous settings. In this model, conditional on the underlying factor process, we find an explicit closed-form solution of the saddlepoint equation for each point in the loss distribution given the factor. We study both constant and stochastic recoveries that are correlated with the default times via the factor. The default intensities can be arbitrary as long as they are conditionally independent given the factor. Under the assumption that the stochastic recoveries are binomial distributions conditionally on the factor and correlated with the default times, we derive convenient semi-closed form expression for the credit portfolio loss distribution. We give several numerical applications when the default intensities follows a CIR process. We study the time evolution of Value-at-Risk for a portfolio with stochastic recoveries correlated with the default times. We compute the so called average of total expected exposures used for central clearing for stylized swaps that depend on a portfolio of defaultable names. Finally we compute the portfolio credit loss distribution using the saddlepoint approximation when the default intensities follows a finite state continuous time Markov chain and compare this approximation with the exact distribution obtained via the Kolmogorov equations.

Martin Herdegen (University of Warwick, United Kingdom)

Equilibrium asset pricing with transaction costs

We study risk-sharing economies where heterogenous agents trade subject to quadratic transaction costs. The corresponding equilibrium asset prices and trading strategies are characterised by a system of nonlinear, fully-coupled forward-backward stochastic differential equations. We show that a unique solution generally exists provided that the agents' preferences are sufficiently similar. In a benchmark specification with linear state dynamics, the illiquidity discounts and liquidity premia observed empirically correspond to a positive relationship between transaction costs and volatility. The talk is based on joint work with Johannes Muhle-Karbe and Dylan Possamaï.

Calypso Herrera (ETH Zurich, Switzerland)

Optimal stopping via randomized neural networks

This paper presents new machine learning approaches to approximate the solution of optimal stopping problems. The key idea of these methods is to use neural networks, where the hidden layers are generated randomly and only the last layer is trained, in order to approximate the continuation value. Our approaches are applicable for high dimensional problems where the existing approaches become increasingly impractical. In addition, since our approaches can be optimized using a simple linear regression, they are very easy to implement and theoretical guarantees can be provided. In Markovian examples our randomized reinforcement learning approach and in non-Markovian examples our randomized recurrent neural network approach outperform the state-of-the-art and other relevant machine learning approaches.

Juri Hinz (University of Technology Sydney, Australia)

Variables reduction in sequential resource allocation problems

This talk presents a general framework to address diverse notoriously difficult problems arising in the area of optimal resource management, exploitation of natural reserves, pension fund valuation, environmental protection, and storage operation. Using some common abstract features of this problem class, we present a technique which provides a significant reduction of decision variables. As an application, we discuss a battery storage control to show how a decision problem, which is practically unsolvable in the original formulation, can be treated by our method.

Julian Hölzermann (King's College, United Kingdom)

Term structure modeling under volatility uncertainty

We study a forward rate model in the presence of volatility uncertainty. The forward rate is modeled as a diffusion process in the spirit of Heath, Jarrow, and Morton [Econometrica 60 (1), 77-105]. The uncertainty about the volatility is represented by a G-Brownian motion, being the driver of the forward rate dynamics. Within this framework, we derive a sufficient condition for the absence of arbitrage, known as the drift condition. In contrast to the traditional model, the drift condition consists of several equations and several market prices, termed market price of risk and market prices of uncertainty, respectively. The drift condition is still consistent with the classical one if there is no volatility uncertainty. Similar to the traditional model, the risk-neutral dynamics of the forward rate are completely determined by its diffusion term. Furthermore, we obtain robust versions of classical term structure models as examples in this framework.

Ulrich Horst (Humboldt University of Berlin, Germany)

The microstructure of stochastic volatility models with self-exciting jump dynamics

We provide a general probabilistic framework within which we establish scaling limits for a class of continuous-time stochastic volatility models with self-exciting jump dynamics. In the scaling limit, the joint dynamics of asset returns and volatility is driven by independent Gaussian white noises and two independent Poisson random measures that capture the arrival of exogenous shocks and the arrival of self-excited shocks, respectively. Various well-studied stochastic volatility models with and without self-exciting price/volatility co-jumps are obtained as special cases under different scaling regimes. We analyze the impact of external shocks on the market dynamics, especially their impact on jump cascades and show in a mathematically rigorous manner that many small external shocks may trigger endogenous jump cascades in asset returns and stock price volatility. The talk is based on joint work with Wei Xu.

Blanka Horvath (King's College, United Kingdom)

Insights from deep hedging under rough volatility

We know that hedging in rough volatiliy models can be more delicate than in standard stochastic models. At the same time we know that rough models more closely reflect typical phenomena observed in market data, which deem them more attractive sources for synthetic training data for deep hedging algorithms. In fact, quantifying model performance under hedging has been proposed as a similarity metric for financial models and data streams. From this application-specific starting point we unravel this perspective and investigate different, more universal similarity metrics for stochastic processes and data streams.

Emma Hubert (Imperial College London, United Kingdom)

Epidemic control through incentives, lockdown, and testing: the government's perspective

In this talk, we consider the control of the COVID-19 pandemic from the point of view of a government. The spread of the epidemic can be represented through either stochastic SIS or SIR compartmental models, but, for clarity, we will focus here on the SIR model. When the epidemic is ongoing, the population, who is considered as a single agent in this model, can reduce interactions between individuals in order to decrease the transmission rate of the virus, and thus limit the epidemic. Indeed, the transmission rate depends essentially on two factors: the disease characteristics and the contact rate within the population. Although the population cannot modify the disease characteristics, each individual can choose (or be incentivised) to reduce his/her contact rate with other individuals in the population. Unfortunately, reducing social interactions is costly for the population. This cost takes into account both the obvious social cost, due to accrued isolation during the lockdown period, and an economic cost (loss of employment due to the lockdown,...). Therefore, the government can put into place incentive policies to encourage the lockdown of the population. In addition, the government may also implement a testing policy in order to know more precisely the spread of the epidemic within the country, and to isolate infected individuals. The interaction between the population and the government is represented through a principal-agent problem. More precisely, given the populations problem, we are able to determine the optimal form of the tax policy χ. Given this tax policy χ, and an arbitrary testing policy α, one can solve the populations optimisation problem, and thus find the optimal transmission rate, namely $\beta^\star\chi, \alpha$. Then, finding the optimal tax and testing policy from the governments point of view is equivalent to solving an Hamilton-Jacobi-Bellman equation. We provide numerical examples and compare the results with those obtained in two benchmark cases: one where the government can directly choose the optimal transmission rate (first-best case), the other where there is no incentive from the government. The numerical results confirm the relevance of a tax and testing policy to improve the control of an epidemic. More precisely, if a tax policy is put into place, even in the absence of a specific testing policy, the population is encouraged to significantly reduce its interactions, thus limiting the spread of the disease. If the government also adjusts its testing policy, less effort is required on the population side, so individuals can interact almost as usual, and the epidemic is largely contained by the targeted isolation of positively-tested individuals. Joint work with Thibaut Mastrolia, Dylan Possamaï, and Xavier Warin.

Akif Ince (Birkbeck College, United Kingdom)
Risk contributions of lambda quantiles

Risk contributions of portfolios form an indispensable part of risk adjusted performance measurement. The risk contributions of a portfolio, e.g., in the Euler or Aumann-Shapley framework, is given by the partial derivatives of a risk measure applied to the portfolio return in direction of the asset weights. For risk measures that are not positively homogeneous, however, these capital allocation principles do not hold. We study the class of lambda quantile risk measures, that includes the well-known Value-at-Risk, but for which no known allocation rule is applicable. We prove differentiability and derive explicit formulae of the derivatives of lambda quantiles with respect to their portfolio composition, that is their risk contributions. For this, we define lambda quantiles on the space of portfolio compositions (instead of random variables) and consider generic (non-linear) portfolio operators. We further derive the Euler decomposition of lambda quantiles for generic portfolios and show that lambda quantiles are homogeneous in the space of portfolio compositions, with a homogeneity degree that depends on the portfolio composition and the lambda function. A result that is in stark contrast to the positive homogeneity properties of risk measures defined on the space of random variables. We provide financial interpretations of the homogeneity degrees of lambda quantiles and introduce the notion of event-specific homogeneity of portfolio operators.

Joseph Jerome (University of Warwick, United Kingdom)
Infinite horizon stochastic differential utility

Stochastic differential utility has been widely studied since its formulation by Duffie and Epstein in 1992. It allows modelling of a much wider range of risk and intertemporal preferences and therefore provides a natural extension to the Merton problem for time-additive utility. However, whilst the finite time horizon problem is now fairly well understood, few have investigated the infinite horizon 'lifetime' problem. In our paper we provide a novel formulation of the lifetime problem, highlighting and explaining the role of the transversality condition. We then discuss the parameters governing the agent's preferences and show that certain parameter combinations considered in the literature are ill-posed over the infinite horizon. We prove existence of a finite valued utility process for a large class of consumption streams and then show that, by considering a natural generalisation, we may assign a meaningful utility to any non-negative progressively measurable process. This means that, regardless of the choice of financial market, self-financing consumption streams are always evaluable. Finally, we show existence and uniqueness of an optimal strategy in a Black-Merton-Scholes market.

Sven Karbach (University of Amsterdam, Netherlands)
An affine stochastic volatility model in Hilbert spaces with state-dependent jumps

We present a flexible and tractable class of stochastic volatility models in Hilbert spaces with constant and state-dependent jumps. The models consist of a Hilbert-space valued Ornstein-Uhlenbeck process joint by an affine Markov process, which we use to model the operator-valued instantaneous variance process of the former. The Ornstein-Uhlenbeck process is driven by an infinite dimensional Brownian motion and admits for a possibly unbounded drift operator. The variance process is recruted from a class of pure-jump Markov processes with values in the positive self-adjoint Hilbert- Schmidt operators and such that its Laplace transform exhibits an exponential- affine form in the initial value of the process. We show that this affine property inherits to the characteristic function of the joint model and we provide existence and uniqueness results for the associated generalized Riccati equations.

Nazem Khan (Warwick University, United Knigdom)

Mean-ρ portfolio selection and ρarbitrage for coherent risk measures

We revisit mean-risk portfolio selection in a one-period financial market where risk is quantified by a positively homogeneous risk measure ρ. We first show that under mild assumptions, the set of optimal portfolios for a fixed return is nonempty and compact. However, unlike in classical mean-variance portfolio selection, it can happen that no efficient portfolios exist. We call this situation ρ-arbitrage, and prove that it cannot be excluded – unless ρ is as conservative as the worst-case risk measure. After providing a primal characterisation of ρ-arbitrage, we focus our attention on coherent risk measures that admit a dual representation and give a necessary and sufficient dual characterisation of ρ-arbitrage. We show that the absence of ρ-arbitrage is intimately linked to the interplay between the set of equivalent martingale measures (EMMs) for the discounted risky assets and the set of absolutely continuous measures in the dual representation of ρ. A special case of our result shows that the market does not admit ρ-arbitrage for Expected Shortfall at level α if and only if there exists an EMM $Q \sim P$ such that $dQ/dP < 1/\alpha$.

Florian Krach (ETH Zürich, Switzerland)

Neural jump ordinary differential equations: consistent continuous-time prediction and filtering

Combinations of neural ODEs with recurrent neural networks (RNN), like GRU-ODE-Bayes or ODE-RNN are well suited to model irregularly observed time series. While those models outperform existing discrete-time approaches, no theoretical guarantees for their predictive capabilities are available. Assuming that the irregularly-sampled time series data originates from a continuous stochastic process, the L^2-optimal online prediction is the conditional expectation given the currently available information. We introduce the Neural Jump ODE (NJ-ODE) that provides a data-driven approach to learn, continuously in time, the conditional expectation of a stochastic process. Our approach models the conditional expectation between two observations with a neural ODE and jumps whenever a new observation is made. We define a novel training framework, which allows us to prove theoretical guarantees for the first time. In particular, we show that the output of our model converges to the L^2-optimal prediction. This can be interpreted as solution to a special filtering problem. We provide experiments showing that the theoretical results also hold empirically. Moreover, we experimentally show that our model outperforms the baselines in more complex learning tasks and give comparisons on real-world datasets.

Silvia Lavagnini (University of Oslo, Norway)

Accuracy of deep learning in calibrating HJM forward curves

We price European-style options written on forward contracts in a commodity market, which we model with an infinite-dimensional Heath-Jarrow-Morton (HJM) approach. For this purpose, we introduce a new class of state-dependent volatility operators that map the square integrable noise into the Filipovic space of forward curves. For calibration, we specify a fully parametrized version of our model and train a neural network to approximate the true option price as a function of the model parameters. This neural network can then be used to calibrate the HJM parameters based on observed option prices. We conduct a numerical case study based on artificially generated option prices in a deterministic volatility setting. In this setting, we derive closed pricing formulas, allowing us to benchmark the neural network based calibration approach. We also study calibration in illiquid markets with a large bid-ask spread. The experiments reveal a high degree of accuracy in recovering the prices after calibration, even if the original meaning of the model parameters is partly lost in the approximation step.

Felix-Benedikt Liebrich (Leibniz University of Hannover, Germany)

Model uncertainty: a reverse approach

In robust finance, Knightian uncertainty is often captured by sets of probability measures on the future states of the world. If these measures are nondominated, this usually comes at the cost of losing tractability, and advanced functional analytic tools are often not available anymore. This tends to be mitigated by ad hoc assumptions that guarantee a certain degree of tractability, for instance concerning the aggregation of consistent random variables. We investigate from a reverse perspective what implications the validity of certain functional-analytic tools has. In this vein, we categorise the Kreps-Yan property, robust variants of the Brannath-Schachermayer Bipolar Theorem and the Grothendieck Lemma, and uncertain volatility models.

Fabrizio Lillo (University of Bologna, Italy)

Instabilities in multi-asset and multi-agent market impact games

We consider the general problem of a set of agents trading a portfolio of assets in the presence of transient price impact and additional quadratic transaction costs and we study, with analytical and numerical methods, the resulting Nash equilibria. Significantly extending the framework of Schied & Zhang (2019) and Luo & Schied (2020), who considered the one asset case, we focus our attention on the conditions on the value of transaction cost making the trading profile of the agents, and as a consequence the price trajectory, wildly oscillating and the market unstable. We prove the existence and uniqueness of the corresponding Nash equilibria for the related mean-variance optimization problem. We find that the presence of more assets and a large number of agents make the market more prone to large oscillations and instability. When the number of assets is fixed, a more complex structure of the cross-impact matrix, i.e. the existence of multiple factors for liquidity, makes the market less stable compared to the case when a single liquidity factor exists. With Francesco Cordoni.

Chong Liu (University of Oxford, United Kingdom)

Adapted topologies and higher rank signatures

The topology of weak convergence does not account for the growth of information over time contained in the filtration of an adapted stochastic process. For example, two adapted stochastic processes can have very similar laws but give completely different results in applications such as optimal stopping, queuing theory, or stochastic programming. To address such disconinuities, Aldous introduced extended weak convergence, and subsequently, Hoover and Keisler showed that both weak convergence and extended weak convergence are just the first two topologies in a sequence of topologies index by a rank that get increasingly finer as the rank increases. By using so-called higher rank expected signatures to describe laws of stochastic processes that evolve in spaces of measures on pathspace, we embed adapted processes into graded linear spaces and show that these embeddings induce the Hoover–Keisler topology of any given rank, as moments mapping determines laws of random variables. This approach provides an alternative perspective on a recent important work by Backhoff–Veraguas, Bartl, Beiglboeck and Eder regarding adapted topologies and causal Wasserstein metrics, and will have many significant applications in machine learning of e.g. pricing of American option or utility maximization.

Giacomo Marangoni (Politecnico di Milano, Italy)

An integrated multi-objective appraisal of mitigation and climate engineering under uncertainty

Managing global climate risks poses at least two formidable decision-analysis challenges. First, trade-offs arise when evaluating climate solutions against multiple economic and environmental performance metrics. Second, the coupled human-Earth systems are subject to deep and dynamic uncertainties. The Integrated Assessment Models (IAMs) literature scarcely address these issues in isolation, and never jointly. Here, we propose an approach to identify robust mitigation strategies taking into account both diverse societal preferences and multiple dynamic uncertainties. We first consider adaptive abatement strategies, which modulate emission reductions depending on the observed global temperature changes. We analyze their potential trade-offs and quantify the value of the temperature information feedback under well-characterized and deep climate uncertainties. We do so with a modified version of the Dynamic Integrated Climate-Economy (DICE) model. This framework might be especially beneficial with geoengineering technologies: their profound uncertainties and controversial acceptability have hindered so far an effective use of IAMs to navigate the space of related climate solutions. Thus, we extend DICE to include Solar Radiation Management (SRM), and provide a multi-objective assessment of combined mitigation and geoengineering strategies. We then identify those strategies that are consistent with safe climate thresholds and that are most robust to the uncertainties of climate response and SRM effectiveness.

Elisa Mastrogiacomo (Università degli Studi dell'Insubria, Italy)

Optimization of coherent multivariate risk measures

In the last decades stochastic programming was introduced to deal with uncertain values of coefficients which were observed in applications of linear programming. These uncertainties were modeled as random and the assumption of complete knowledge of the probability distribution P of random parameters became a standard. In many practical problems, however, the involved probability distributions are never known exactly. To overcome this difficulty, one can try to hedge against the worst expected value resulting from a considered set of permissible distributions A. The objective of the problem is then reformulated under worst case analysis over the choice of a distribution in the set. Starting with the work of Zackova (1966), these models have been investigated by many authors (see, e.g., among many others, Dupacova (1987,2001), Gaivoronski (1991) and Shapiro and Kleywegt (2001)) and since then has been referred as minimax stochastic programming or distributionally robust optimization.

Shapiro and Kleywegt (2001), in particular, proved that, under mild regularity conditions, optimization problems of this kind can be formulated as an expected value problem with respect to some weighted distribution in the set A. In this talk we want to generalize the study of minimax stochastic programming to the case where the objective function is a multi-objective function. In doing this, we will consider two possible approaches: the vector approach and the set approach and, in both cases, we will firstly provide necessary and sufficient condition of optimality in terms of suitable first order conditions. Later, we intend to compare the previous approaches with the minimization of vector-valued and set-valued risk-measures. Measuring the risk of a random payoff consists in computing statistical quantities describing the loss distribution of the portfolio over some predetermined horizon and, recently, risk assessment has been introduced even in a vector- and set-valued framework (see Jouini et. al (2004), Cascos and Molchanov (2007) and Hamel and Heyde (2010)). We intend to show that minimization of a certain of vector- (respectively, set-)valued risk measure is, in a sense, equivalent to a vector (respectively, set) optimization of an expected value problem with respect to some weighted distribution in the set permissible distributions. We also introduce and analyze specific optimization problems involving risk functions. Examples include the well-known Conditional Value-at-Risk and their multivariate and set-valued extensions that have been recently introduced in the aforementioned papers. The talk will be based on a joint paper with Matteo Rocca.

Andrea Mazzon (LMU Munich, Germany)

Optional projection under equivalent local martingale measures

In this paper we study optional projections of $\mathbb{G}$-adapted strict local martingales into a smaller filtration $\mathbb{F}$ under changes of equivalent martingale measures. Some general results are provided as well as a detailed analysis of two specific examples given by the inverse three dimensional Bessel process and a class of stochastic volatility models. The novelty is that we provide such results not only under a reference measure P but more in general for a set of equivalent local martingale measures. This analysis contributes to clarify some properties, for example absence of arbitrage opportunities of market models under restricted information.

Alessandro Milazzo (Imperial College London, United Kingdom)

Dynamic programming principle for singular control with discretionary stopping problems

Problems of singular control with discretionary stopping arise from several applications, for instance, target tracking problems in engineering and consumption/investment problems with transaction cost in mathematical finance. We develop a rigorous probabilistic study of general problems of singular control with discretionary stopping in finite horizon which results in the proof of the dynamic programming principle.

Alexander Molitor (Goethe-University Frankfurt, Germany)

Semimartingale price systems in models with transaction costs beyond efficient friction

A standing assumption in the literature on proportional transaction costs is efficient friction. Together with robust no free lunch with vanishing risk, it rules out strategies of infinite variation, as they usually appear in frictionless markets. In this talk, we show how the models with and without transaction costs can be unified. The bid and the ask price of a risky asset are given by càdlàg processes which are locally bounded from below and may coincide at some points. In a first step, we show that if the bid-ask model satisfies no unbounded profit with bounded risk for simple strategies, then there exists a semimartingale lying between the bid and the ask price process. In a second step, under the additional assumption that the zeros of the bid-ask spread are either starting points of an excursion away from zero or inner points from the right, we show that for every bounded predictable strategy specifying the amount of risky assets, the semimartingale can be used to construct the corresponding self-financing risk-free position in a consistent way. Finally, the set of most general strategies is introduced, which also provides a new view on the frictionless case.

Marcel Nutz (Columbia University, United States)

Entropic optimal transport

Computational progress has lead to manifold applications of optimal transport in high-dimensional problems ranging from machine learning and statistics to image and language processing. In this context, entropic regularization is crucial to enable efficient large-scale computation via Sinkhorn's algorithm. In this talk we discuss the convergence of entropic optimal transport to the unregularized counterpart as the regularization parameter vanishes, as well as the stability of entropic optimal transport with respect to the marginals. A geometric approach reminiscent of c-cyclical monotonicity is emphasized. Based on joint works with Espen Bernton (Columbia), Promit Ghosal (MIT), Johannes Wiesel (Columbia).

Gilles Pagès (Sorbonne Université, France)

Stationary Heston model: calibration and pricing of exotics using product recursive quantization

A major drawback of the Standard Heston model is that its implied volatility surface does not produce a steep enough smile when looking at short maturities. For that reason, we consider the Stationary Heston model where the deterministic initial condition of the volatility process is replaced by its invariant measure. We show, based on calibrated parameters, that this model produces a steeper smile for short maturities than the original Heston model. We also present numerical procedure based on Product Recursive Quantization for the pricing of exotic options (Bermudan and Barrier options).

Andrea Pallavicini (Banca IMI, Italy)

A general framework for a joint calibration of VIX and VXX options

We analyze the VIX futures market with a focus on the exchange-traded notes written on such contracts, in particular, we investigate the VXX notes tracking the short-end part of the futures term structure. Inspired by recent developments in commodity smile modeling, we present a multi-factor stochastic local-volatility model able to jointly calibrate plain vanilla options both on VIX futures and VXX notes. We discuss numerical results on real market data by highlighting the impact of model parameters on implied volatilities.

Raymond Pang (LSE, United Kingdom)

Assessing and mitigating fire sales risk under partial information

We consider the problem of assessing and mitigating fire sales risk for banks under partial information. Using data from the European Banking Authority's stress tests, we consider the matrix of asset holdings of different banks. We first analyse fire sales risk under both full and partial information using different matrix reconstruction methods. We then investigate how well some policy interventions aimed at mitigating fire sales risk perform if they are applied based on only partial information. We compare the performance of policy interventions under full and partial information. We find that even under partial information, using suitable network reconstruction methods to decide on policy interventions can significantly mitigate risk from fire sales. Furthermore, we show that some interventions based on reconstructed networks significantly outperform ad hoc methods that decide on interventions only based on the size of an institution and do not account for overlapping portfolios.

Alexandre Pannier (Imperial College London, United Kingdom)

Large and moderate deviations for stochastic Volterra systems

We provide a unified treatment of pathwise Large and Moderate deviations principles for a general class of multidimensional stochastic Volterra equations with singular kernels, not necessarily of convolution form. Our methodology is based on the weak convergence approach by Budhiraja, Dupuis and Ellis. We show in particular how this framework encompasses most rough volatility models used in mathematical finance, yields pathwise moderate deviations for the first time and generalises many recent results in the literature.

Antonis Papapantoleon (NTU Athens, Greece)

Model-free bounds for multi-asset options using option-implied information and their exact computation

We consider derivatives written on multiple underlyings in a one-period financial market, and we are interested in the computation of model-free upper and lower bounds for their arbitrage-free prices. We work in a completely realistic setting, in that we only assume the knowledge of traded prices for other single- and multi-asset derivatives, and even allow for the presence of bid-ask spread in these prices. We provide a fundamental theorem of asset pricing for this market model, as well as a superhedging duality result, that allows to transform the abstract maximization problem over probability measures into a more tractable minimization problem over vectors, subject to certain constraints. Then, we recast this problem into a linear semi-infinite optimization problem, and provide two algorithms for its solution. These algorithms provide upper and lower bounds for the prices that are ϵ-optimal, as well as a characterization of the optimal pricing measures. Moreover, these algorithms are efficient and allow the computation of bounds in high-dimensional scenarios (e.g. when $d = 60$). Numerical experiments using synthetic data showcase the efficiency of these algorithms, while they also allow to understand the reduction of model-risk by including additional information, in the form of known derivative prices.

Marco Patacca (University of Verona, Italy)

Regime switches and commonalities of the cryptocurrencies asset class

In this paper we test for regime changes and possible regime commonalities in the price dynamics of Bitcoin, Ethereum, Litecoin and Monero, as representatives of the cryptocurrencies asset class. Several parametric models are considered for the joint dynamics of the basket price where parameters are modulated through a Hidden Markov Chain with finite state space. Best specifications within Gaussian and Autoregressive models for price differences are selected by means of the AIC and BIC information criteria and through an out-of-sample forecasting performance. The empirical results, within the period January 2016 to October 2019, suggest that three or four states may be relevant to describe the dynamics of each individual cryptocurrency, depending on the selection criteria, while the entire basket displays at most three common states. Finally, we show how the identification of appropriate models may be exploited in order to build profitable investment strategies on the considered cryptocurrencies.

Andrea Perchiazzo (Vrije Universiteit Brussel, Belgium)

Implied Value-at-Risk and model-free simulation

We propose a novel model-free approach for extracting the risk-neutral quantile function of an asset using option prices. We develop two applications. First, we show that the asset's implied Value-at-Risk and Tail Value-at-Risk can be directly estimated using the options that are written on it. Second, we show how for a given stochastic asset model our approach makes it possible to simulate the underlying terminal asset value in a direct manner. Specifically, it is shown that our approach outperforms existing approaches for simulating asset values for stochastic volatility models such as the Heston and the SABR models.

Athena Picarelli (University of Verona, Italy)

Deep XVA solver - a neural network based counterparty credit risk management framework

In this paper, we present a novel computational framework for portfolio-wide risk management problems, where the presence of a potentially large number of risk factors makes traditional numerical techniques ineffective. The new method utilizes a coupled system of BSDEs for the valuation adjustments (xVA) and solves these by a recursive application of a neural network based BSDE solver. This not only makes the computation of xVA for high-dimensional problems feasible, but also produces hedge ratios and dynamic risk measures for xVA, and allows simulations of the collateral account.

Jan Pospíšil (University of West Bohemia, Czech Republic)

Robustness and sensitivity analyses for rough Volterra stochastic volatility models

In this talk we perform robustness and sensitivity analysis of several continuous-time rough fractional stochastic volatility (RFSV) models with respect to the process of market calibration. The analyses should validate the hypothesis on importance of the roughness in the volatility process dynamics. Empirical study is performed on a data set of Apple Inc. equity options traded in four different days in April and May 2015. In particular, the results for

RFSV, rBergomi and aRFSV models are provided.

Dylan Possamaï (ETH Zurich, Switzerland)
Moral hazard for time-inconsistent agents and BSVIEs

We address the problem of Moral Hazard in continuous time between a Principal and an Agent that has time-inconsistent preferences. Building upon previous results on non-Markovian time-inconsistent control for sophisticated agents, we are able to reduce the problem of the principal to a novel class of control problems, whose structure is intimately linked to the representation of the problem of the Agent via a so-called extended Backward Stochastic Volterra Integral equation. We will present some results on the characterization of the solution to the problem for different specifications of preferences for both the Principal and the Agent.

David Prömel (University of Mannheim, Germany)
A cadlag rough path foundation for robust finance

Using rough path theory we provide a pathwise foundation for stochastic Ito integration, which covers most commonly applied trading strategies and mathematical models of financial markets possibly under Knightian uncertainty. To that end we introduce the so-called Property (RIE) for cadlag paths, which is shown to imply the existence of a cadlag rough path and of quadratic variation in the sense of Follmer. Assuming Property (RIE), we prove that the corresponding rough integrals exist as limits of left-point Riemann sums along suitable sequences of partitions. As a direct consequence, this allows to treat integrands of non-gradient type and gives access to the powerful stability estimates from rough path theory. Additionally, we verify that (path-dependent) functionally generated trading strategies and Cover's universal portfolio are admissible integrands and that Property (RIE) is satisfied by (Young) semimartingales and typical price paths.

Sergio Pulido (University of Évry, France)
American options in the rough Heston model

Rough volatility models have emerged as compelling alternatives to classical semimartingale models to capture important stylized features of the implied volatility surface and the time series of realized volatility. The rough Heston model is particularly appealing because its affine structure facilitates the pricing of European options using Fourier techniques. In this work we consider the problem of pricing American options in the rough Heston model. The complexity of the problem stems from the absence of a Markovian-semimartingale structure in the model. To overcome this difficulty we work with a Markovian multi-factor semimartingale stochastic volatility model, which approximates the rough Heston model. In this approximated model, American options can be priced using a backward approach and simulation-based methods. We prove the convergence of American options prices in the multi-factor model towards the prices in the rough Heston model. The proof relies on the explicit expression of the conditional characteristic function of the joint forward process and the spot price , which is a consequence of the affine structure of the model. We illustrate with some numerical examples the behavior of American option prices with respect to some parameters in the model. This is joint work with Etienne Chevalier and Elizabeth Zúniga.

Iacopo Raffaelli (Scuola Normale Superiore, Italy)

Revisiting the Implied Remaining Variance framework of Carr and Sun (2014): locally consistent dynamics and sandwiched martingales

Implied volatility is at the very core of modern finance, notwithstanding standard option pricing models continue to derive option prices starting from the joint dynamics of the underlying asset price and the spot volatility. These models often causes difficulties: no closed formulas for prices, demanding calibration techniques, unclear maps between spot and implied volatility. Inspired by the practice of using implied volatility as quoting system for option prices, models for the joint dynamics of the underlying asset price and the implied volatility have been proposed to replace standard option pricing models. Starting from Carr and Sun (2014), we develop a framework based on the Implied Remaining Variance where minimal conditions for absence of arbitrage are identified, and smile bubbles are dealt with. The key concepts arising from the new IRV framework are those of locally consistent dynamics and sandwiched martingale. Within the new IRV framework, the results of Schweizer and Wissel (2008b) are retrieved, while those of El Amrani, Jacquier, and Martini (2021) are independently derived.

Frank Riedel (University of Bielefeld, Germany)

Frank Knight's legacy: the economics of uncertainty and risk

Motivated by the centenary of the publication of Frank Knight's book "Risk, Uncertainty, and Profit", we review some of his ideas and discuss how they are reflected in current research in finance and economics. We discuss three recent contributions including insurance premia, viability and arbitrage in financial markets, and market breakdown due to uncertainty in prices.

Stefan Rigger (University of Vienna, Austria)

Propagation of minimality in the supercooled Stefan problem

The one-dimensional one-phase Supercooled Stefan Problem is a PDE problem with free boundary which serves as a model for the freezing of supercooled liquids. Under certain conditions, this model will exhibit blow-up in finite time. Following the methodology of Delarue, Nadtochiy and Shkolnikov, we construct solutions to the Supercooled Stefan Problem through the Fokker-Planck equation associated to a stochastic process that solves a certain McKean-Vlasov equation. This technique allows us to define solutions globally even in the presence of blow-ups. Solutions to the associated McKean-Vlasov equation can be constructed via an approximating particle system, and we prove Propagation of Chaos. The particle system in question appears in the literature on systemic risk, establishing the connection of the aforementioned results to Mathematical Finance. Finally, we prove a conjecture of Delarue, Nadtochiy and Shkolnikov, relating the solution concepts of so-called minimal and physical solutions, showing that minimal solutions of the McKean-Vlasov equation are physical whenever the initial condition is integrable.

Emanuela Rosazza Gianin (University of Milano Bicocca, Italy)

Capital allocation rules: new perspectives in a static and dynamic setting

In the theory of risk measures, capital allocation is a well-known problem consisting in sharing "ad hoc" the margin required for a position among the different sources of riskiness. Such a problem has been faced in the literature by using different approaches (depending on the nature of the risk measure behind) also in connection with systemic risk and game theory. Although there is a wide literature on the relation between dynamic risk measures and BSDEs and on capital allocation rules in a static setting, only a few recent papers on capital allocation work in a dynamic setting by focusing mainly on the gradient approach. In this talk, we discuss new perspectives to the capital allocation problem going beyond those already existing in the literature. In particular, a new approach to face capital allocation problems from the perspective of acceptance sets and a general approach to capital allocations in a dynamic framework for risk measures induced by g-expectations will be introduced and studied in an axiomatic way. Based on joint works with G. Canna, F. Centrone and E. Mastrogiacomo.

Ioanid Rosu (HEC Paris, France)
Dynamic adverse selection and liquidity

Does a larger fraction of informed trading generate more illiquidity, as measured by the bid-ask spread? We answer this question in the negative in the context of a dynamic dealer market where the fundamental value follows a random walk, provided we consider the long run (stationary) equilibrium. More informed traders tend to generate more adverse selection and hence larger spreads, but at the same time cause faster learning by the market makers and hence smaller spreads. These two effects offset each other in the long run.

Francesco Rotondi (Università Bocconi and University of Padova, Italy)
On time-consistent multi-horizon portfolio allocation

We analyse the problem of constructing multiple mean-variance portfolios over increasing investment horizons in stochastic interest rate markets. The traditional one-period mean-variance optimal portfolios of Hansen and Richard (1987) require the replication of two payoffs. When several maturities are considered, different payoffs have to be replicated each time, with an impact on transaction costs. Using martingale decomposition techniques and introducing a family of risk-adjusted measures linked to increasing maturities, we provide an intertemporal version of the traditional orthogonal decomposition of asset returns. This allows us to construct a multi-horizon mean-variance frontier that is time-consistent and requires the replication of solely two payoffs for all horizons under consideration. When transaction costs are taken into account, our time-consistent mean-variance frontier may outperform the traditional mean-variance optimal strategies in terms of Sharpe ratio. Some interesting examples of this fact come from long-term contracts as life annuities.

Agnieszka Rygiel (Cracow University of Economics, Poland)
Semi-static hedging under volatility uncertainty

We consider a financial market in discrete time consisting of the stock and options where the stock is traded dynamically and options are traded statically. Unit prices of the assets depend on the sign of a trade (buy or sell) and on the quantity of the traded amount. We study the super-hedging of (path dependent) European options in the setup of model uncertainty. We first use the Kuhn-Tucker theory to prove the super-hedging result in a discrete path space. Using the discretization technique, we then get the duality in the original setting with uncertain volatilities.

Emel Savku (University of Oslo, Norway)
Stochastic differential games via dynamic programming principle with regimes

We apply dynamic programming principle to discuss two optimal investment problems by using zero-sum and nonzero-sum stochastic game approaches in a continuous-time Markov regime-switching environment. We represent different states of an economy by a D-state Markov chain. For example, this mathematical structure may correspond investors' floating levels of psychological reactions. Our first application is a zero-sum game between an investor and the market, and the second one formulates a nonzero-sum stochastic differential portfolio game as the sensitivity of two investors' terminal gains. We derive regime-switching Hamilton-Jacobi-Bellman-Isaacs equations and obtain explicit optimal portfolio strategies. We illustrate our results in a two-state special case and observe the impact of regime switches by comparative results.

Thorsten Schmidt (University of Freiburg, Germany)
Arbitrage in Insurance

In this talk, we aim at a fundamental valuation principle of insurance contracts. Insurance contracts are inherently linked to financial markets, be it via interest rates - or like in hybrid products, equity-linked life insurance or variable annuities - directly to stocks or indices. By defining portfolio strategies on an insurance portfolio and combining them with financial trading strategies we arrive at the notion of insurance-finance arbitrage (IFA). A fundamental theorem provides two sufficient conditions for presence or absence of IFA, respectively. For the first one it utilizes the conditional law of large numbers and risk-neutral valuation. As a key result we obtain a simple valuation rule, called QP-rule, which is market consistent and excludes IFA. The generality of the approach allows to incorporate many important aspects, like mortality risk or dependence of mortality and stock markets which is of utmost importance in the recent corona crisis. For practical applications, we provide an affine formulation which leads to explicit valuation formulas for a large class of hybrid products.

Simone Scotti (Université de Paris (Paris Diderot), France)
The Alpha-Heston stochastic volatility model

We introduce an affine extension of the Heston model, called the α-Heston model, where the instantaneous variance process contains a jump part driven by α-stable processes with $\alpha \in (1, 2]$. In this framework, we examine the implied volatility and its asymptotic behavior for both asset and VIX options. Furthermore, we study the jump clustering phenomenon observed on the market. We provide a jump cluster decomposition for the variance process where each cluster is induced by a "mother jump" representing a triggering shock followed by "secondary jumps" characterizing the contagion impact.

Patrizia Semeraro (Politecnico di Torino, Italy)

Model risk in credit risk

We provide sharp analytical upper and lower bounds for Value-at-Risk and sharp bounds for Expected Shortfall of portfolios of any dimension subject to default risk. The main mathematical contribution of this work consists in analytically finding the convex hull generators for the class of exchangeable Bernoulli variables with given mean and for the class of exchangeable Bernoulli variables with given mean and correlation. The analytical solution allows us to work in any dimension. The second contribution consists in describing all the joint distributions of defaults, even for large portfolios, and/or the possible distributions of the loss. This is because the multivariate Bernoulli variables represent the default indicators of a portfolio of obligors, through the ray densities, that we can nd analytically. Because we can represent all the possible distributions of the loss, we can compute the bounds for two synthetic risk measures used in the nance literature, Value-at-Risk (VaR) and Expected Shortfall (ES). The paper then provides a third contribution: we show that the sharp - or attainable - VaR bounds are reached on the ray densities and we find an analytical expression for them. We also explicitly find bounds for the ES. We then measure the consequence of using a specic model looking at the range of the possible VaR and ES and how model risk aects Value-at-Risk and Expected Shortfall.

Carlo Sgarra (Politecnico di Milano, Italy)

A Barndorff-Nielsen and Shephard model with leverage in Hilbert space for commodity forward markets

We propose an extension of the model proposed by Barndorff-Nielsen and Shephard, based on stochastic processes of Ornstein-Uhlenbeck taking values in Hilbert spaces, including the leverage effect. We compute explicitly the characteristic function of the logreturn and the volatility processes. By introducing a measure change of Esscher type we provide a relation between the dynamics described with respect to the historical and to the risk-neutral measures. We discuss in detail the application of the proposed model in order to describe the commodity forward curve dynamics in a Heath-Jarrow-Morton framework, including the modelling of forwards with delivery period occurring in energy markets and pricing of options. For the latter, we show that a Fourier approach can be applied in this infinite-dimensional setting, relying on the attractive property of conditional Gaussianity of our stochastic volatility model. In our analysis, we study both arithmetic and geometric models of forward prices and provide appropriate martingale conditions in order to ensure a no-arbitrage dynamics. Joint work with F.E. Benth.

Osian Shelley (University of Warwick, United Kingdom)

Transaction tax in a general equilibrium model

In this talk, we consider the effects of a quadratic tax rate levied against two agents with heterogeneous risk aversions in a continuous-time, risk-sharing equilibrium model. The goal of each agent is to choose a trading strategy which maximises the expected changes in her wealth, for which an optimal strategy exists in closed form, as the solution to an FBSDE. This tractable set-up allows us to analyse the utility loss incurred from taxation. In particular, we show why in some cases an agent can benefit from the taxation before redistribution. Moreover, when agents have heterogeneous beliefs about the traded asset, we discuss if taxation and redistribution can dampen speculative trading and benefit the agents, respectively.

David Shkel (University of Hagen, Germany)

Barrier option pricing with trading and non-trading hours

Continuously monitored barrier options are common components of derivative retail structured products. Because barriers can only be breached during trading hours, traditional pricing formulas severely overestimate the barrier hit probability and consequently underestimate the option value, especially if the underlying is close to the barrier. While it is possible to integrate non-trading hours in a Monte Carlo simulation to calculate prices, market makers need to continuously quote prices for thousands of products. Consequently, computational speed can be an issue. We introduce a semi-analytical pricing approach, which takes non-trading hours into account. With this approach, we are able to analyze the behavior of down-and-out put option prices throughout the trading day and find a common pattern across different market conditions. Given a small and constant distance to the barrier, prices of down-and-out puts tend to rise over the trading day, with a steep increase close to the end of the trading day. This can be linked to the barrier hit probability, which is adequately captured in the proposed valuation approach, but is overestimated in classical pricing formulas.

Bernard Sinclair-Desgagné (Skema Business School and Université Côte d'Azur, France)

Climate policy under model uncertainty

This presentation will introduce a general approach to conceive climate policy when there is no consensual risk assessment model. This approach builds on a basic attribute of rational policymakers, namely their ability to appraise their experts' scenarios and forecasts. It also uses only one normative criterion: that the value to policymakers of a remedy's projected outcomes meets their willingness to get out of the current situation. Unlike the methods currently put forward in the literature, it does not need (but is compatible with) a representative policymaker's objective function (as in the ambiguity aversion literature), a reference model (as in robust control theory) or some prior probability distribution over the set of supplied scenarios (as in Bayesian model-averaging). Policies constructed in this manner would be effective, robust, simple and precautionary in a precise and intuitive sense.

Natalia Sirotko-Sibirskaya (University of Oslo, Norway)

Deep reinforcement learning-based portfolio management for the cryptocurrency market

Deep learning learning methods are gaining popularity in various fields due to their versatility in applications and accurate predictions. In particular, reinforcement learning methods are proven to be successful in dynamic portfolio optimization, see, e. g., Sato (2019) for an overview of reinforcement learning in portfolio allocation. A substantial drawback of deep-learning-based methods still lies in their convergence which is either not guaranteed or limited to very particular cases. Adaptation of existing methods to address the real-world challenges is an active area of research. In our work we consider chance-constrained reinforcement learning algorithm for non-stationary environments modelled with constrained non-stationary Markov decision processes. Our approach is based on reward constrained policy optimization which uses a penalty to guide the policy towards the constraint satisfying one, see Tessler et al. (2018). In order to account for non-stationarity of the underlying environment we combine above mentioned reward policy optimization with a change-point detection algorithm which adapts the penalty to the changes in the environment, see Padakandla et al. (2020). We demonstrate our approach on the example of cryptocurrency portfolio management.

Andreas Sojmark (Imperial College London, United Kingdom)

Contagious McKean-Vlasov systems under heterogenous interactions

In this talk I will introduce a tractable heterogenous formulation of a class of contagious McKean-Vlasov systems that appear, for example, in the modelling of financial solvency cascades and synchronised spiking of neurons. Most importantly, I will discuss the convergence of the underlying finite particle system, and I will then present an intuitive characterisation of the limiting system's inherent fragility, which may emerge if the contagious forces concentrate into a singularity.

Tommi Sottinen (University of Vaasa, Finland)

Conditional-mean hedging in Gaussian long-memory models with transaction costs

We consider invertible Gaussian Volterra processes and derive a formula for their prediction laws. Examples of such processes include long-memory processes such as fractional Brownian motions and mixed fractional Brownian motions. We then consider conditional-mean hedging under transaction costs in Black-Scholes type pricing models where the Brownian motion is replaced with a more general invertible Gaussian Volterra process.

Lukasz Stettner (Institute of Mathematics Polish Acad. Sci., Poland)

Long run risk sensitive impulse control problems

We consider impulse control of Feler Markov processes with long run risk sensitive cost functional. Existence of solution to suitable Bellman equation is shown. The study of such equation requires results from optimal stopping with multiplicative functionals. Such problem is important in risk sensitive portfolio optimization where portions of capital invested in assets plus potential ergodic process of economic factors form a Markov process. The problem is also important when risk factor is positive since then we study asymptotics of power utility function of terminal wealth. In the talk summary of known and new results will be presented. A number of open problems will be formulated.

Agnès Sulem (INRIA Paris, France)

Mean-field BSDEs with jumps and global risk measures

We study mean-field BSDEs with jumps and a generalized mean-field operator that can capture higher order interactions. We interpret the BSDE solution as a dynamic risk measure for a representative bank whose risk attitude is influenced by the system. This influence can come in a wide class of choices, including the average system state or average intensity of system interactions. We provide convergence results of finite interacting systems to the limit mean-field BSDE. We prove comparison and strict comparison results for mean-field BSDE and using Fenchel-Legendre transforms, we prove a dual representation for the expectation of the associated global risk measure. Talk based on joint works with Zhongyuan Cao (INRIA Paris), Rui Chen (INRIA Paris), Roxana Dumitrescu (King's College London), Andreea Minca (Cornell University).

Sara Svaluto-Ferro (University of Vienna, Austria)

Universality of affine and polynomial processes and application to signature processes

Already in the well studied finite dimensional framework, affine and polynomial processes are two fascinating classes of models. This is mostly due to the so-called affine transform formula and moment formula, respectively. In several recent works we could show that many models which are at first sight not recognized as affine or polynomial can nevertheless be embedded in this framework via infinite dimensional lifts. For instance, many examples of rough stochastic volatility models in mathematical finance can be viewed as infinite dimensional affine or polynomial processes. This suggests an inherent universality of these model classes. In this talk we perform a further step in that direction, showing that generic classes of diffusion models are projections of infinite dimensional affine processes (which in this setup coincide with polynomial processes). The final part of the talk is dedicated to applications. We first show how to apply the introduced mechanism to one-dimensional diffusion processes with analytic coefficients, and which type of formulas can be obtained in that framework. Then, we consider the so-called signature process and explain the advantages to use the obtained formulas in the context of the corresponding signature based models. These fascinating objects play a central role in this new era overparametrized models. The talk is based on an ongoing joint work with Christa Cuchiero, Guido Gazzani and Josef Teichmann.

Guillaume Szulda (Université de Paris, France)

CBI-time-changed processes for multi-currency modeling

We propose a general stochastic volatility model for multiple currencies based on CBI-Time-Changed Lévy processes (CBITCL). By combining the key properties of Continuous-state Branching processes with Immigration (CBI) with those of time-changed Lévy processes, the proposed approach offers a good balance between empirical flexibility and analytical tractability. First, the model can capture the most relevant empirical facts of the FX market, while preserving the peculiar symmetries of FX rates. Then, by relying on the structure of the model, we can derive a simple semi-closed-form pricing formula for currency options via Fourier techniques. In particular, by exploiting their affine property, we provide a complete modeling framework for CBITCL processes, which is of independent interest in the theory of CBI processes. Motivated by the volatility clustering phenomenon in the FX market, we design a parsimonious specification based on tempered stable CBITCL processes of CGMY type. The latter is finally tested numerically, by using deep learning techniques, through calibration to market data and sensitivity analysis.

Marco Tarsia (University of Insubria, Italy)

Subgame-perfect equilibrium strategies in state-constrained recursive stochastic control problems

In this talk we investigate time-inconsistent recursive stochastic control problems. Since, for this class of problems, classical optimal controls may fail to exist or to be relevant in practice, we focus on subgame-perfect equilibrium policies. In a continuous time setting, such kind of controls have been introduced in the papers Ekeland and Lazrak (2006) and Ekeland and Pirvu (2008), and can be thought of as "infinitesimally optimal via spike variation": that is, they are optimal with respect to a penalty represented by unilateral deviations during an infinitesimal amount of time. The theory of recursive optimal control problems in continuous time has become very popular in the recent years. For the time-consistent framework we refer, in particular, to the fundamental works by Duffie and Epstein (1992) and El Karoui et al. (2001). For the time-inconsistent setting we mention the series of work carried out by Yong (2011, 2012, 2017) whose approach focuses on dynamic programming (Hamilton-Jacobi-Bellman equations). The approach followed in our work, instead, is inspired by Ekeland and Pirvu (2008) and Hu (2017) and relies on the stochastic maximum principle; see also Pardoux (1993). We adapt the classical spike variation technique to obtain a characterization of equilibrium strategies in terms of a generalized Hamiltonian function defined through a flow of pairs of BSDEs. That generalized Hamiltonian function, compared to the classical one, contains the driver coefficient of the recursive utility and of the presence of a second-order stochastic process. We emphasize that, differently from the classical case, equilibrium strategies are characterized not only by means of a necessary condition, but also through a sufficient condition involving the generalized Hamiltonian even in the absence of extra convexity conditions. Going further, our analysis extends to treat time-inconsistent recursive stochastic control problems under a state constraint defined by means of an additional recursive utility. In dealing with that, we had to adapt Ekeland?s variational principle to this more tricky situation. We would like to point out that this procedure seems to be able to manage a wide variety of constraints (quite different from the one just mentioned), such as the ones considered, e.g., in Ji and Zhou (2006), Zhuo (2018) and Frankowska et al. (2019). Finally, the theoretical results are applied to the financial field of finite horizon investment- consumption policies with non-exponential actualization. Under appropriate hypotheses, our results cover the case where the constraint is, more specifically, a risk constraint: that is, the additional recursive utility derives from a suitable dynamic risk measure defined by means of a g-expectation as, e.g., in Rosazza Gianin (2006).

Josef Teichmann (ETH Zurich, Switzerland)

Representation of path functionals and non-parametric drift estimation

We apply signature or randomized signature of price paths to represent non-parametric drift estimators. These estimators are applied to construct optimal portfolios. (joint work with Erdinc Akyildirim and Syang Zhou).

Giacomo Toscano (University of Firenze, Italy)

Rate-efficient asymptotic normality of the Fourier estimator of the leverage process

We prove a Central Limit Theorem for two estimators of the leverage process based on the

Fourier method of Malliavin and Mancino (2009), showing that they reach the optimal rate 1/4 and a smaller variance with respect to different estimators based on a pre-estimation of the instantaneous volatility. The obtained limiting distributions of the estimators are confirmed by simulation results. Further, we exploit the availability of efficient leverage estimates to show, using S&P500 prices, that adding an extra term which accounts for the leverage effect to the Heterogeneous Auto-Regressive volatility model by Corsi (2009), increases the explanatory power of the latter.

Kerem Ugurlu (Nazarbayev University, Kazakhstan)

Terminal wealth maximization under drift uncertainty

We study the portfolio optimization problem of an investor seeking to maximize his terminal wealth. The portfolio is composed of one risky asset, a stock, and one riskless asset, a bond. We assume there is Knightian uncertainty on the drift term representing the long-term growth rate of the risky asset. We further assume that the investor has a prior estimate about the drift term and quantify the diffidence of the investor in his prior about the mean. It is assumed that the investor has a logarithmic or power utility. Explicit solutions under this framework have been retrieved. Numerical illustrations are also presented.

Mikhail Urusov (University of Duisburg-Essen, Germany)

Optimal trade execution in an order book model with stochastic liquidity parameters

We analyze an optimal trade execution problem in a financial market with stochastic liquidity. To this end we set up a limit order book model in which both order book depth and resilience evolve randomly in time. Trading is allowed in both directions and at discrete points in time. We derive an explicit recursion that, under certain structural assumptions, characterizes minimal execution costs. We also discuss several qualitative aspects of optimal strategies, such as existence of profitable round trips or closing the position in one go, and compare our findings with the literature. This talk is based on [1].

References: [1] Julia Ackermann, Thomas Kruse, Mikhail Urusov. Optimal trade execution in an order book model with stochastic liquidity parameters, arXiv:2006.05843

Almut Veraart (Imperial College London, United Kingdom)

High-frequency estimation of the Levy-driven graph Ornstein-Uhlenbeck process with applications to wind capacity factor measurements

We consider the Graph Ornstein-Uhlenbeck (GrOU) process observed on a non-uniform discrete time grid and introduce discretised maximum likelihood estimators with parameters specific to the whole graph or specific to each component, or node. Under a high frequency sampling scheme, we study the asymptotic behaviour of those estimators as the mesh size of the observation grid goes to zero. We prove two stable central limit theorems to the same distribution as in the continuously observed case under both finite and infinite jump activity for the Levy driving noise. When a graph structure is not explicitly available, the stable convergence allows to consider purpose-specific sparse inference procedures, i.e. pruning, on the edges themselves in parallel to the GrOU inference and preserve its asymptotic properties. We apply the new estimators to wind capacity factor measurements, i.e. the ratio between the wind power produced locally compared to its rated peak power, across fifty locations in Northern Spain and Portugal. We show the superiority of those estimators compared to the standard least squares estimator through a simulation study extending known univariate results across graph configurations, noise types and amplitudes. This is joint work with Valentin Courgeau (Imperial College London).

Stéphane Villeneuve (Toulouse School of Economics, France)
Agency problems, long memory and linear contracts

This paper extends the classical model of Holmstrom-Milgrom (1987) to general Gaussian settings where the agent?s privately observed shocks have autocorrelation. This novel class of principal-agent models is rich enough to encompass dynamic agency models with effort persistence and also allows us to go beyond the usual semi-martingale framework which generally solves for the optimal contract by the means of a Hamilton-Jacobi-Bellman equation. Our main contribution is to show that this framework allows surprisingly for optimal linear contracts with a non constant optimal level of effort.

Johannes Wiesel (Columbia University, USA)
Data driven robustness and sensitivity analysis

In this talk I consider sensitivity of a generic stochastic optimization problem to model uncertainty, where I take a non-parametric approach and capture model uncertainty using Wasserstein balls around the postulated model. I provide explicit formulae for the first order correction to both the value function and the optimizer and further extend our results to optimization under linear constraints. Then I present applications to statistics, machine learning, mathematical finance and uncertainty quantification. In particular, I prove that LASSO leads to parameter shrinkage, propose measures to quantify robustness of neural networks to adversarial examples and compute sensitivities of optimised certainty equivalents in finance. I also propose extensions of this framework to a multiperiod setting. This talk is based on joint work with Daniel Bartl, Samuel Drapeau and Jan Obloj.

Anton Yurchenko-Tytarenko (University of Oslo, Norway)
Stochastic volatility modelling via sandwiched processes with Volterra noise

We introduce a new stochastic volatility market model with the d-dimensional price process $S = (S_1, ..., S_d)$ given by

$$\begin{cases} dS_i(t) = \mu_i(t)S_i(t)ds + Y_i(t)S_i(t)dB_i^S(t), \\ dY_i(t) = b_i(t, Y_i(t))dt + dZ_i(t), \end{cases} \qquad t \in [0, T],\ i = 1, ..., d, \tag{3}$$

where $\mu_i \in C([0, T])$, B_i^S are correlated standard Brownian motions, Z_i are arbitrary Gaussian Volterra processes with λ-Hölder continuous paths, $\lambda \in (0, 1)$, and b_i are functions such that $b_i(t, y) \sim (y - \varphi_i(t))^{-\gamma_i}$ as $y \to \varphi_i(t)+$, $b_i(t, y) \sim -(\psi(t) - y)^{-\gamma_i}$ as $y \to \psi_i(t)-$ for some $\gamma_i > 0$ and Hölder continuous functions φ_i, ψ_i such that $0 < \varphi_i(t) < \psi_i(t)$, $t \in [0, T]$. This shape of b_i ensures Y_i to be "sandwiched" between φ_i and ψ_i, i.e. $\varphi_i(t) < Y_i(t) < \psi_i(t)$ a.s., $t \in [0, T]$ (see [**?**] for more details).

Such model allows to go far beyond Markovianity and covers both rough volatility and long memory cases due to the flexibility in the choice of the noise: Z_i can be e.g. fractional Brownian motions with any Hurst indices $H_i \in (0, 1)$, multifractional Brownian motions, linear combinations of those etc. The property of being sandwiched, in turn, both gives more modelling flexibility (since one can choose proper φ_i, ψ_i to make the model fit data better) and is very convenient from the technical point of view due to boundedness of the volatility processes. For example, it ensures $\mathbb{E}S_i^r(t) < \infty$ for all $r \in \mathbb{R}$ and $t \in [0, T]$, while boundedness away from zero simplifies the analysis of pricing measures.

Our research covers the structure of local martingale measures on such market and numerical aspects of the model (3). In particular, using estimates for the inverse moments of Y_i, we get a convergence rate of the backward Euler numerical scheme for the volatility processes. Moreover, we exploit the technique of quadrature via Malliavin integration by parts to introduce an algorithm of numerical estimation of $\mathbb{E}f(S_1(T), ..., S_d(T))$ for discontinuous payoffs f.

Reference:

[DNMYT] Di Nunno, G., Mishura, Y., Yurchenko-Tytarenko, A. *Sandwiched SDEs with unbounded drift driven by Hölder noises.* ArXiv: 2012.11465, 2021.

Yuchong Zhang (University of Toronto, Canada)

Mean field contest with singularity

We formulate a mean field game where each player stops a privately observed Brownian motion with absorption. Players are ranked according to their level of stopping and rewarded as a function of their relative rank. There is a unique mean field equilibrium and it is shown to be the limit of associated n-player games. Conversely, the mean field strategy induces n-player ε-Nash equilibria for any continuous reward function - but not for discontinuous ones. In a second part, we study the problem of a principal who can choose how to distribute a reward budget over the ranks and aims to maximize the performance of the median player. The optimal reward design (contract) is found in closed form, complementing the merely partial results available in the n-player case. We then analyze the quality of the mean field design when used as a proxy for the optimizer in the n-player game. Surprisingly, the quality deteriorates dramatically as n grows. We explain this with an asymptotic singularity in the induced n-player equilibrium distributions. (Joint work with M. Nutz)

Yuliang Zhang (LSE, United Kingdom)

A macroprudential view on portfolio compression and rebalancing

We analyse the consequences of post-trade risk reduction services for systemic risk. Our focus is on portfolio compression and portfolio rebalancing, which are multilateral netting mechanisms for derivatives markets. Both services are designed to achieve risk mitigation while ensuring market risk neutrality. Portfolio compression aims to reduce outstanding notional amount by trades termination and replacement, and portfolio rebalancing injects new trades to reduce the overall counterparty risk. We first focus on portfolio rebalancing that allows for a complete rewiring of the financial network. We provide sufficient conditions under which it reduces systemic risk by considering financial contagion arising from only partial repayments in a network of payment obligations. We also provide an extension of results that incorporates a second channel of systemic risk: price-mediated contagion in the form of fire sales. Next, we investigate portfolio compression and rebalancing under the scenario where financial institutions react to stress strategically and make delayed payments. We highlight the role of both services in mitigating liquidity risk and propose that they could be used as macroprudential tools.

Mingchuan Zhao (University of Limerick, Ireland)
Mean-variance option portfolio and their performances

This paper find long-short portfolios of call and put options on a single underlying asset and expiration, with different strike prices, so to maximize the Sharpe Ratio of portfolio returns. From analytical and numerical optimization methods we select those that can tackle the problem of high dimensionality. Combining analytical covariance estimation with quadratic constrained optimization, optimal options portfolios on the S&P 500 generate positive excess returns over the past two decades, controlling for their exposure to the underlying and accounting for the large bid-ask spreads in options' prices. Optimal options portfolios typically entail nonzero positions in few strikes.

Yihan Zou (Southwestern University of Finance and Economics, China)
Monte Carlo methods for optimal stopping under parameter uncertainty in multidimensional models

We introduce Monte Carlo methods to solve optimal stopping problems in economic models based on multidimensional stochastic differential equations with model uncertainty in the drift coefficients. From the perspective of an ambiguity-averse economic agent, we transform the problem to the solution of a reflected backward stochastic differential equation (RBSDE) with a uniformly Lipschitz continuous generator. We propose two Monte Carlo algorithms based: one based on the theory of RBSDEs and stratification, and the other based on approximate dynamic programming. We demonstrate the accuracy and convergence of both the propose schemes through numerical simulations and show that the RBSDE algorithm with stratification is more efficient when an explicit formula for the optimal generator is available.

Zan Zuric (Imperial College, United Kingdom)
Joint SPX and VIX calibration with neural SDEs

After the introduction of VIX futures and VIX options the year after in 2006 many researchers have tried to construct a model that would jointly calibrate to instruments on both SPX and VIX. Such a model is extremely important when pricing options whose payoff depend on both the underlying and its volatility. Moreover, one may even face arbitrage when pricing other simpler exotics if his model does not consolidate liquid derivatives on both indices. The joint calibration, however, proved to be a fairly diffcult problem. We attempt to solve this long standing problem using Neural SDEs, which provide a framework for model selection and simultaneously produce a robust pricing model that can be used for hedging. This is achieved by using SDEs for the model dynamics, but instead of choosing a fixed parametrization for the model SDEs we allow the drift and diffusion to be given by overparametrized neural networks.

5 List of conference participants (as of June 20, 2021)

- Abi Jaber Eduardo (Université Paris 1 Panthéon-Sorbonne)
- Acciaio Beatrice (ETH Zurich)
- Ackermann Julia (University of Giessen)
- Alasseur Clémence (EDF)
- Allan Andrew (ETH Zurich)
- Alos Elisa (University Pompeu Fabra)
- Anthropelos Michalis (University of Piraeus)
- Antonelli Fabio (Universitá di L'Aquila)
- Awerkin Almendra (Universitá degli studi di Padova)
- Aydogan Burcu (Atilim University)
- Barrieu Pauline (London School of Economics and Political Science)
- Bayraktar Erhan (University of Michigan)
- Bovo Andrea (University of Leeds)
- Callegaro Giorgia (University of Padova)
- Calvia Alessandro (LUISS University)
- Calzolari Antonella (Universitá Tor Vergata, Rome)
- Canna Gabriele (University of Milano-Bicocca)
- Cao Haoyang (Alan Turing Institute)
- Ceci Claudia (University of Chieti-Pescara)
- Chong Carsten (Columbia University)
- Cohen Asaf (University of Michigan)
- Cordoni Francesco (Scuola Normale Superiore)
- Courgeau Valentin (Imperial College London)
- Cuchiero Christa (University of Vienna)
- Cui Xuecan (Southwestern University of Finance and Economics)
- Danilova Albina (London School of Economics and Political Science)
- Davletzhanova Aigerim (Heriot-Watt University)
- De Angelis Tiziano (University of Torino)

- De Marco Stefano (École Polytechnique)
- De Vecchi Corrado (Vrije Universiteit Brussels)
- Delarue François (University of Nice Sophia-Antipolis)
- Di Giacinto Marina (Università degli studi di Cassino e del Lazio Meridionale)
- Di Nunno Giorgia (University of Oslo)
- Djete Fabrice (École polytechnique)
- Doldi Alessandro (Universitá degli Studi di Milano)
- Dong Huayuan (Dublin City University)
- dos Reis Goncalo (University of Edinburgh)
- Dupret Jean-Loup (University of Leuven)
- Federico Salvatore (University of Genova)
- Ferrari Giorgio (Bielefeld University)
- Fontana Claudio (University of Padova)
- Frey R̈diger (Vienna University of Economics and Business)
- Garces Len Patrick Dominic (University of South Australia)
- Garcin Matthieu (ESILV)
- Gardini Matteo (University of Genoa)
- Gaudenzi Marcellino (University of Udine)
- Gazzani Guido (University of Vienna)
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- Glas Silke (Cornell University)
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- Goulard Aline (Université de Mons)
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- Havrylenko Yevhen (Technical University of Munich)
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- Herbertsson Alexander (University of Gothenburg)
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- Hinz Juri (University of Technology Sydney)
- Hölzermann Julian (University of Bielefeld)
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- Horvath Blanka (King's College London)
- Hubert Emma (Imperial College London)
- Ince Akif-Birkbeck (University of London)
- Grbac Zorana (University of Paris)
- Jelito Damian (Jagiellonian University in Krakow)
- Jerome Joseph (University of Warwick)
- Karbach Sven (University of Amsterdam)
- Kemper Annika (University of Bielefeld)
- Khan Nazem (University of Warwick)
- Krach Florian (ETH Zürich)
- Kḧn Christoph (Goethe University Frankfurt)
- Kurt Kevin (Vienna University of Economics and Business)
- Larsson Martin (Carnegie Mellon University)
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- Njike Leunga Charles Guy (UCLouvain)
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