ICCF24 Conference Program

All plenary sessions will take place in the Turing Room.

Tuesday, April 2nd

Start 8:30 AM: Registration (at Science Park Congress Centre)

Morning:

9:00 : Turing Room: Welcome *(chair: Kees Oosterlee)*

9:15 – 10:00 : Turing Room: Plenary 1: **Emmanuel Gobet** *(Ec. Polytechnique, Palaiseau cedex, France):* "Quantitative modelling and analysis of the Automated Market Maker Uniswap"

Abstract: As Decentralised Finance increased in popularity, it quickly became necessary to find tools that could play the same role as Limit Order Books in traditional finance, so that actors could easily exchange crypto assets. This has led to the design of Automated Market Makers (AMM) which are protocols that permit the automated execution of buy and sell orders in a blockchain. Two types of actor play role in AMM: the Liquidity Providers (LP) who deposit their tokens in a liquidity pool; the swap traders who exchange one token for another in the pool and pay swap fees. This talk will focus on Uniswap protocols which are the most widely used AMMs. In particular the protocol Uniswap v3 is challenging from a quantitative point of view, as it allows LP to choose where they wish to concentrate liquidity. As a difference with some heuristics in the literature, we will do our best to stay close to the open source code of Uniswap v3 to describe the true mechanisms of this protocol. This detailed study allows for instance to mathematically describe the risks taken by LPs as covered call options, to use that protocol to replicate any concave vanilla payoffs and to get asymptotic formulas for the fees collected by the Liquidity Providers. This is a joint work with Mnacho Echenim (University Grenoble Alpes) and Anne-Claire Maurice (Kaiko).

10:00 – 10:45: Turing Room: Plenary 2: **Alvaro Leitao Rodriguez** *(U. Oberta de Catalunya, Spain):* "Quantum computing for computational finance: overview, challenges, opportunities"

Abstract: Quantum computers could bring unparalleled competitive advantage to financial companies in areas like portfolio optimization, option pricing, quantitative risk management or, more generally, mimicking the behavior of Machine Learning models. Quantum algorithms could potentially overcome their classical counterparts in dealing with combinatorial explosions and the curse of dimensionality. However, bringing this to practice encounters several bottlenecks, especially with the current or near-term quantum technologies. This presentation firstly reviews the state of the art and recent advances in quantum computing applied to derivative pricing and the computation of risk estimators like Value at Risk. We will mainly focus on the quantum alternatives to classical Monte Carlo. The cornerstone of these alternatives to Monte Carlo rely on Quantum Amplitude Estimation and more modern variations of this technique. Further, quantum methods for solving derivative pricing models using PDEs are also discussed, as well as the quantum counterparts of machine (deep) learning models. Next, we discuss the main remaining challenges for the quantum algorithms to achieve their potential advantages. In particular, a review of the key aspects for quantum alternatives to Monte Carlo methods and machine learning to deliver their potential advantage is included. The described challenges directly lead to research opportunities for contributing in this field, which will be also summarized. Finally, some recent contributions are presented. A general-purpose framework to design quantum algorithms has been proposed. This framework relies on two pillars: a basic data structure and a modular design, which aims to provide a friendly environment to researchers coming from other fields. On top of that, we have introduced the so-called Real Quantum Amplitude Estimation (RQAE) algorithm, an extension of Quantum Amplitude Estimation which is sensitive to the sign of the amplitude and offers explicit control over the amplification policy through an adjustable parameter. We provide a rigorous analysis of the RQAE performance and prove that it achieves the expected quadratic speedup.

10:45 – 11:15: Break, coffee

11:15 – 12:55: Mini-symposium session 1 (4 presentations), 4 rooms

Turing Room: Computational and statistical methods for extremes in finance

(chair: Stéphane Girard)

Short description: The mini-symposium is dedicated to the simulation and estimation of extreme events with application to risk assessment in finance. We shall focus on multivariate extremes i.e. events lying in multivariate distribution tails which have low probability of occurence but may have high impact. The asymptotic theory on multivariate extremes is now well-established but several difficulties remain for its practical use in finance. First, the simulation in distribution tails is challenging and cannot be achieved with standard generative models based on neural networks. Second, the inference is made difficult by the data scarcity in multivariate tails. We shall present a selection of new statistical and computational methods adressing these two issues with applications to finance data.

- **Michaël Allouche** (Kaiko, France) "Learning of extreme Expected Shortfall with neural networks. Application to cryptocurrency data"

  Abstract: We propose new parametrizations for neural networks in order to estimate extreme Value-at-Risk and Expected-Shortfall in heavy-tailed settings. All proposed neural network estimators feature a bias correction based on an extension of the usual second-order condition to an arbitrary order.The convergence rate of the uniform error between extreme log quantities and their neural network approximation is established. The finite sample performances of the neural network estimator are compared to other bias-reduced extreme-value competitors on both real and simulated data. It is shown that our method outperforms them in difficult heavy-tailed situations where other estimators almost all fail.

- **Yi He** (Amsterdam, Netherlands) "Detecting spurious factor models"

  Abstract: Spurious factor behaviors arise in large random matrices with high-rank signal components and heavy-tailed spectral distributions. This paper establishes analytical probabilistic limits and distribution theory of these spurious behaviors for stationary systems with near-unit-root spatial processes across cross sections. We transform scree plots into Hill plots to detect spectral patterns in these spurious factor models and develop multiple t-tests to distinguish between spurious and genuine factor models. Numerical analysis indicates that the term structure of interest rates adheres to genuine factor models rather than the local correlation model.

- **Jean Pachebat** (Ecole Polytechnique, France) "Simulation of multivariate extreme events with generative models"

  Abstract: Dealing with heavy tailed-data is an important task in financial and actuarial modelling. More specifically, simulating large sets of heavy-tailed data from a training set may lead to a better estimation of the Value-at-Risk and, more generally, to a better insight on the inner working of financial ecosystems. To this extent, we leverage data generation algorithms and extreme-value theory to understand heavy-tailed financial signals. However, out of the box Generative Models typically produce data distributions with light tails. In this talk, we will discuss findings on the theoretical and practical aspects of the proposed neural network method, which aims at mitigating the limitation of classical GANs by introducing a heavy-tailed latent noise. We prove that this new method creates samples that are heavy-tailed with the desired tail dependence. Also, as for classical GANs, training may be tricky. We will discuss insights from training, including the selection of optimal parameter ranges, on both synthetic and real datasets. This is joint work with Stéphane Girard and Emmanuel Gobet.

- **Chen Zhou** (Rotterdam, Netherlands) "Estimating probabilities of multivariate failure sets based on pairwise tail dependence coefficients"

  Abstract: When assessing complex tail risk involving multiple risksources, a statistical problem is to estimate the probability that ahigh-dimensional random vector falls into an extreme failure set. This paper provides a parametric approach to this problem, based on a generalization of a tail pairwise dependence matrix (TPDM). The TPDM gives a partial summary of tail dependence for all pairs of components of the random vector. We propose an algorithm to obtain an approximate completely positive decomposition of the TPDM. The decomposition is easy to compute and applicable to both moderate and high dimensions. Based on the decomposition, we obtain parameter estimates of a max-linear model whose TPDM coincides with the original random vector. Risk assessment based on the estimated max-linear model can be achieved via Monte Carlo simulation. We apply the proposed decomposition algorithm to industry portfolio returns and maximal wind speeds to illustrate its applicability.

Euler Room: Algorithmic trading and market microstructures *(chair: Shuaiqiang Liu)*

- **Fenghui Yu** *(Delft, Netherlands):* "Execution probabilities in a limit order book with stochastic order flows"

Abstract: This paper focuses on computing the fill probabilities of limit orders placed at different price levels, which plays a crucial role in optimizing executions. We adopt a stochastic model to capture the dynamics of the order book, where the number of orders at each price level in the order book is modelled as a birth-death process. Based on this model, we then derive tractable semi-analytical expressions to compute fill probabilities of orders posted at the best ask/bid price before the price moves, and also the orders placed one price level below. The expressions can be further generalised for orders posted even deeper in the order book. Detailed numerical methods are also provided so that all the computations can be done explicitly and efficiently. Finally, we conduct the numerical experiments with real order book data from the foreign exchange spot market.

- **Peng Guo** *(Peking U., China):* "Optimal execution with relative entropy, a Schrödinger bridge approach"

Abstract: We consider the problem of meta order execution in Almgren-Chriss model under order fill uncertainty. A broker-dealer agency is authorized to execute an order of trading on client's behalf. The strategies that the agent is allowed to deploy is subject to a benchmark regulated by the client. We formulate the broker's problem as an entropy-regularized version of optimal density control and impose a Gaussian density constraint at a specified time on the maximum entropy optimal control to directly control state uncertainty. Moreover, we derive the explicit form of the optimal density control. In addition, we also consider the case where the density constraint is replaced by a fixed-point constraint, and the associated state process reduces to a pinned process, which is a generalization of the Brownian bridge to linear systems. Finally, we reveal that the optimal density control gives the so-called Schrödinger bridge associated to a linear system.

- **Xue Cheng** *(Peking, China):* "Optimal execution subject to reservation strategies"

Abstract: The paper addresses the problem of meta order execution from a broker-dealer's point of view in Almgren-Chriss model under order fill uncertainty. A broker-dealer agency is authorized to execute an order of trading on client's behalf. The strategies that the agent is allowed to deploy is subject to a benchmark, referred to as the reservation strategy, regulated by the client. We formulate the broker's problem as a utility maximization problem in which the broker seeks to maximize his utility of excess profit-and-loss at the execution horizon. Optimal strategy in feedback form is obtained in closed form. In the absence of execution risk, the optimal strategies subject to reservation strategies are deterministic. We establish an affine structure among the trading trajectories under optimal strategies subject to general reservation strategies using implementation shortfall and target close orders as basis. We conclude the paper with numerical experiments illustrating the trading trajectories as well as histograms of terminal wealth and utility at investment horizon under optimal strategies versus those under TWAP strategies. This is a joint work with Peng Guo and Tai-ho Wang.

- **Shuaiqiang Liu** *(Delft & ING Bank, Netherlands):* "A generative deep learning model for volatility surfaces implied in the market"

Abstract: An essential component of financial derivatives pricing and risk management is the implied volatility surface. To model these volatility surfaces, there are two popular approaches: mathematical modeling or data-driven modeling. Mathematical models, such as the Heston stochastic volatility model, assume the price of involved underlying assets follows certain stochastic dynamics, thus this method requires a calibration procedure to determine the model's parameters given a volatility surface. Calibrating such models is often computationally expensive and slow. Alternatively, the data-driven approach treats implied volatility surfaces non-parametrically,

without assuming any specific dynamics. This method, however, faces its own challenges in managing high-dimensional features like volatility smiles, term structures. In this talk, we will start with Calibration Neural Network, a deep learning-based framework for fast model calibration. Then we will introduce Generative Diffusion Models, i.e., a generative AI model, which can efficiently learn high-dimensional features from existing volatility surfaces. Its potential applications include, for example, generating synthetic volatility surfaces or completing partial volatility surfaces to improve risk management in scenarios of scarce data. These deep learning-based methods, while distinct, complement each other when dealing with implied volatility surfaces.

Hypatia Room: Computational Finance I: *(chair: Carlos Vazquez Cendon)*

- **Thomas Kruse** *(Wuppertal, Germany):* "Multilevel Picard iteration for high-dimensional semilinear parabolic PDEs"

Abstract: We present the multilevel Picard approximation method for high-dimensional semilinear parabolic PDEs. A key idea of our method is to combine multilevel approximations with Picard fixed-point approximations. We prove in the case of semilinear heat equations with Lipschitz continuous nonlinearities that the computational effort of the proposed method grows polynomially both in the dimension and in the reciprocal of the required accuracy. Moreover, we present further applications of the multilevel Picard approximation method and illustrate its efficiency by means of numerical simulations. The talk is based on joint works with Weinan E, Martin Hutzenthaler, Arnulf Jentzen, Tuan Nguyen and Philippe von Wurstemberger.

- **Long Teng** *(Wuppertal, Germany):* "A regression-based approach to solve high-dimensional nonlinear pricing BSDEs"

Abstract: In this study, we explore an approach utilizing backward stochastic differential equation (BSDE) to evaluate options. Initially, we demonstrate the versatility of the BSDE approach in pricing and hedging by reformulating several pricing models, encompassing the classical SABR and Heston-SABR models, as BSDEs. Moreover, we introduce a novel algorithm for solving these high-dimensional pricing BSDEs. Utilizing temporal discretization for time-integrands in BSDEs, we demonstrate the efficient application of a regression-based approach to approximate resulting conditional expectations. This approach provides access to highly complex, high-dimensional problems. A rigorous analysis of convergence is presented. In our numerical experiments, we assess diverse options within certain pricing models, including highly-dimensional nonlinear pricing. Through a comparative analysis between our pricing results and those derived from state-of-the-art numerical methods, we illustrate the efficiency and accuracy of our proposed algorithms. Furthermore, the BSDE approach enables us to achieve delta-hedging during pricing without incurring additional costs. Several of our findings regarding delta-hedging are novel in the literature.

- **Christina Christara** *(Toronto, Canada):* "Analysis of high-order time stepping schemes for parabolic PDEs with nonsmooth initial conditions"

Abstract: Nonsmooth payoff functions are common in financial contracts and pose difficulties in obtaining high-order solutions of the contract prices. In this work, we consider parabolic PDEs with initial conditions involving various types of nonsmoothness. We apply a fourth-order finite difference (FD) discretization on a uniform grid in space, and BDF4 time stepping initialized with two steps of an explicit third-order Runge-Kutta (RK3) method and one step of BDF3. Using Fourier analysis on the discrete system, we prove that the low-order errors generated by RK3 for nonsmooth data in the high-frequency domain get damped away by BDF steps, which prevents spurious oscillations in the solution; while low-order errors in the low-frequency domain come from the low-order initial condition discretization. To achieve globally fourth-order convergence, we apply fourth-order smoothing to the initial conditions, and provide explicit formulas of the discretization. By combining the initial condition smoothing with the proposed time-stepping scheme, we mathematically prove and numerically verify that fourth-order convergence is obtained. The analysis is easily generalizable to higher order methods. Numerical examples on the model PDE and various option pricing problems are also given to demonstrate the fourth-order convergence of our method.

- **Martyna Zdeb** *(Wroclaw, Poland):* "Modelling and pricing of multi-region catastrophe bonds"

Abstract: The insurance-linked securities (ILS) market, as a form of alternative risk transfer, has been at the forefront of innovative risk-transfer solutions. The catastrophe bond (CAT bond) market now stands for almost half of the whole ILS market and is steadily growing. Since CAT bonds are often tied to risks in different regions, we follow this idea by constructing different pricing models that incorporate various scenarios of dependence between catastrophe losses in different areas. Namely, we consider independent, proportional, and arbitrary two-dimensional distributions cases. We also derive normal approximations of the prices and compare them with prices obtained via bootstrapping. We find significant differences between those approaches. We believe that these findings can be helpful in modelling and pricing of other ILS tied to natural disasters. For illustration purposes we analyse Property Claim Services data.

Ada Room: PDE methods in Finance *(chair: Karel in 't Hout, Michèle Vanmaele)*

- **Fabien Le Floc'h** *(Calypso, Paris, France):* "Instabilities in super time-stepping schemes"

Abstract: This talk explores in detail instabilities of explicit super-time-stepping schemes, such as the Runge-Kutta-Chebyshev or Runge-Kutta-Legendre schemes, noticed in the litterature, when applied to the Heston stochastic volatility model. The stability remarks are relevant beyond the scope of super-time-stepping schemes.

- **Luis Ortiz Gracia** *(U. Barcelona, Spain):* "Climate-related default probability"

Abstract: Climate risk refers to the risk related to climate change, and has already started to have an impact on different aspects of our society. Regulators and financial institutions have identified two types of financial risks related to climate change, such as physical risk and transition risk. While physical risk emerges from the impact of either isolated or chronic extreme weather on individuals or businesses, transition risk is due to a late introduction of climate policies that can lead to a disorderly transition to a low-carbon economy. In this work, we present a methodology for assessing the impact caused by an increase of the atmospheric temperature in the default probability of companies subject to physical climate risk. More precisely, we model the log-returns of a big company of the agricultural sector in terms of the temperature anomalies with respect to a base reference period. The asset value of the firm is driven by a stochastic process and the default occurs when its value at maturity is below the debt threshold in the sense of the Merton model framework.

- **Karel in 't Hout** *(U. Antwerp, Belgium):* "On the approximation of Greeks for American-style options"

Abstract: In this talk we consider the approximation of the Greeks Delta and Gamma of American-style options through the numerical solution of time-dependent partial differential complementarity problems (PDCPs). This approach is very attractive as it can yield accurate approximations to these Greeks at essentially no additional computational cost during the numerical solution of the PDCP for the pertinent option price function. For the time discretization, the Crank-Nicolson method is arguably the most popular method in computational finance. However, it is known in the literature that this method can show an undesirable convergence behaviour in the approximation of the Greeks Delta and Gamma for American-style options, even when Rannacher time stepping (backward Euler damping) and suitable variable time steps are applied. In this talk we first illustrate this and next study an interesting family of diagonally implicit Runge-Kutta (DIRK) methods that can yield a regular, second-order convergence behaviour for the option price as well as the Greeks Delta and Gamma. Among others, the application to American-style options on two assets will be considered.

- **Xian-Ming Gu** *(Chengdu, China, and Utrecht, NL):* "A parallel-in-time iterative method for American option pricing"

Abstract: For American option pricing, a sequence of linear complementarity problems (LCPs) is discretized using the suitable space and time discretizations. The resulting system of LCPs at each time step is solved through the policy iteration in the step-by-step pattern. In this talk, we try to get all the solutions simultaneously by using the policy iteration for an "all-at-once" form of LCP and the parallel-in-time implementation of policy iteration will be described in details. Our proposed method is general in solving the all-at-once form of LCP arising from the option pricing with many styles of optimal stopping and complex underlying asset models. Numerical examples are presented to confirm the feasibility of the proposed method and some robust convergence behaviors are also found.

13:00 – 14:00 Lunch

Afternoon:

14:00 – 15:40: Mini-symposia session 2 (4 presentations), 4 rooms

Turing Room: Machine Learning methods in Finance I *(chair: Jasper Rou)*

Description: We propose hosting a Mini-Symposium centered on the intersection of Machine Learning and Financial Mathematics, aiming to investigate the profound impact of artificial intelligence on financial modeling and decision-making processes. Machine learning stands as a versatile tool in the realm of finance, finding applications in predictive analytics, risk management, algorithmic trading, portfolio optimization, fraud detection, and the formulation of investment strategies. This Mini-Symposium will provide a comprehensive exploration of these applications, shedding light on the transformative influence of machine learning in the financial domain. The event will specifically focus on the integration of machine learning techniques in areas such as option pricing, addressing backward stochastic differential equations (BSDEs), and developing more resilient and adaptable financial models. Participants will have the opportunity to delve into advanced techniques, including neural network algorithms, deep solvers, and intelligent kernel factors, gaining insights into their practical applications and implications. Throughout the Mini-Symposium, attendees will be exposed to the latest advancements in machine learning methodologies tailored for financial modeling. This unique forum promises to deliver valuable perspectives, fostering a deeper understanding of the cutting-edge developments within the evolving landscape of quantitative finance. Join us in this exploration of innovative machine learning applications in financial mathematics, and gain invaluable insights into the dynamic future of quantitative finance.

- **Costas Smaragdakis** *(Univ. Samos, Greece):* "A deep implicit-explicit minimizing movement method for option pricing in jump-diffusion models"

  Abstract: We develop a novel deep-learning approach for pricing European basket options written on assets that follow jump-diffusion dynamics. The option pricing problem is formulated as a partial integro-differential equation, which is approximated via a new implicit-explicit minimizing movement time-stepping approach, involving approximation by deep, residual-type Artificial Neural Networks (ANNs) for each time step. The integral operator is discretized via two different methods: a) a sparse-grid Gauss--Hermite approximation following localised coordinate axes arising from singular value decompositions, and b) an ANN-based high-dimensional special-purpose quadrature rule. Crucially, the proposed ANN is constructed to ensure the asymptotic behaviour of the solution for large values of the underlyings and also leads to consistent outputs with respect to priori known qualitative properties of the solution. The performance and robustness with respect to the dimension of the methods are assessed in a series of numerical experiments involving the Merton jump-diffusion model.

- **Silvia Lavagnini** *(BI Norwegian Business School, Norway):* "Deep Quadratic Hedging"

  Abstract: We present a novel computational approach for quadratic hedging in a high-dimensional incomplete market. This covers both mean-variance hedging and local risk minimization. In the first case, the solution is linked to a system of BSDEs, one of which being a backward stochastic Riccati equation (BSRE); in the second case, the solution is related to the Fölmer-Schweizer decomposition and is also linked to a BSDE. We apply (recursively) a deep neural network-based BSDE solver. Thanks to this approach, we solve high-dimensional quadratic hedging problems, providing the entire hedging strategies paths, which, in alternative, would require to solve high dimensional PDEs. We test our approach with a classical Heston model and with a multi-dimensional generalization of it.

- **Alessandro Gnoatto** *(Università degli Studi di Verona, Italy):* "A Deep Solver for BSDEs with Jumps"

  Abstract: The aim of this work is to propose an extension of the Deep BSDE solver by Han, E, Jentzen (2017) to the case of FBSDEs with jumps. As in the aforementioned solver, starting from a discretized version of the BSDE and parametrizing the (high dimensional) control processes by means of a family of ANNs, the BSDE is viewed as

model-based reinforcement learning problem and the ANN parameters are fitted so as to minimize a prescribed loss function. We take into account both finite and infinite jump activity by introducing, in the latter case, an approximation with finitely many jumps of the forward process. We also discuss error estimates. This talk is based on joint works with Athena Picarelli, Katharina Oberpriller and Marco Patacca.

- **Yannick Limmer** *(University of Oxford, UK):* "Robust Hedging GANs - Towards Automated Robustification of Hedging Strategies"

Abstract: The deep hedging framework has revolutionized hedging under different market conditions. However, models are prone to errors, and deviations from market reality can lead to risks. This raises the question of how to deal with model ambiguity in an automated way. We propose a GAN-based solution using concepts from rough-path theory to automate robustification in hedging. Our method uses a hedging engine, a market generator, and a metric to measure distances between data and beliefs. It can operate independently of the data generating process and is easily adaptable for existing functional settings. We demonstrate this in various examples, and this approach is expected to inspire solutions for related challenges.

Euler Room: Recent advances in transform (Fourier/Laplace) methods for computational finance and insurance, part I *(chair: Chiheb Ben Hammouda)*

Short description: The mini-symposium is about recent numericaland theoretical advances in transform (E.g., Fourier and Laplace) methods to address differentchallenges in computational finance and insurance. Challenges and Applications range from the efficient pricing of multi-asset options, option pricing under novel challenging (rough) models, the valuation of complex life insurance contracts, and the efficient computation of risk measures and risk exposures for portfolios.

- **Sergio Pulido** *(Paris-Saclay, France):* "Affine Volterra processes with jumps"

Abstract: The theory of affine processes has been recently extended to continuous stochastic Volterra equations. These so-called affine Volterra processes overcome modeling shortcomings of affine processes by incorporating path-dependent features and trajectories with regularity different from the paths of Brownian motion. More specifically, singular kernels yield rough affine processes. This paper extends the theory by considering affine stochastic Volterra equations with jumps. This extension is not straightforward because the jump structure and possible singularities of the kernel may induce explosions of the trajectories. The study also provides exponential affine formulas for the conditional Fourier-Laplace transform of marked Hawkes processes. This is joint work with Alessandro Bondi and Giulia Livieri.

- **Michael Samet** *(RWTH Aachen, Germany):* "Optimal damping and hierarchical adaptive quadrature for efficient Fourier pricing of multi-asset options"

Abstract: Efficient pricing of multi-asset options is a challenging problem in quantitative finance. Fourier-based methods are competitive compared to alternative techniques when the characteristic function is available because the integrand in the frequency space often has a higher regularity than that in the physical space. However, when designing a numerical quadrature method for most Fourier pricing approaches, two key aspects affecting the numerical complexity should be carefully considered: (i) the choice of damping parameters that ensure integrability and control the regularity class of the integrand and (ii) the effective treatment of high dimensionality. To address these challenges, we propose an efficient numerical method for pricing European multi-asset options based on two complementary ideas. First, we smooth the Fourier integrand via an optimized choice of damping parameters based on a proposed optimization rule. Second, we employ sparsification and dimension-adaptivity techniques to accelerate the convergence of the quadrature in high dimensions. The extensive numerical study on basket and rainbow options under the multivariate geometric Brownian motion and some L´evy models demonstrates the advantages of adaptivity and the damping rule on the numerical complexity of quadrature methods. Moreover, for the tested two-asset examples, the proposed approach outperforms the COS method in terms of computational time. Finally, we show significant speed-up compared to the Monte Carlo method for up to six dimensions.This talk draws its basis from the following publication:

C. Bayer, C. Ben Hammouda, A. Papapantoleon, M. Samet, and R. Tempone. Optimal damping with hierarchical adaptive quadrature for efficient Fourier pricing of multi-asset options in Lévy models. Journal of Computational Finance, 27(3):43–86, 2024

- **Xiaoyu Shen** *(FF Quant Advisory, Netherlands):* "A cosine tensor network for XVA calculations"

Abstract: The computation of various valuation adjustments (XVA) and counterparty credit risk (CCR) at the portfolio level is commonly acknowledged as a challenging computational task. In general, analytical solutions are not available, necessitating the utilization of numerical methods. In this paper we introduce a novel Fourier tensor network to enhance the supervised learning of the characteristics function (ch.f.) of the combined dynamics of the XVA/CCR risk factors, with which the targeted expectation can be easily recovered. The ch.f. itself is again a multi-dimensional expectation. We demonstrate that, in several cases, the ch.f. is represented by a network expression consisting of Fourier basis functions and coefficients. Our numerical tests show that the Fourier tensor network offers a substantial improvement in computational speed and efficiency, in comparison to the industrial standard Monte Carlo simulation method.

- **Evgenii Vladimirov** *(Rotterdam, Netherlands):* "iCOS: Option-Implied COS Method"

Abstract: This paper proposes the option-implied Fourier-cosine method, iCOS, for non-parametric estimation of risk-neutral density, option prices, and option sensitivities. The iCOS method leverages the Fourier-based COS technique, proposed by Fang and Oosterlee (2008), by utilizing the option-implied cosine series coefficients. Notably, this procedure does not rely on any model assumptions about the underlying asset price dynamics, it is fully non-parametric, and it does not involve any numerical optimization. These features make it rather general and computationally very appealing. Furthermore, we derive the asymptotic properties of the proposed non-parametric estimators and study their finite-sample behavior in Monte Carlo simulations. Our empirical analysis using S&P 500 index options and Amazon equity options illustrates the effectiveness of the iCOS method in extracting valuable information from option prices in different market conditions.

Hypatia Room: Financial Modelling *(chair: Griselda Deelstra)*

- **Griselda Deelstra** *(ULB, Brussels, Belgium):* "Consistent asset modelling with randomness in the coefficients and switches between regimes"

Abstract: We explore a stochastic model for asset prices that enables capturing external influences in two specific ways. The model allows for the expression of uncertainty in the parametrisation of the stochastic dynamics and incorporates patterns to account for different behaviours across various times or regimes. To establish our framework, we initially construct a model with random parameters, where the switching between regimes can be dictated either by random variables or deterministically. Such a model is highly interpretable. We further ensure mathematical consistency by demonstrating that the framework can be elegantly expressed through local volatility models taking the form of standard jump diffusions. Additionally, we consider a Markov-modulated approach for the switching between regimes characterized by random parameters. For all considered models, we derive characteristic functions, providing a versatile tool with wide-ranging applications. In a numerical experiment, we apply the framework to the financial problem of option pricing. The impact of parameter uncertainty is analysed in a two-regime model, where the asset process switches between periods of high and low volatility imbued with high and low uncertainty, respectively. This is joint work with Felix L. Wolf and Lech A. Grzelak.

- **Donatien Hainaut** *(U. Louvain-la-Neuve, Belgium):* "A mutually exciting rough jump-diffusion for financial modelling"

Abstract : This article introduces a new class of diffusive processes with rough mutually exciting jumps for modeling financial asset returns. The novel feature is that the memory of positive and negative jump processes is defined by the product of a dampening factor and a kernel involved in the construction of the rough Brownian motion. The jump processes are nearly unstable because their intensity diverges to $+\infty$ for a brief duration after a shock. We first infer the stability conditions and explore the features of the dampened rough (DR) kernel, which defines a fractional operator, similar to the Riemann-Liouville integral. We next reformulate intensities as infinite-dimensional Markov processes. Approximating these processes by discretization and then considering the limit allows us to retrieve the Laplace transform of asset log-return. We show that this transform depends on the solution of a particular fractional integro-differential equation. We also define a family of changes of measure that preserves the features of the process under a risk-neutral measure. We next develop an econometric estimation procedure based on the peak over threshold (POT) method. To illustrate this work, we fit the mutually exciting

rough jump-diffusion to time series of Bitcoin log-returns and compare the goodness of fit to its non-rough equivalent. Finally, we analyze the influence of roughness on option prices.

- **Edouard Motte** *(U. Louvain-la-Neuve, Belgium):* "Partial hedging in rough volatility models"

Abstract: The paper studies the problem of partial hedging within the framework of rough volatility models in an incomplete market setting. We employ a stochastic control problem formulation to minimize the discrepancy between a stochastic target and the terminal value of a hedging portfolio. As rough volatility models are neither Markovian nor semi-martingales, stochastic control problems associated with rough models are quite complex to solve. Therefore, we propose a multifactor approximation of the rough volatility model and introduce the associated Markov stochastic control problem. We establish the convergence of the optimal solution for the Markov partial hedging problem to the optimal solution of the original problem as the number of factors tends to infinity. Furthermore, the optimal solution of the Markov problem can be derived by solving a Hamilton-Jacobi-Bellman (HJB) equation and more precisely a nonlinear partial differential equation (PDE). Due to the inherent complexity of this nonlinear PDE, an explicit formula for the optimal solution is generally unattainable. By introducing the dual solution of the Markov problem and expressing the primal solution as a function of the dual solution, we derive approximate solutions to the Markov problem using a dual control method. This method enables for sub-optimal choices of dual control to deduce lower and upper bounds on the optimal solution as well as sub-optimal hedging ratios. In particular, explicit formulas for partial hedging strategies in rough Heston model are derived.

- **Iñigo Arregui** *(U. A Coruña, Spain):* "Models and numerical methods for XVA pricing under mean reversion spreads in a multicurrency framework"

Abstract: We make some contributions to the computation of total valuation adjustments (XVA) for financial derivatives involving several currencies. From the modelling point of view, for the credit spreads we consider the more realistic exponential Vasicek and CIR positive mean reversion processes. Moreover, the derivative is partially collateralized in cash in a foreign currency and the collateral value is a percentage of the derivative prices. Under this modelling assumptions and using appropriate dynamic hedging methodologies, we obtain formulations in terms of linear and nonlinear partial differential equations, which are solved by means of Lagrange-Galerkin methods in low dimension. For higher dimensions, we use Monte Carlo techniques for the equivalent formulations in terms of expectations, including a multilevel Picard iteration method for the nonlinear case. Finally, these methodologies are applied to several European options with different payoffs and the numerical results are discussed. Co-authors: Roberta Simonella, Carlos Vázquez.

Ada Room: Optimization and pricing in finance and actuarial science *(chair: Maria do Rosário Grossinho)*

- **Ying Ni** (Mälardalens U., Västerås, Sweden)*:* "X Hedging: An explainable artificial intelligence hedging framework"

Abstract: We develop a financial option hedging framework called X Hedging that utilizes new artificial intelligence methods, is inherently explainable, and is adaptable to different market models, market frictions, and hedging instruments. The topic of pricing and hedging options is broadly studied in financial literature. Recent methods use neural networks' ability to map complex non-linear relationships to create general and versatile methods, however, at the expense of explainability. We propose a hedging framework that uses gradient-boosted decision trees to increase the explainability of the state-of-the-art frameworks without sacrificing performance. Along these lines, X Hedging complies with the current guidelines and regulations related to explainable artificial intelligence through local explainability, highlighting the practical usability of the hedging framework in the industry.

- **Anthony Britto** *(Karlsruhe Institute of Technolog, Germany):* "Some practical considerations for regression methods for stochastic control problems involving utility functions"

Abstract: The focus of this talk is the application of regressions methods to stochastic control and stopping problems involving utility functions and wealth dynamics, a common use-case in the literature: we discuss our

methodology regarding the choice of basis functions, regression model, and optimisation approach. We illustrate our approach with a stochastic control and stopping model for optimal residential energy consumption and timing of an energy-efficiency investment.

- **Manuel Guerra** *(ISEG & Management Universidade de Lisboa, Portugal):* "Optimal reinsurance under the Parisian ruin criterion"

Abstract: The focus of this talk is the application of regressions methods to stochastic control and stopping problems involving utility functions and wealth dynamics, a common use-case in the literature: we discuss our methodology regarding the choice of basis functions, regression model, and optimisation approach. We illustrate our approach with a stochastic control and stopping model for optimal residential energy consumption and timing of an energy-efficiency investment.

- **Carlos Oliveira** *(Norwegian U. Science and Technology, Norway):* "How to manage the occurrence of adverse events: adopting risk mitigation measures or exiting?"

Abstract: In this presentation, we consider a firm that may face sudden decreases in its revenue. Its revenue is modeled by a geometric Brownian motion, and the cumulative effect of negative shocks is modeled by a compound Poisson process. The firm has two options: either to exit the market or to adopt risk mitigation measures to reduce the impact of the revenue decrease. The firm's option value is modeled as an optimal stopping problem, which we analyze in this presentation. Furthermore, we examine the impact of protective strategies on the firm's option value.

15:40 – 16:00: Coffee/tea break

Chair: Antonis Papapantoleon

16:00 – 16:45: Turing Room: Plenary 3: **Christian Bayer** *(WIAS, Berlin, Germany):* "Primal and dual optimal stopping with signatures"

Abstract: We propose two signature-based methods to solve the optimal stopping problem - that is, to price American options - in non-Markovian frameworks. Both methods rely on a global approximation result for Lp–functionals on rough path-spaces, using linear functionals of robust, rough path signatures. In the primal formulation, we present a non-Markovian generalization of the famous Longstaff-Schwartz algorithm, using linear functionals of the signature as regression basis. For the dual formulation, we parametrize the space of square-integrable martingales using linear functionals of the signature, and apply a sample average approximation. We prove convergence for both methods and present first numerical examples in non-Markovian and non-semimartingale regimes. (Joint work with Luca Pelizzari and John Schoenmakers.)

16:50 – 18:05: Contributed talks 1 (3 presentations), 3 rooms

Turing Room: Stochastic volatility models *(chair Iñigo Arregui)*

- **Wei Xu** *(Toronto, Canada):* "VIX option pricing for nonparameter Heston stochastic local volatility model"

Abstract: The Heston-Dupire model is a well-established stochastic local volatility model that offers a non-parametric representation. This model is known to closely match the implied volatility surface of options observed in the market. However, due to its non-parametric local component, Monte Carlo simulation is the only viable numerical method for derivative pricing under this model. This paper proposes a novel willow tree method to replace Monte Carlo simulation for pricing exotic options and VIX options under the Heston-Dupire model. We provide the convergence rate of this method and conduct several numerical experiments to demonstrate its

accuracy and efficiency. Our proposed method offers an alternative numerical technique that can enhance the computational efficiency of pricing derivatives under the Heston-Duprie model.

- **Stefano De Marco** *(Ecole polytechnique, Palaiseau Cedex, France):* "Evaluating skew-stickiness under stochastic and rough volatility"

Abstract: We study the dynamic properties of some classes of stochastic and rough volatility models (including well-known classical examples with their "rough volatility counterpart": 2-factor Bergomi model, rough Bergomi model, Heston, rough Heston). For dynamic properties, we intend the dynamics of option implied volatilities, as induced by the model. For some of the recently introduced models (notably rough volatility models), quite some effort has been focused on the analysis of their static properties such as their calibration power or the term structure of ATM skews but, to the best of our knowledge, their dynamic properties have received only little attention so far. One specific indicator of joint spot-price and implied volatility dynamics is the Skew-Stickiness Ratio (SSR), introduced by Bergomi [Bergomi, Smile dynamics IV, Risk 2009] and related to classical smile dynamic regimes (sticky-strike and sticky-delta). We evaluate different estimators of the model SSR -- mainly Monte Carlo based -- and compare the results with the empirical market SSR for some large stock indices, which sheds light on the interest of using a certain modeling choice with respect to another. With a view on explicit approximation formulas, we build on the celebrated Bergomi-Guyon expansion for ATM implied volatilities and skews so to obtain explicit expansions of the model SSR, for which we analyse the accuracy with respect to our Monte Carlo benchmark. Joint work with Florian Bourgey (Bloomberg NY) and Jules Delemotte (Ecole polytechnique).

- **Sarath Kumar Jayaraman** *(Calgary, Canada):* "A general option pricing framework for affine fractionally integrated models"

Abstract: This article studies the impact of fractional integration on volatility modelling and option pricing. We propose a general discrete-time pricing framework based on affine multi-component volatility models that admit ARCH(∞) representations. This not only nests a large variety of option pricing models from the literature, but also allows for the introduction of novel covariance-stationary long-memory affine GARCH pricing models. Using an infinite sum characterization of the log-asset price's cumulant generating function, we derive semi-explicit expressions for the valuation of European-style derivatives under a general variance-dependent stochastic discount factor. Moreover, we carry out an extensive empirical analysis using returns and S&P 500 options over the period 1996–2019. Overall, we find that once the informational content from options is incorporated into the parameter estimation process, the inclusion of fractionally integrated dynamics in volatility is beneficial for improving the out-of-sample option pricing performance. The largest improvements in the implied volatility root-mean square errors occur for options with maturities longer than one year, reaching 33% and 13% when compared to standard one- and two-component short-memory models, respectively.

Euler Room: Jump processes *(chair: Alvaro Leitao Rodriguez)*

- **Josep Vives** *(U. Barcelona, Spain):* "Approximate option pricing under jump-diffusion stochastic volatility models based on a Hull and White type formula"

Abstract: In [1], a Hull and White type formula, that is, a theoretical and exact decomposition of the price of a plain vanilla option, is used to obtain approximate prices of plain vanilla options under the Heston model. These ideas have subsequently been extended to different stochastic volatility models with and without jumps (see [2], [3], [4]) and the methodology for obtaining approximate prices has been improved, see [5]. Results for more complex models (rough volatility, hybrid, two-factor, infinite activity jumps) have recently been obtained, see [6], [7], [8] and [9]. The aim of the talk is to summarize this methodology and discuss its competitiveness in terms of accuracy and computational cost with other recent methodologies for approximating option prices.
[1] E. Al`os, R. De Santiago and J. Vives (2015): Calibration of stochastic volatility models via second order approximation: the Heston case. International Journal of Theoretical and Applied Finance 18 (6): 1550036.
[2] R. Merino and J. Vives (2015): A generic decomposition formula for pricing vanilla options under stochastic volatility. International Journal of Stochastic Analysis, volume 2015, article ID 103647.
[3] R. Merino and J. Vives (2017): Option price decomposition in spot dependent volatility models and some applications. International Journal of Stochastic Analysis. Volume 2017, Article ID 8019498.
[4] R. Merino, J. Posp´ısil, T. Sobotka and J. Vives (2018): Decomposition formula for jump diffusion models. International Journal of Theoretical and Applied Finance 21 (8).
[5] A. Gulisashvili, M. Lagunas, R. Merino and J. Vives (2020): Higher order approximation of call option prices in stochastic volatility models. Journal of Computational Finance 24 (1).

[6] R. Merino, J. Pospisil, T. Sobotka, T. Sottinen and J. Vives (2021): Decomposition formula for rough Volterra stochastic volatility models. International Journal of Theoretical and Applied Finance 24 (2).
[7] Y. El-Khatib, S. Goutte, Z. S. Makumbe and J. Vives (2022): Approximate pricing formula to capture leverage effect and stochastic volatility of a financial asset. Finance Research Letters 44. Business and Finance-SSCI (2020).
[8] Y. El-Khatib, Z. S. Makumbe, J. Vives (2023): Approximate option pricing under a two factor Heston-Kou stochastic volatility. Submitted to Computational Management Science.
[9] Y. El-Khatib, Z. S. Makumbe, J. Vives (2024): Decomposition of the option pricing formula for infinite activity jump-diffusion stochastic volatility models. Preprint.

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- **Ruben Bosch** *(ING Bank, Amsterdam, NL):* "Improved VaR/ES backtesting by using self-exciting point processes"

Abstract: With FRTB around the corner, regulators and banks look for ways to assess the performance of expected shortfall (ES) models – the main element of the internal models approach for calculating market risk capital requirements. Established ES backtests suffer from low power and require assumptions on the return distribution. In this talk, I present my newly developed SEPP ES backtest that incorporates a self-exciting point process (SEPP), a process originating from earthquake analysis, to allow for a more natural and flexible way of measuring time dependence across tail observations. By doing so, the backtest is better at identifying clusters of extreme events (VaR exceptions) and thereby rejecting faulty risk models that do not account for the underlying return distribution. Moreover, the only input required to perform the novel SEPP ES backtest are the returns and reported VaR and ES and is therefore readily applicable in current risk management practices. Contrary to most existing ES backtests, the SEPP ES backtest does not require assumptions on the return distribution. Compared to other existing ES backtests, the SEPP ES backtest achieves higher power in a multitude of settings and therefore offers regulators and risk managers an improved method for assessing the risk model at hand.

- **Burcu Aydogan** *(RWTH Aachen, Germany):* "Optimal Investment Strategies under the Relative Performance in Jump-Diffusion Markets"

Abstract: We work on an optimal portfolio management problem in a continuous-time setting for one agent and a large group of agents where the agents interact with each other strategically and determine their investment strategies depending on the others' performances. Herein, we define two wealth dynamics: the agent's and the group's wealth. The wealth dynamics appear in jump-diffusion markets. We measure the performance of the representative agent with preferences linked to the group performance. Therefore, we have a classical Merton problem to determine the agent's optimal strategy relative to the group performance. By the classical stochastic optimal control techniques, we obtain the optimal proportions of the agent in the portfolio. Furthermore, our framework assumes that the agent's utility performance does not affect the group, while the group affects the agent's utility. Moreover, we investigate the case when all agents are homogeneous in their risk aversion and relative performances. As a conclusion, we explore the optimal investment strategies of the representative agent under the relative performance concerns. This is a joint work with Mogens Steffensen at the University of Copenhagen.

Hypatia Room: Calibration *(chair: Emmanuel Gobet)*

- **Bouazza Saadeddine** *(Crédit Agricole, France):* "Fast calibration using complex-step Sobolev training"

Abstract: We present a new fast calibration technique where we propose to train neural networks to directly perform the orthogonal projection of simulated payoffs of the calibration instrument with randomized model parameters and we enrich the learning task by including path-wise sensitivities of the payoffs with respect to model and product parameters. We show that this particular instance of Sobolev training can be reformulated in a way that requires computing only (stochastic) directional derivatives and we provide a fast, memory-efficient and numerically stable approach to compute those using complex-step differentiation. Our experiment with a fixed-grid piecewise linear local volatility example demonstrates that one can get competitive price approximations without having to train the neural network on Monte Carlo prices and that both data-set construction and training can be done in reasonable time while preserving a very general framework that can be applied to a broad range of pricing models. A preprint is available: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4275942

- **Guido Gazzani** *(Ecole des Ponts ParisTech,Marne la Vallée, France):* "Pricing and calibration of path-dependent volatility models"

  Abstract: We consider a stochastic volatility model where the dynamics of the volatility process are described by a linear combination of a (exponentially) weighted sum of past daily returns and the square root of a weighted sum of past daily squared returns in the spirit of Guyon and Lekeufack (2023). With respect to the former we discuss the influence of an additional parameter that unlocks enough volatility of volatility to reproduce the implied volatility smiles of SPX an VIX options within a 4-factor Markovian model (4FPDV). The empirical nature of this class of path-dependent volatility models (PDVs) comes with computational challenges, especially in relation to VIX options pricing and calibration. To address these challenges, we propose an accurate neural network approximation of the VIX leveraging on the markovianity of the 4FPDV. This approximation is subsequently used to tackle the joint calibration problem of SPX and VIX options. We additionally discuss a possible local volatility extension of the 4FPDV, in order to exactly calibrate market smiles. This is based on a joint work with Julien Guyon.

- **Maria Olympia Tsianni** *(Oxford U., UK):* "Convergence of the Euler–Maruyama particle scheme for a regularised McKean–Vlasov equation arising from the calibration of local-stochastic volatility models"

  Abstract: We study the Euler–Maruyama scheme for a particle method to approximate the McKean–Vlasov dynamics of calibrated local-stochastic volatility (LSV) models. Given the open question of well-posedness of the original problem, we work with regularised coefficients and prove that under certain assumptions on the inputs, the regularised model is well-posed. Using this result, we prove the strong convergence of the Euler–Maruyama scheme to the particle system with rate 1/2 in the step-size and obtain an explicit dependence of the error on the regularisation parameters. Finally, we implement the particle method for the calibration of a Heston-type LSV model to illustrate the convergence in practice and to investigate how the choice of regularisation parameters affects the accuracy of the calibration.

Wednesday, April 3rd

Morning:

Chair morning session: Matthias Ehrhardt

9:00 – 9:45 : Turing Room: Plenary 4: **Roxana Dumitrescu** (King's, London, UK): "The linear programming formulation for control/stopping mean-field games: theoretical and numerical aspects"

Abstract: In this talk, we present recent results on the linear programming approach to control/stopping mean-field games in a general setting. This relaxed control approach allows to prove existence results under weak assumptions, and lends itself well to numerical implementation. We will first consider mean-field game problems where the representative agent chooses the optimal time to exit the game, where the instantaneous reward function and the coefficients of the state process may depend on the distribution of the other agents. We then establish the equivalence between mean-field games equilibria obtained by the linear programming approach and the ones obtained via other approaches used in the previous literature. We then present a fictious play algorithm to approximate the mean-field game population dynamics in the context of the linear programming approach. Finally, if time permits, we will discuss the linear programming approach for mixed control / stopping mean-field games. The talk is based on several works, joint with R. Aïd, G. Bouveret, M. Leutscher and P. Tankov.

9:45 – 10:30: Turing Room: Plenary 5: **Lech Grzelak** *(Utrecht U. and Rabobank, NL):* **"**Beyond affine models: On inclusion of random parameters in pricing models"

Abstract: In this talk, we challenge the traditional reliance on Affine (Jump) Diffusion (AD) models in financial pricing through the introduction of Randomized AD (RAnD) models. By integrating exogenous stochasticity into model parameters, RAnD extends beyond the limitations of affine models, offering enhanced flexibility and precision in option pricing. This approach not only overcomes the linearity constraints of AD models but also maintains the benefits of quick calibration and efficient Monte Carlo simulations. We explore the theoretical foundations and practical implementations of RAnD, including the derivation of characteristic functions, simulation techniques, and sensitivity analysis. Specifically, we demonstrate the superiority of randomized stochastic volatility models through the consistent pricing of options on the S&P 500 and VIX. Furthermore, we extend our investigation to short-rate models within the Heath-Jarrow-Morton framework, applying RAnD to achieve controlled implied volatility and improved calibration quality. The randomized Hull-White model exemplifies the potential of RAnD in producing local volatility dynamics and achieving near-perfect calibration to swaption implied volatilities. This talk underscores the significance of incorporating random parameters into pricing models, marking a departure from traditional affine models towards a more nuanced and practical modelling approach in financial markets.

10:30 – 11:00: Coffee break

11:00 – 12:40: Mini-symposia session 3 (4 presentations), 3 rooms

Turing Room: Stochastic Optimal Control Problems: New algorithms and new applications *(chair: Yuying Li)*

Short description: Many financial application problems can be formulated as stochastic optimal control problems. This minisymposium will focus on (i) new data-driven approaches for high dimensional problems and (ii) new application areas. These new approaches include methods based on Neural Networks for high dimensional problems. New applications include societal environmental solutions posed as optimal stochastic control.

- **Margaret Insley** *(U. Waterloo, Canada):* "Environmental bonds and public liability for resource extraction site cleanup"

Abstract: Inadequate cleanup and site remediation from natural resource extraction activity pose threats to human health and the environment. In many jurisdictions, firms are legally obligated to cleanup their sites once extraction operations have terminated. However, the option to declare bankruptcy has left governments with large liabilities for site cleanup. Mining and the oil and gas industry are notable examples. Requiring firms to post financial surety (an environmental bond) prior to starting resource extraction is one way to address this problem. Governments are often reluctant to impose adequate bond requirements for fear of depressing industry activity. This research studies the impacts of an environmental bond on a firm's optimal actions over the full life cycle of a resource extraction project where firm bankruptcy may shift cleanup costs to the government. A firm's stochastic optimal control problem is described by an HJB equation with the resource price modelled as an Ito process. A numerical solution is implemented for hypothetical resource extraction projects in the mining and oil and gas sectors. Numerical results examine the impact of an environmental bond on firm behaviour and the cleanup liability imposed on government.

- **Zhipeng Huang** *(Utrecht, NL):* "Convergence of the deep BSDE method for a coupled FBSDE system"

Abstract: In this article, we solve high-dimensional coupled FBSDEs with Z-dependency in the drift coefficient, in the spirit of the deep BSDE method, as proposed by Han et al. (2018). Under mild conditions, we derive a posterior-type convergence result of the deep BSDE method for this class of coupled FBSDEs, which extends the result of Han and Long (2020) by Z coupling in the drift. Consequently, this enables us to treat coupled FBSDE systems stemming from stochastic control. In particular, we provide a theoretical justification for the non-convergence of the Deep BSDE for specific FBSDE systems, as observed in Andersson et al. (2023) and give sufficient conditions guaranteeing convergence. Numerical results for solving

high-dimensional coupled FBSDEs with consistent performance are presented as well. This is joint work with Balint Negyesi and Cornelis W. Oosterlee.

- **Christoph Reisinger** *(Oxford U., UK):* "K-nearest-neighbor resampling for off-policy evaluation with applications to trade execution and market making"

Abstract: We propose a novel K-nearest neighbor resampling procedure for estimating the performance of a policy from historical data containing realized episodes of a decision process generated under a different policy. We provide statistical consistency results under weak conditions. In particular, we avoid the common assumption of identically and independently distributed transitions and rewards. Instead, our analysis allows for the sampling of entire episodes, as is common practice in most applications. To establish the consistency in this setting, we generalize Stone's Theorem, a well-known result in nonparametric statistics on local averaging, to include episodic data and the counterfactual estimation underlying off-policy evaluation (OPE). By focusing on feedback policies that depend deterministically on the current state in environments with continuous state-action spaces and system-inherent stochasticity effected by chosen actions, and relying on trajectory simulation similar to Monte Carlo methods, the proposed method is particularly well suited for stochastic control environments. Compared to other OPE methods, our algorithm does not require optimization, can be efficiently implemented via tree-based nearest neighbor search and parallelization, and does not explicitly assume a parametric model for the environment's dynamics. Numerical experiments demonstrate the effectiveness of the algorithm compared to existing baselines in a variety of stochastic control settings, including a linear quadratic regulator. In this talk, we will particularly focus on trade execution and market making in limit order books. This is joint work with Michael Giegrich and Roel Oomen.

- **Yuying Li** *(U. Waterloo, Canada):* "Optimal allocation under constraints using NN without dynamic programming"

Abstract: We propose a data driven learning framework to directly compute stochastic optimal asset allocation strategies under constraints. Traditionally, computing finite time horizon discrete dynamic optimal controls is based on dynamic programming (DP), e.g., PDE or reinforcement learning. Using DP, computing a value function at each rebalancing time requires maximizing a conditional expectation. Using tailored activation function and without resorting to dynamic programming (DP), we propose a neural network (NN) Policy Function Approximation (PFA) approach learns the optimal policies directly from data based on unconstrained minimization. While DP requires computing a high dimensional conditional expectation, our proposed approach achieves efficiency by solving a low dimensional control directly based on a single optimization problem. We demonstrate effectiveness of the proposed approach for different financial decision problems, including pension accumulation and decumulation. We validate and compare computed optimal strategies with benchmark solutions based on simulations from synthetic models.

Euler Room: Recent advances in transform (Fourier/Laplace) methods for computational finance and insurance, part II *(chair: Antonis Papapantoleon)*

- **Laura Ballotta** *(Bayes, London, UK):* "Time changes, Fourier transforms and the joint calibration to the S&P500/VIX Smiles"

Abstract: We develop a model based on time changed Lévy processes and study its ability of reproducing the joint S&P500/VIX implied volatility smiles and the VIX futures prices - a problem known in the literature as the `joint calibration problem'. The model admits semi-analytical characteristic functions for the key quantities, and therefore efficient Fourier based pricing schemes can be deployed. We focus on a specification of the proposed general setting which uses purely discontinuous processes. Results from the application to market data show satisfactory performances in solving the joint calibration problem, and therefore demonstrate that the class of affine processes can provide a workable fit. This is joint work with Ernst Eberlein and Gregory Rayée.

- **Chiheb Ben Hammouda** *(Utrecht, NL):* "Empowering Fourier-based pricing methods through quasi-Monte Carlo and domain transformation techniques"

Abstract: Efficiently pricing multi-asset options poses a significant challenge in quantitative finance. While the Monte Carlo (MC) method remains a prevalent choice, its slow convergence rate can impede practical applications. Fourier methods, leveraging the knowledge of the characteristic function, have shown promise in valuing single-asset options but face hurdles in the high-dimensional context. This work advocates using the randomized quasi-MC (RQMC) quadrature to improve the scalability of Fourier methods with high dimensions. The RQMC technique benefits from the smoothness of the integrand and alleviates the curse of dimensionality while providing practical error estimates. Nonetheless, the applicability of RQMC on the unbounded domain, $\mathbb{R}^d$, requires a domain transformation to $[0,1]^d$, which may result in singularities of the transformed integrand at the corners of the hypercube, and deteriorate the rate of convergence of RQMC. To circumvent this difficulty, we design an efficient domain transformation procedure based on the derived boundary growth conditions of the integrand. This transformation preserves the sufficient regularity of the integrand and hence improves the rate of convergence of RQMC. To validate this analysis, we demonstrate the efficiency of employing RQMC with an appropriate transformation to evaluate options in the Fourier space for various pricing models, payoffs, and dimensions. Finally, we highlight the computational advantage of applying RQMC over quadrature methods in the Fourier domain, and over the MC method in the physical domain for options with up to 15 assets.

- **Gero Junike** *(Oldenburg, Germany):* "The multidimensional COS method for option pricing."

Abstract: The multidimensional COS method is a numerical tool to price financial options, which depend on several underlyings. The method makes use of the characteristic function of the logarithmic returns of the underlyings and it is advantageous if the Fourier-cosine coefficients of the payoff function are given in closed-form. However, in important cases, neither this characteristidc function nor the payoff coefficients are given analytically but need to be recovered numerically. We make the following main contributions: First, we prove the convergence of the multidimensional COS method including numerical uncertainty on the characteristic function and the payoff coefficients. Second, we find formulas for two parameters required by the COS method in multivariate dimensions: the truncation range and the number of terms. Third, by damping the payoff function, we can approximate the payoff coefficients through the Fourier transform of the damped payoff function, to speed up the COS method significantly. We also analyze the order of convergence of the COS method.This talk is based on:

[1] Junike, G., & Pankrashkin, K. (2022). Precise option pricing by the cos method-How to choose the truncation range. *Applied Mathematics and Computation*, *421*, 126935.
[2] Junike, G. (2024). On the number of terms in the COS method for European option pricing. *Numerische Mathematik,* to appear.
[3] Junike, G., & Stier, H. (2023). The multidimensional COS method for option pricing. *arXiv preprint arXiv:2307.12843*.

- **Fang Fang** *(Delft and FF Quant, NL):* "A cosine tensor network for pricing European, barrier and Bermudan options under rough Heston's model"

Abstract: Efficient and rapid option pricing plays a pivotal role in the finance industry, enabling traders to make timely, well-informed decisions in the fast-paced derivatives market. This paper introduces a novel cosine tensor network designed to expedite the supervised learning process for the characteristic function (ch.f.) of the lifted Heston model, which in turn supports fast and accurate calculation of option prices. The genesis of this idea can be traced back to a crucial insight inspired by the popular COS (Fourier-cosine series expansion) method for option pricing. The Fourier-series coefficients of the density function of the underlying asset price are essentially "drawn" from a very smooth function, namely the ch.f. This insight led to the development of a novel cosine tensor network, grounded in mathematical derivations, presenting itself as a "white box" construction. In essence, we expand the ch.f. through a multi-dimensional Fourier series expansion, where each dimension represents a distinct model parameter. By employing the Canonical Polyadic Decomposition on the coefficient tensor, we express the ch.f. as a network composed of a few sets of univariate Fourier-cosine basis functions. This novel approach is termed the CPD-COS approach. The training of the weights for the univariate Fourier-cosine basis functions occurs offline and is based on the Alternative Least Squares, combined with the Conjugate

Gradient (CG) method. The efficacy of this network is demonstrated through fast speed in calibrating rough Heston model parameters using real-world option prices. Furthermore, this approach extends to the pricing of path-dependent options, such as barrier and Bermudan options, through the 2-dimensional COS method.

Hypatia Room: Computational Finance II *(chair: Kristian Debrabant)*

- **Michal Wronka** *(Wroclaw, Poland):* "Modelling of interest rate volatilities with GARCH processes"

  Abstract: This presentation aims at analysis of GARCH processes to forecast volatility of Vanilla Interest Rate Swap fair rates. We will provide comprehensive formulation of three models from GARCH models family i.e. regular GARCH, GJR-GARCH (Glosten-Jagannathan-RUnkle) and FIGARCH. Upon model formulation and specification we will calibrate the models to log-normal returns of the At-the-Money Forward fair swap rate. Models testing will be performed from two perspectives. At first GARCH filters will be compared against history of ATM implied swaption volatility and secondly we will create a swap rate volatility index, similar to VIX index from CBOE, representing total market variance captured within wide spectrum of payer and receiver Swaptions. This volatility index will be a second benchmark for GARCH filters. We will review models' convergence to long-run variance and perform back testing to finally conclude whether all the tested models are fit for their purpose. Data used in the analysis is ranging from 2007, so before Lehman's collapse and ending in September 2023. We will examine behavior of the GARCH models across three collat-eralization regimes i.e. LIBOR, OIS and SOFR and see whether there any specific model behaviors under these regimes.

- **Lyuben Valkov** *(Ruse, Bulgaria):* "Numerical solution of volatility recovery problems in option pricing"

  Abstract: We apply the duality technique of the Dupire equation to formulate volatility recovery as a couple of nonlinear inverse parabolic problems. We concentrate on one of them, namely in the case when the coefficients of the Dupire equation depend only on the strike price K. The volatility \sigma = \sigma (K) and the interest rate r=r(K) are unknowns and have to be determined by the price v=v(K,T) measurements:

  v(K,T_{1}) = v_{1}(K) ,   v(K,T_{2}) = v_{2}(K) , K \in R^{+} ,   0 < T_{1} < T_{2} < t_{f},

  where t_{f} is the final time. This overspecified information is used to transform the inverse coefficient problem to the forward problem with non-local terms in the differential operators and the initial condition. We provide results on existence and uniqueness of solution to the inverse problem. Then, we propose numerical iterative schemes for solving the differential problem. Various numerical experiments with synthetic and real market data are discussed. We also apply these techniques when an arbitrage opportunity exists and the volatility and drift must be recovered.

- **Slavi Georgiev** *(Ruse, Bulgaria):* "Computational recovery of the time-dependent volatility of volatility in the Heston model"

  Abstract: The accurate model calibration using market option data is one of the most important problems in contemporary finance. We study the well-posedness of a time-dependent coefficients Heston model on a truncated domain. A robust algorithm for numerical identification of time-dependent volatility of volatility from integral price observations is developed. This inverse problem is quadratically nonlinear. An average linearization in time of the diffusion terms of the semi-discrete initial boundary value problem is employed. Then, a decomposition with respect to the volatility of volatility of the approximate solution is applied so that the transition to the new temporal layer is carried out by solving mixed-derivative elliptic problems. The correctness of the numerical algorithms is studied.

- **Anna Clevenhaus** *(Wuppertal, Germany):* "A gradient-based calibration of the Heston model on real life data"

  Abstract: We present a further step towards a novel space-mapping approach for parameter calibration of the well-known two-dimensional financial Heston model. The calibration of the gradient based method on real data. For the approach, we use a gradient descent algorithm, which requires us to determine the formal adjoint of the

Heston PDE as well. Since the model and the gradient descent algorithm are well known, this is a proof of concept for introducing the space mapping approach to financial calibration. Calibrating model parameters to real market data is challenging because some parameters are implicit and nonlinear. Fortunately, our method is also able to calibrate time-dependent parameters. Finally, we present the calibration to real data.

12:45 – 13:30 Lunch

Afternoon:

Chair: Christoph Reisinger

13:45 – 14:30: Turing Room: Plenary 6: **Blanka Horvath** (Oxford U., UK): "Pathwise methods and generative models for pricing and trading"

Abstract: The deep hedging framework as well as related deep trading setups have opened new horizons for solving hedging problems under a large variety of models and market conditions. In this setting, generative models and pathwise methods rooted in rough paths have proven to be a powerful tool from several perspectives. At the same time, any model – a traditional stochastic model or a market generator – is at best an approximation of market reality, prone to model-misspecification and estimation errors. In a data-driven setting, especially if sample sizes are limited by constraints, the latter issue becomes even more prevalent, which we demonstrate in examples. This raises the question, how to furnish a modelling setup (for deriving a strategy) with tools that can address the risk of the discrepancy between model and market reality, ideally in a way that is automatically built in the setting. A combination of classical and new tools yields insights into this matter.

14:30 – 14:45: Coffee/tea break

14:45 – 16:15: Festivity Peter Forsyth's age 70! (chair Kees Oosterlee)

Chair: Christoph Reisinger

16:30 – 17:15: Turing Room: Plenary 7: **Peter Forsyth** *(U. Waterloo, Canada):* "Decumulation of retirement savings: Are modern tontines the solution?"

Abstract: We consider the holder of an individual tontine retirement account, with maximum and minimum withdrawal amounts (per year) specified. The tontine account holder initiates the account at age 65 and earns mortality credits while alive, but forfeits all wealth in the account upon death. The holder wants to maximize total withdrawals and minimize expected shortfall at the end of the retirement horizon of 30 years (i.e. it is assumed that the holder survives to age 95). The holder controls the amount withdrawn each year and the fraction of the retirement portfolio invested in stocks and bonds. The optimal controls are determined based on a parametric model fitted to almost a century of market data. The optimal control algorithm is based on dynamic programming and the solution of a partial integro differential equation (PIDE) using Fourier methods.The optimal strategy (based on the parametric model) is tested out of sample using stationary block bootstrap resampling of the historical data. In terms of an expected total withdrawal, expected shortfall (EW-ES) efficient frontier, the tontine overlay dramatically outperforms an optimal strategy (without the tontine overlay), which in turn outperforms a constant weight strategy with withdrawals based on the ubiquitous four per cent rule.

Followed by drinks, celebration party 17:30-19:00

Thursday, April 4th

Morning:

Chair morning session: Pasquale Cirillo

9:00 – 9:45 : Turing Room: Plenary 8: **Irene Monasterolo** *(Utrecht U., NL):* **"**Climate credit risk and corporate valuation"

Abstract: We analyse the level of potential carbon risk implied by alternative future climate policy sce- narios. To this end, we develop a novel climate credit risk model (CLIMACRED) for climate scenario-contingent valuation, linking the firm's default probability to the climate scenarios developed by financial authorities. Transition risk emerges from changes in markets' expectations about the materialization of climate transition scenarios, which lead to adjustments in the firms' default probability and in the value of their corporate bonds. We derive closed-form expressions for the ad- justments in firms' default probability considering asset-level technology, and for the value of issued bonds and equities. Our results show that valuation adjustments vary greatly with the severity of adjustments in market expectations, decarbonization scenarios and the energy technology composition of the firms' revenues. Losses in equity values can range up to 80% for firms focusing on fossil fuel activities, but can be much lower for firms with diversified energy technology profiles.
Paper available here: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4124002

9:45 – 10:00: Coffee break

10:00 – 11:40: Mini-symposia session 4 (4 presentations), 4 rooms

Turing Room: Machine Learning methods in Finance II *(chair: Costas Smaragdakis)*

- **Jasper *Rou*** *(Delft U., NL):* "Deep Gradient Flow Methods for Option Pricing in Diffusion Models"

  Abstract: We develop a novel deep learning approach for pricing European options written on assets that follow (rough) diffusion dynamics. The option pricing problem is formulated as a partial differential equation, which is approximated via a new implicit-explicit gradient flow time-stepping approach, involving approximation by deep, residual-type Artificial Neural Networks (ANNs) for each time step. In particular, we split the PDE operator in a symmetric gradient flow with known energy functional and an asymmetric part in which we substitute the neural network of the previous time step, so that we can treat it explicitly. We compare our method with the related Deep Galerkin Method and with deriving the conditional characteristic function of the stock price which leads to the option price with the COS method. In the lifted Heston model with twenty volatility processes, the curse of dimensionality makes deriving the characteristic function too slow, while our method remains fast and accurate.

- **Ruben Wiedemann** *(Imperial College London, UK):* "Neural Operators for Implied Volatility Smoothing"

  Abstract: We develop new techniques for local volatility calibration, based on discretisation-invariant neural operators. A classical method to achieve this calibration is via implied volatility smoothing, namely fitting an arbitrage-free surface to option quotes and computing local volatility from Dupire's equation. Analogously, our operator deep smoothing approach refines given quotes to high-resolution grids. While implied volatility smoothing conventionally involves an instance-by-instance optimisation routine, our approach uses a single forward pass through a graph neural operator (GNO). This GNO is trained offline and operates coherently on inputs of variable size and spatial distribution, greatly streamlining online calibration. We benchmark our approach on historical S&P500 option data against SSVI. An alternative calibration strategy is to model local volatility and to optimise model parameters based on implied price error. Effective such calibration requires an efficient pricing method. We assess as pricing surrogate a Fourier neural operator (FNO) trained in a Physicsinformed fashion through penalisation of deviations from Dupire's equation. The unsupervised training economises the use of a large synthetic dataset. Combined with our hybrid calibration-optimisation scheme, which allows to fine-tune the FNO during online parameter search, we achieve robust calibration.

- **Kristoffer Andersson (Utrecht, NL)** "A robust deep learning method for fully coupled FBSDEs"

Abstract: The deep BSDE method and its extensions have brought significant progress in approximating PDEs and FBSDEs, especially when dealing with complex, high-dimensional problems. However, it is a well-known fact that the method sometimes fails to converge for specific equations. In this presentation, we dive into the details of when and why the deep BSDE method encounters issues. Additionally, we introduce a new approach that successfully handles situations where the deep BSDE method struggles.

- **Urban Ulrych** *(EPFL, Swiss Finance Institute, Switzerland):* "Smart Kernel Factors"

Abstract: Factor models are widely employed in finance to capture the relationship between asset returns and underlying, often latent, factors. These models are typically linear and assume a linear relationship between the factors and asset returns. However, in many cases, the underlying relationship between the factors and asset returns may not be linear, leading to potential misspecification and inaccurate predictions and inference. In this paper, we enhance factor models by introducing non-linearity through low-rank kernel functions, which provide a more flexible representation of the complex, non-linear relationships between factors and asset returns. To achieve this, we select a reproducing kernel Hilbert space with the associated reproducing kernel as a hypothesis space for modeling the factors (i.e., factor portfolios) and their corresponding factor loadings. By incorporating low-rank kernel functions, our approach captures the complex and non-linear interactions between factors and asset returns, improving the accuracy and predictive power of factor models in asset pricing. The proposed framework addresses the limitations of linear models, contributing to an enhanced understanding of financial market dynamics and highlighting the role of machine learning in advancing quantitative methodologies in finance.

Euler Room: Climate risk and financial risk impact *(chair: Aurélien Alfonsi)*

Short description: Facing climate challenges, the financial institutions and investors are encouraged to transfer their activities and investments towards low-carbon supporting economy. Climate risks in finance encompass two primary categories: physical and transition risks. Physical risks entail immediate impact of climate events on companies whereas transition risks, on the other hand, result from firms shifting towards low-carbon production methods. Modeling such risks is a complex task with many uncertainties and limitations but it is essential to understand the climate challenge on the financial system and risks.
In this mini-symposium, we propose fours talks on financial risk evaluation and management when taking into account climate risk impact. The topics cover the pricing of climate derivatives, credit risk of large-sized portfolio under carbon transition scenario, portfolio optimization with ESG consideration and optimal model adaptation. Different mathematical methodologies and computational techniques are adopted and developed such as stochastic control, Monte-Carlo simulations, polynomial chao expansions, numerical optimization resolutions. Empirical studies are also included.

- **Aurélien Alfonsi** *(Ecole des Ponts, France):* "Risk valuation of quanto derivatives on temperature and electricity."

Abstract: We develop a coupled model for day-ahead electricity prices and average daily temperature which allows to model quanto weather and energy derivatives. These products have gained on popularity as they enable to hedge against both volumetric and price risks. Electricity day-ahead prices and average daily temperatures are modelled through non homogeneous Ornstein-Uhlenbeck processes driven by a Brownian motion and a Normal Inverse Gaussian Lévy process, which allows to include dependence between them. A Conditional Least Square method is developed to estimate the different parameters of the model and used on real data. Then, explicit and semi-explicit formulas are obtained for derivatives including quanto options and compared with Monte Carlo simulations. Last, we develop explicit formulas to hedge statically single and double sided quanto options by a portfolio of electricity options and temperature options (CDD or HDD).

- **Florian Bourgey** *(Bloomberg, USA):* "Climate risk assessment of a large-sized credit portfolio"

Abstract: We examine climate-related exposure within a large-sized credit portfolio, encompassing both transition and physical risks. Our primary emphasis lies in understanding how climate risks affect the portfolio's credit risk. We explore various mitigation scenarios, potential policy interventions, and risk factors to elucidate effective emission strategies and the corresponding value dynamics of the constituent firms. The interdependence among default events is modeled using a Gaussian factor model framework. We combine dimension-reduction techniques with a polynomial chaos expansion to analyze the cumulative loss distribution to ensure computational efficiency.

- **Elisa Ndiaye** *(Ecole Polytechnique and BNP Paribas, France):* "Optimal business model adaptation plan for a company under a transition scenario"

Abstract: Tackling climate change is one of the biggest challenges of today. Limiting climate change translates to drastically cutting carbon emissions to net zero as soon as possible. More and more commitments have been made worldwide by various authorities and companies to mitigate their GHG emissions accordingly, notably the Paris Agreement in 2015 that has set the 'well-below 2°C' target. This energy transition generates the so-called 'transition risks' as described by M. Carney: "the financial risks which could result from the process of adjustment towards a lower-carbon economy". This has impulsed the launch of a new type of financial risks assessment exercise: Climate Stress-Tests. However, the tools used for these frequent risk management practices remain limited. We propose a model whose goal is to improve the modeling of companies' adaptation in a given transition scenario for credit stress testing in climate stress tests. Our model is a scenario and sector invariant model for a firm's business model based on probability theory. Following microeconomics theory logic, we use optimization to model the firm's adaptation. Precisely, we use stochastic control to derive the best intensity reduction strategy according to our definition, as well as the inherent sales revenues and total emissions. Because of the complexity of our stochastic control problem, we solve the minimization program us- ing a numerical resolution method that we call Backward Sampling. We find that usual intensity reduction strategies, such as following the same decrease rate as the sector, or investing the same amount as the total carbon cost, are non-optimal according to our definition, and which could lead to a misevaluation of credit risk for both high-carbon and low-carbon companies.

- **Jörg Müller** *(Chemnitz, Germany):* "Credit value-at-risk in the context of ESG"

Abstract: The banking supervisory authorities expect banks to integrate sustainability risks into their traditional risk quantification systems. July 2023, Capelli et al. published a proposal for the integration of ESG risks in the measurement of market value-at-risk. However, banks not only bear risks in the context of trading transactions, but also in their customer loan portfolio. As part of the research presented here, the idea of Capelli et al. will be applied to the concept of credit value-at-risk relevant to banks' loan portfolios. The focus here is on corporate loans. Due to the special features of the credit value-at-risk concept, various adjustments are necessary compared to Capelli et al. As part of the research, adaptation options are presented and their strengths and weaknesses are weighed against each other. The question also arises as to the method of collecting data on the ESG behaviour of borrowers in the rather less transparent corporate credit market. A proposal is made for this.

Hypatia Room: Computational Finance III *(chair: Lyuben Valkov)*

- **Ray Ruining Wu** ***(****U. Toronto, Canada):* "The sparse grid combination method for multidimensional Black-Scholes partial differential equations"

Abstract: In computational finance, multidimensional partial differential equations (PDEs) arise from the pricing of multiasset options or options with multiple risk factors considered, as each asset/risk factor leads to a spatial variable. A fundamental challenge in the numerical solution of multidimensional PDEs is the curse of dimensionality -- that is, the exponential increase of the number of unknowns with respect to dimension, which creates difficulties in obtaining accurate numerical solutions of even moderate-dimension PDEs. We use the

sparse grid combination method to alleviate the curse of dimensionality and present computationally efficient results for multidimensional European and American options under the Black-Scholes model. Additionally, we show how smoothing techniques can be applied to remove spurious oscillations that arise due to non-smooth initial conditions that are characteristic of computational finance problems when using the sparse gri combination method.

- **Daniel Sevcovic** *(U. Bratislava, Slowakia):* "Multidimensional linear and nonlinear partial integro-differential equation in Bessel potential spaces with application in option pricing"

Abstract: In this talk we analyze solutions of a non-local nonlinear partial integro-differential equation (PIDE) in multidimensional spaces. Such class of PIDE often arises in financial modeling. We employ the theory of abstract semilinear parabolic equations in order to prove existence and uniqueness of solutions in the scale of Bessel potential spaces. We consider a wide class of Levy measures satisfying suitable growth conditions near the origin and infinity. The novelty consists in the generalization of already known results in the one space dimension to the multidimensional case. We consider Black-Scholes models for option pricing on underlying assets following a Levy stochastic process with jumps. As an application to option pricing in the one-dimensional space, we consider general shift function arising from nonlinear option pricing models taking into account a large trader stock-trading strategy. We prove existence and uniqueness of a solution to the nonlinear PIDE in which the shift function may depend on a prescribed large investor stock-trading strategy function.

- **Pascal Halffmann** *(Kaiserslautern, Germany):* "Risk management in portfolio optimization: A multicriteria approach"

Abstract: Portfolio optimization in the realm of risk management is a critical endeavour for investors seeking to strike an optimal balance between risk and return. The traditional Markowitz model often falls short in addressing the multifaceted nature of real-world uncertainties, leading to suboptimal decision-making. Previously, we have addressed some limitations by transforming the Markowitz model into a multiobjective optimization problem. However, the uncertain nature of asset data such as expected returns remains a challenge in classical and multiobjective Markowitz models. We investigate how multiobjective (robust) optimization can not only enhance the decision support for portfolio optimization but also improve the risk management and analysis. In particular, we show how multiobjective optimization can provide a sensitivity analysis under changing parameter values. Further, we consider different scenarios for parameters, such as financial crises or economic growth, with unknown probability and present an innovative multiobjective robust optimization concept, extending the established min-regret-robustness from single-objective optimization.

- **Neda Bagheri** *(U. Bratislava, Slowakia):* "A Comparison Study of ADI and ADE Methods of the Black-Scholes equation on option pricing"

Abstract: The focus of this study is on the pricing of marketing options involving two risky underlying assets and one risk-free underlying asset. The research utilizes the Black-Scholes model and European option applicable at maturity. Solving an equation with partial derivatives involving two spatial variables is necessary to determine the appropriate price for the European option. Finite differences for a one-dimensional equation usually end up in a three-dimensional set, which is solved with O(n) computation costs, where n is the number of discrete points. But here, since the problems are two-dimensional, Alternate Direction Implicit (ADI) and Alternate Direction Explicit (ADE) are used to reduce the computational cost. These methods operate at discrete points, providing an advantage in terms of computational efficiency and offer acceptable stability. An evaluation of these methods in option pricing indicates that the (ADI) method is sensitive to discontinuity or non derivability, a common characteristic of income functions. In this project, by use of Python programming, we will show which method is more stable over time as well as during the steps taken by these two methods. Thus, this means that with the increase in the inflation rate and the interest rate, the sensitivity and error It will show less and can be used in the stock markets in the feature.

Ada Room: <u>Stochastic Modeling and Complex System Methods in Finance</u> *(chairs: Drona Kandhai, Sven Karbach, and Simon Trimborn)*

Short description: This mini symposium explores the intricacies of financial markets as complex stochastic systems. The focus is on advances in stochastic and information theory-based network modeling methods, quantifying the complexities of financial markets and enabling the understanding of their interconnectedness. Contributed talks will cover how stochastic models predict risks and market dynamics, leadership of assets and institutions in financial markets, and risk management of energy markets. This symposium serves as a platform for academicians, practitioners, and researchers to collaborate and exchange ideas, deepening their understanding of modern stochastic methods used to model complex financial systems.

- **Drona Kandhai** *(U. Amsterdam and ING Bank, NL):* "Recent Advances in WWR modeling for xVAs"

  Abstract: In recent decades, pricing and risk management of financial derivatives has seen a major change due the credit crisis. As a result, different valuation adjustments have been introduced (CVA, FVA, KVA and MVA). At the same time, advances in complex systems science and machine learning research has entered the field of financial risk-management and trading. In this talk, after providing a brief introduction to xVAs, the application of network models in combination with machine learning algorithms will be discussed. More specifically, we will consider the application of these approaches to Wrong-Way-Risk (WWR) modeling, and focus on efficient approaches tailored at incorporating portfolio level impacts and model calibration. In concluding remarks, a summary of important open problems for future research will be presented.

- **Simon Trimborn** *(U. Amsterdam, NL):* "Influential Assets in Large-Scale Vector Auto-Regressive Models"

  Abstract: When a company releases earnings results or makes announcements, a sectoral wide lead-lag effect from the stock on the entire system may occur. To improve the estimation of a system experiencing system-wide lead-lag effects from a single asset in the presence of short time series, we introduce a model for Large-scale Influencer Structures in Vector AutoRegressions (LISAR). We study the asymptotic properties of the estimator and validate its performance in extensive synthetic data experiments. We study the performance of the LISAR model on high-frequency data for the constituents of the S&P100, separated by sectors. We find the LISAR model to significantly outperform on up to 14.7% of the days in terms of forecasting accuracy. Trading strategies with signals derived from the LISAR model achieved up to 60% excess return compared to other strategies. We show in this study, that in the presence of influencer structures within a sector, the LISAR model, compared to alternative models, provides higher accuracy, better forecasting results, and improves the understanding of market movements and sectoral structures.

- **Sven Karbach** *(U. Amsterdam, NL):* "Dependency Modeling in Renewable Energy Markets"

  Abstract: In this presentation, we introduce a novel stochastic covariance model based on Lévy-driven multivariate continuous-time autoregressive moving average (MCARMA) processes. This model is specifically designed to capture the complex dependency structures within and across coupled electricity markets, as well as to describe the intricate spatio-temporal relationships among weather variables, the dynamics of electricity demand and supply, and electricity spot and forward prices. Within our framework, these variables are characterized by a mean-reverting CARMA process, which is modulated by an instantaneous covariance process. Importantly, this instantaneous covariance process itself is represented by a Lévy-driven MCARMA process, with values in the cone of symmetric and positive semi-definite matrices. We also undertake a comparative analysis of our model's ability to describe the dependency structure in renewable energy markets against that of a generic model based on Lévy copulas.

- **Ioannis Anagnostou** *(European Investment Bank – EIB, Luxembourg):* "Network Modeling Methods for Portfolio Credit Risk"

  Abstract: Traditional portfolio credit risk models are frequently criticized for their inadequacy in capturing complex dependencies, such as default clustering and financial interconnectedness. These models, reliant on a conditional independence framework, may fall short in providing sufficient capital buffers, leaving the financial system vulnerable to crises. Our work introduces network modelling techniques to overcome these limitations by integrating contagious default mechanisms and uncovering both direct and indirect relationships between credits through Bayesian network methods. We propose an augmented framework that not only considers systematic risk factors but also accounts for contagion effects, thereby significantly impacting the tails of loss distributions. The structure and parameters of financial networks are learned from real Credit Default Swap data. Moreover, we explore the mesoscopic credit market structure through Random Matrix Theory, identifying internally correlated and anticorrelated communities that traditional models fail to recognize. This approach offers a more accurate representation of risk by acknowledging the intricacies of financial interconnectedness. The implications of these network modelling techniques on standard risk metrics will be discussed, with detailed demonstrations on stylized portfolios.

11:40 – 13:00: Contributed talks 2 (3 presentations), 4 rooms

Turing Room: Portfolios *(chair: Peter Forsyth)*

- **Cyril Izuchukwu Udeani** *(U. Bratislava, Slowakia):* “Approximating the solution operator of nonlinear parabolic equations arising from portfolio selection using deep learning.”

  Abstract: This study focuses on approximating the solution operator of a fully nonlinear partial differential equation arising from finance using machine learning techniques. We consider a fully nonlinear Hamilton--Jacobi--Bellman (HJB) equation arising from the stochastic optimization problem, where the goal of an investor is to maximize the conditional expected value of the terminal utility of a portfolio. The value function of the nonlinear HJB equation describes the optimal portfolio selection strategy. The fully nonlinear HJB equation is first transformed into a quasilinear parabolic equation using the Ricatti transform. Then, the solution of the transformed quasilinear equation is approximated using deep learning. Our qualitative analysis shows that the solution operator of the associated HJB equation can effectively be learned using a deep learning approach.

- **Eva Lütkebohmert** *(U. Freiburg, Germany):* “Deep Learning Name Concentration Risk in Loan Portfolios of Multilateral Development Banks”

  Abstract: As institutions that predominantly lend to sovereign borrowers to achieve their development goals, Multilateral Development Banks' (MDBs) loan portfolios typically consist of a small number of borrowers. The approaches currently applied by rating agencies to account for this exposure to single name concentration risk in the assessment of MDBs' capital adequacy have been criticized for being overly conservative and thereby restricting MDBs' lending headroom. In this paper, we suggest a new deep learning approach for the quantification of single name concentrations that is tailored for the specifics of MDB portfolios. Based on realistic portfolios that adequately represent MDB portfolios, we demonstrate the accuracy of our new approach and its superior performance compared to existing analytical methods for assessing name concentration risk in small and concentrated portfolios.

- **Jari Toivanen** *(Jyväskylä, Finland):* “Monte Carlo based Portfolio Optimization”

  Abstract: Multi-period portfolio optimization problems inspired by Peter Forsyth's work are considered using Monte Carlo sampled risky asset paths. A nonlinear programming formulation is described which allows using very general asset and optimization goals under realistic constraints on investment policies. This formulation does not require dynamic programming or any transformations. The resulting optimization problems can be solved efficiently using a quasi-Newton method for which the gradient is computed using an adjoint technique or an automatic differentiation. Mean-variance and mean-semivariance portfolio optimizations with two and five assets are presented as examples. This is joint work with Raino A.E. Mäkinen.

Euler Room: Insurance / Finance *(chair: Luis Ortiz Gracia)*

- **Koos Gubbels** *(Achmea, Tilburg U, NL.):* “Principal component copulas for capital modeling”

Abstract: We present a class of copulas that we call Principal Component Copulas. This class intends to combine the strong points of copula-based techniques with principal component-based models. We show that the class gives flexibility in modelling tail dependence using the most important directions in multivariate data. The proposed techniques have conceptual similarities and technical differences with the increasingly popular class of factor copulas. Such copulas can generate complex dependence structures and also perform well in high dimensions. We show that Principal Component Copulas give rise to technical advantages over existing techniques. We apply the copula to multivariate return data and find that the copula class performs particularly well on aggregate measures of tail risk, which is of importance for capital modeling.

- **Naoyuki Ishimura** *(Chuo U., Tokyo, Japan):* "Insurance design against epidemic outbreaks involving Cramér-Lundberg model"

Abstract: A simple model of the insurance coverage for the damage of COVID-19 is introduced. Concerning the estimation of the numbers of patients and/or deaths, we employ the Cram\'er-Lundberg model for the risk process, combined with the discrete SIR model. Under suitable premium principles, we are able to design appropriate insurance. Numerical research with the data of the Tokyo region is also performed, which shows our model works well.

- **Pasquale Cirillo** *(ZHAW, Zürich, Switzerland):* "Probability pas de deux in finance: connecting two probability measures via non-Newtonian calculus"

Abstract: Exploiting the non-Newtonian calculus developed by Grossman and Katz, we present an alternative method for connecting two probability measures. While our approach may initially evoke similarities to the utilisation of the distortion functions often found in the actuarial literature, it distinguishes itself by offering a broader framework. In fact, what we propose not only facilitates and generalizes the connection between probabilities, including objective and subjective ones, but it also accommodates unconventional and seemingly irrational operations by agents. After introducing the key theoretical findings, we discuss some financial applications. Additionally, we offer insights into the potential integration of this new approach within the field of machine learning.

Hypatia Room: Monte Carlo methods *(chair: Tony Ware)*

- **Michele Azzone** *(Milano, Italy):* "A fast Monte Carlo scheme for additive processes and option pricing"

Abstract: We present a very fast Monte Carlo scheme for additive processes: the computational time is of the same order of magnitude of standard algorithms for simulating Brownian motions. We analyze in detail numerical error sources and propose a technique that reduces the two major sources of error. We also compare our results with a benchmark method: the jump simulation with Gaussian approximation. We show an application to additive normal tempered stable processes, a class of additive processes that calibrates "exactly" the implied volatility surface. Numerical results are relevant. This fast algorithm is also an accurate tool for pricing path-dependent discretely-monitoring options with errors of one basis point or below.

- **Maria Kalicanin Dimitrov** *(Mälardalen U., Sweden):* "Almost-Exact Scheme for Heston-type Models: American and Bermudan Option Pricing"

Abstract: In this study, Monte Carlo simulation methods are employed for pricing American and Bermudan options, focusing on using an almost exact simulation scheme. This efficient scheme allows simulations to be conducted only on potential early exercise dates. For the classical Black-Scholes model, which follows a stochastic differential equation with a known closed-form solution, an exact scheme is applicable. However, for the more complex Heston model, characterized by a single stochastic volatility process, an Almost Exact Scheme (AES) is used. The AES leverages the non-central chi-square probability distribution to model the variance process. The research addresses the valuation of American and Bermudan options under Heston-type stochastic volatility models, implementing the AES for simulation. Two models are examined: the standard Heston model with a single stochastic volatility and the Double Heston model, which features dual stochastic volatilities. An analytical derivation of the AES for the Double Heston model is presented, along with a numerical analysis to assess the benefits of using AES in both the Heston and Double Heston models. The findings suggest that the AES is

particularly effective when the number of simulation steps corresponds with the number of exercise dates, enhancing efficiency.

- **Luca Gonzato** *(Vienna, Austria):* “Bayesian calibration of option pricing models using sequential Monte Carlo samplers"

Abstract: Calibration of option pricing models to the implied volatility surface is a complicated, yet fundamental, task in the quantitative finance community. By exploiting Sequential Monte Carlo methods we turn the standard calibration problem into a Bayesian estimation task. In this way we can construct a sequence of distributions from the prior to the posterior which allows to compute any statistic of the estimated parameters, to overcome the strong dependence on the starting point and to avoid troublesome local minima; all of which are typical plagues of the standard calibration. To highlight the strength of our approach we consider the calibration of the double jump stochastic volatility model of Duffie et. al (2000) both on simulated and real option data. From the results on both single dates and time series of implied volatilities we find that our Bayesian approach largely outperforms the benchmark in terms of run time-accuracy, option pricing errors and statistical fit. Finally, we show how to further speed up computations by leveraging delayed-acceptance Markov Chain Monte Carlo methods and deep learning.

Ada Room: Model-free methods, uncertainty *(chair: Roxana Dumitrescu)*

- **Antonis Papapantoleon** (Delft, Netherlands): “Model-free and data driven methods in mathematical finance”

Abstract: Academics, practitioners and regulators have understood that the classical paradigm in mathematical finance, where all computations are based on a single "correct" model, is flawed. Model-free methods, were computations are based on a variety of models, offer an alternative. More recently, these methods are driven by information available in financial markets. In this talk, we will discuss model-free and data driven methods and bounds and present how ideas from probability, statistics, optimal transport and machine learning can be applied in this field.

- **Rodolphe Vanderveke** *(UCLouvain, Belgium):* “Optimal Diversification under Parameter Uncertainty”

Abstract: Conventional investment wisdom advocates that investors should be well diversified and invest in as many assets as possible, i.e. increase portfolio size. We show instead that due to the estimation errors in the inputs of portfolio strategies, the portfolio size that optimizes the out-of-sample performance is finite. The optimal portfolio size we derive strikes the trade-off between accessing additional investment opportunities and limiting estimation risk, and can be relatively small compared to usual portfolio sizes. We also propose a set of procedures to select which assets are part of the size-restricted portfolio. Empirically, we show that restricting the portfolio size with our method substantially outperforms unrestricted portfolios and makes portfolio theory valuable even in high-dimensional settings.

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- **Afrasiab Kadhum** *(Ortec Finance, Rotterdam, NL):* “Creating model-agnostic prediction intervals”

Abstract: We present a novel model-agnostic method to calculate prediction intervals for regression problems. This direct method predicts the quantile of the absolute error to construct an interval around a point estimate. We compare the performance to existing methods on a dataset of residential transaction prices, and on transaction prices simulated using a Bayesian approach to let us gauge the absolute performance of the different prediction interval methods. We find that all methods, on average, create wider intervals than the true interval width for a given confidence level. On the actual data the direct method consistently creates the smallest intervals by a large margin, while achieving similar coverage levels as quantile regression. The cross conformal prediction method constructs on average intervals with the most accurate coverage levels, although it also creates the widest intervals and cannot model the heteroskedasticity in the observations.

13:00 – 14:00 Lunch

Afternoon:

14:00 – 15:15: Contributed talks session 3 (3 presentations), 4 rooms

Turing Room: Climate, ESG *(chair: Irene Monasterolo)*

- **Davide Trevisani** *(CITIC, A Coruña, Spain):* "Scope 3 capital design for carbon-emissions-facilitation tax risk"

  Abstract: Among the efforts to address climate change, governments have introduced over seventy carbon pricing instruments (CPIs) in a context where banks are required to maintain capital levels to ensure their "resilience to withstand losses in times of stress". While banks finance a significant fraction of global emissions, on the other hand, it is possible that governments will introduce a CPI impacting banks on their Scope 3 emissions before 2050. Here we design a Scope 3 capital charge to make banks resilient against the possibility, albeit not certainty, that governments could introduce such a Scope 3 CPI. Accordingly, we consider a stylized market model where governments could introduce such a Scope 3 CPI. We provide numerical examples, based on interest rate swaps, which are financially significant for counterparties having high emissions. Our results are expressed in terms of a new Scope 3 CPI capital, obtained through the CCR methodology in force under Basel III. Our examples show that the Scope 3 CPI capital moves from a fraction to multiples of SA-CCR capital as contract move from 5, to 10 or 20 year maturities. As governments may provide limited notice of a new Scope 3 CPI, we conclude that the introduction of a Scope 3 capital deserves consideration from regulators. Here we design a Scope 3 capital charge to make banks resilient against the possibility, albeit not certainty, that governments could introduce such a Scope 3 CPI.

- **Serine Guichoud** *(Ecole des Ponts, Université Paris-Saclay, France):* "Physical propagation of climate extremes across global value chains"

  Abstract: This paper presents a theoretical frame relying on the graph theory for assessing extreme weather events relative damage to global value chains. The approach is defined in three steps: the first part of the paper presents the intuition inspiring the defined model and associated theory, the second part is focused on a scenario analysis declining extreme events relative severity by countries, the third part leverages on the graph theory to translate the damages associated to these events into macro-sectorial value chains disruptions. A numerical application is then run by estimating drought global damages. We consider damage as a score based on extreme events occurrence, calibrated in this article with historical data. Using the graph theory, we incorporate these damages to a network of countries moving from a stationary state of constant flows before a distribution of extreme events, to a modified state considering the extreme events occurrence. The spread of these production damages is modeled as a contagion applied to a network representing intermediate consumption financial flows, to assess the cumulative effect of a damage to value chains.

- **Christian Kappen** *(d-fine, Frankfurt, Germany):* "The Power of Derivatives: Pricing and Hedging of Power Purchase Agreements and Power Options"

  Abstract: The renewable energy transition is supported by power purchase agreements (PPAs), which are long-dated bilateral contracts used to lock in energy prices for stochastic future quantities (e.g., for fixed production ratios). The value of a PPA is driven by the dependency between future production rates and future spot energy prices. In this talk, I present quantitative approaches to pricing PPAs and to hedging the inherent risks of a PPA.

Euler Room: Hedging *(chair: Jari Toivanen)*

- **Carlo Sgarra** *(Bari, Italy):* "Semi-static variance-optimal hedging with self-exciting jumps"

Abstract: We study a hedging problem in an incomplete market model where the underlying log-asset price is driven by a diffusion process with self-exciting jumps of Hawkes type. More precisely, we aim at hedging a claim at time T > 0, using a basket of available contingent claims, so that we minimize the variance of the residual hedging error at time T. In order to minimize the error and targeting perfect replication even in incomplete markets, we look for a hybrid hedging strategy, namely for a semi-static one: one part has to be dynamic (i.e., continuously rebalanced) and another one will be static (i.e., buy-and-hold). Consider S to model the price of some stock. We aim at hedging a claim η0 given a basket of contingent claims η = (η1 . . . , ηd). We are looking for a semi-static variance-optimal strategy. Semi-static hedging strategies consist in taking a dynamic (i.e., continuously rebalanced) position in S, and a static (i.e., buy-and-hold) position in the fixed basket of contingent claims. We also ask the strategy to be variance-optimal, meaning that we will perform a minimization of the variance of the residual hedging error at a certain terminal time T > 0. The purpose of our work is to solve the semi-static variance optimal hedging problem for a new model, in the case where η0 is a variance swap and η a basket of European options. The model taken into consideration is affine and the stock price S has both a Hawkes jump component, which shows self-exciting features, and stochastic Heston-like volatility. Research into models with jumps, especially self-exciting ones, is significant as it has been observed that prices in the financial market - commodity market can exhibit spikes having clustering behavior. In our work, we establish and analyze a new model, studying its properties as an affine semimartingale. We characterize its Laplace transform, studying its existence under suitable parameter conditions. This characterization of the Laplace transform is fundamental, as the contingent claims must be rewritten using a Fourier transform representation.

- **Balint Negyesi** *(Delft., NL):* "Deep BSDE approach for simultaneous pricing and delta-gamma hedging of portfolios consisting of high-dimensional multi-asset Bermudan options"

Abstract: Direct financial applications of our recent works on the One Step Malliavin (OSM) scheme (Negyesi et al. 2024a, 2024b) are presented. Therein a new discretization of (discretely reflected) Markovian backward stochastic differential equations is given which appear naturally in the pricing and hedging of Bermudan options. Our novel discretization schemes exploit a linear BSDE representation for the Z process stemming from Malliavin calculus, which involves a Γ process, corresponding to second-order Greeks of the associated option's price. Therefore, the resulting schemes give a robust and efficient way to perform not just delta- but also delta-gamma hedging. The main contributions of this work is to apply these techniques in the context of portfolio risk management. Large portfolios of a mixture of European and Bermudan derivatives are cast into the framework of a system of discretely reflected BSDEs. The resulting system of equations is simultaneously solved by a neural network regression Monte Carlo approach, similarly to the recently emerging class of Deep BSDE methods. Numerical results are presented on large scale, high-dimensional portfolios, consisting of several European, Bermudan options with possibly different early exercise features. These demonstrate our hedging strategies significantly outperform benchmark methods both in the case of standard delta- and delta-gamma hedging.

- **Leonardo Perotti** *(Utrecht U., NL):* "Modelling and hedging the prepayment option for fixed interest rate mortgages"

Abstract: One of the primary concerns within the fixed-interest rate mortgage domain is ``prepayment risk,'' which is the risk embedded in the right of the mortgage owner to repay the outstanding notional in advance. Because of the magnitude of the underlying market, the development of robust hedging strategies is crucial. A dynamic hedging is proposed, in an incomplete economy, to minimize the prepayment risk. A non-hedgeable risk factor captures the behavioral uncertainty embedded in the mortgage owner's repayment strategy, allowing us to address realistic dynamics where the hypothesis of financially rational behavior is dropped. The hedging strategy is tailored to real-world dynamics (P-dynamics) implied by historical data. The P-dynamics are linked to the pricing framework, developed under an equivalent martingale measure (Q-dynamics), through a suitable, yet non-unique, change of measure, utilizing the tools provided by Girsanov's theorem. The approach provides a

flexible framework for hedging strategies in incomplete economies, and can be extended and employed in a wide range of realistic applications.

Hypatia Room: Market features *(chair: Fenghui Yu)*

- **Yerkin Kitapbayev** *(Abu Dhabi, UAE):* "Valuation of equity and debt with finite maturity using local time"

Abstract: We examine optimal debt contracts in a dynamic model with a finite maturity date and a continuous coupon payments. We provide the valuation formulas for the equity and debt values. The value of equity has an early default premium representation where the endogenous default boundary solves a recursive integral equation. The debt value is given by the representation that involve a local time term. We develop a numerical algorithm that employs these characterizations.

- **Giovanni Amici** *(Torino, Italy):* "Time-inhomogeneity in currency triangles"

Abstract: We show the importance to model time-inhomogeneity in multi-FX option pricing. To this aim, we take advantage of the specific features of currency triangles to extract the joint dynamics of FX log-rates. We then calibrate a model with a multivariate additive subordinator, recently introduced by Semeraro (2022). Such model extends well-known Lévy constructions by including a parameter of time-inhomogeneity. We restrict the attention to a world in which the trading time of FX log-rates is described by an inverse Gaussian-like process. Accordingly, our benchmark is the model of Ballotta et al. (2017) with Normal inverse Gaussian components. Finally, we explore more sophisticated model constructions that allow for multiple parameters of time-inhomogeneity.

Ballotta, L., Deelstra, G., and Rayée, G. (2017). Multivariate FX models with jumps: Triangles, quantos and implied correlation. European Journal of Operational Research, 260(3):1181–1199.

Semeraro, P. (2022). Multivariate tempered stable additive subordination for financial models. Mathematics and Financial Economics, 16(4):685–712.

- **Aditya Nittur Anantha** *(IISc Bangalore, India):* "Measuring and filtering noise in high frequency order flow"

Abstract: Capital markets in India and elsewhere are seeing increased volatility in sub second timeframes when compared to larger time scales. This increased volatility leads to increased instantaneous draw downs, called slippage, in execution algorithms used by market makers and arbitrageurs. We propose two estimators of slippage, using both high frequency order flow and the instantaneous limit order book. We forecast the distribution of slippage using Hawkes processes and introduce the Composite Liquidity Factor (CLF) to measure the slippage from the instantaneous limit order book. We empirically show the convergence of the two measures in markets that have high trading activity and discuss the possibility of using this method to rank the efficiency of price discovery across asset classes and exchanges, in terms of the estimated slippage. Lastly, we present evidence from the Indian capital markets and discuss the efficacy of the proposed estimators.

Ada Room: Selection, Identification *(chair: Long Teng)*

- **Arnaud Germain** *(UCLouvain, Belgium):* "Loan selection for collateralized debt obligations: minimizing the cost of capital release"

Abstract: We tackle the problem of a financial institution willing to identify a set of loans to securitize into a Collateralized Debt Obligation (CDO). Mathematically, the goal is to assign a binary weight to each loan for the sake of minimizing the cost of capital release. This is a high-dimensional mixed-integer non-linear (NP hard) problem. In this paper, we design an efficient optimization procedure relaxing the binary constraint, reducing the dimensionality and addressing the non-linearities. In particular, the Expected Loss of a CDO tranche is linearized thanks to a Large Homogeneous Pool approximation and Gaussian quadrature, whereas the binary and high-dimensional features are addressed via clustering techniques. We propose an analytical expression for the

Weighted Average Life of a tranche inspired by the PSA prepayment model. Our solution outperforms several benchmarks both in terms of the objective function and computation time.

- **Nikeethan Selvaratnam** *(BNP Paribas, Polytechnique de Paris, France):* "Modeling dependency between operational risk losses and macroeconomic variables using hidden Markov triplets"

  Abstract: Predicting future operational risk losses gives rise to a significant challenge due to the heterogeneous and time-dependent structures present in real-world data. Furthermore, during stress testing exercises, there is a requirement to examine the relationship with macroeconomic factors. We propose using a Hidden Markov Triplets model (HMT), which is an advanced variant of the conventional Hidden Markov Chain. This model introduces a third auxiliary variable designed to accommodate the varying non-stationarities in the time-series data. We detail the unique aspects of operational risk data and describe how model calibration is achieved via the Expectation-Maximization (EM) algorithm. Additionally, we provide the calibration results using a high-dimensional dataset, including the selection of macroeconomic variables that influence the loss data.

- **Dorinel Bastide** *(BNP Paribas and Ecole polytechnique, France)*: "Takers identification for defaulted portfolios with simulated annealing algorithms''

  Abstract: We look at the problem of identifying multiple takers of defaulting portfolios on several central clearing house counterparties (CCPs) on a financial network where one common clearing member (CM) defaults on those CCPs and the corresponding portfolios need to be taken over by the other surviving CMs on the same CCPs. Each of the CMs uses a single intractable capital metric on their aggregated potential loss across all CCPs. The CMs are interconnected through the CCPs regarding their losses, posted collaterals and contributions to common default funds to the CCPs, leading to numerous indirect links in the financial network. We undertake an idealized auction resolution where instead of conducting the auction, each CCP selects the taker among its surviving CMs leading to minimal capital costs across all of the members of the CCPs in the network. The resulting minimization cost problem is thus characterized by a high dimension of state space consisting of all possible combinations of takers and a demanding computational costs for the related heavy-tailed potential loss variables of the CMs. We suggest a discrete simulated annealing algorithm approach, under both unlimited and limited number of iterations budget, to identify such optimal combination of takers and associated error bounds based on statistical learning errors. Fictitious yet realistic numerical illustrations based on several CCPs and common clearing members are provided.

15:30 – Afternoon/Evening: Excursion plus conference dinner, on a boat through the Amsterdam canals, dinner in restaurant "Kop van Oost"

Friday April 5th

Morning:

9:00 – 10:40: Mini-symposia session 5 (4 presentations), 4 rooms

Turing Room: Crypto-Finance *(chair: Julien Prat)*

Short description: A new wave of protocols relies on blockchain technology to secure financial transactions without the help of financial intermediaries. It leverages digital assets, smart contracts, and decentralized applications to revolutionize how value is stored and transferred. This symposium on Crypto-Finance will bring together researchers in economics and finance working on the optimal design and economic implications of Decentralized Finance (DeFi). The symposium will be organized around two main topics. Evgeny Lyandres and Andrea Canidio will present their research on the efficiency of decentralized exchange protocols, while Emmanuel Gobet and Julien Prat will explain how blockchain data can be used to monitor and assess in real time the execution risks of DeFi protocols.

- **Emmanuel Gobet** *(IP Paris, France):* "Robust aggregation of crypto data"

Abstract: We study price aggregation methodologies applied to crypto-currency prices with quotations fragmented on different platforms. An intrinsic difficulty is that the price returns and volumes are heavy-tailed, with many outliers, making averaging and aggregation challenging. While conventional methods rely on Volume-Weighted Average Prices (called VWAPs), or Volume-Weighted Median prices (called VWMs), we develop a new Robust Weighted Median (RWM) estimator that is robust to price and volume outliers. Our study is based on new probabilistic concentration inequalities for weighted means and weighted quantiles under different tail assumptions (heavy tails, sub-gamma tails, sub-Gaussian tails). This justifies that fluctuations of VWAP and VWM are statistically important given the heavy-tailed properties of volumes and/or prices. We show that our RWM estimator overcomes this problem and also satisfies all the desirable properties of a price aggregator. We illustrate the behavior of RWM on synthetic data (within a parametric model close to real data): our estimator achieves a statistical accuracy twice as good as its competitors, and also allows to recover realized volatilities in a very accurate way. Tests on real data are also performed and confirm the good behavior of the estimator on various use cases.

- **Evgeny Lyandres** *(Tel Aviv U., Israel):* "Does Market Efficiency Impact Capital Allocation Efficiency? The Case of Decentralized Exchanges"

Abstract: We examine the effect of market efficiency on the efficiency of capital allocation in the setting of decentralized exchanges of crypto assets. Utilizing data on nearly 100 million trades in concentrated liquidity pools on two leading blockchains, we construct a highly granular, capital-market-based measure of capital allocation efficiency. We also design and implement a method of identifying market-efficiency-restoring arbitrage transactions among all blockchain transactions and construct arbitrage-based granular measures of market efficiency. We find that market efficiency has positive, economically and statistically significant, and causal impact on capital allocation efficiency.

- **Andrea Canidio** *(Cow Protocol):* "Combinatorial Auctions with Fairness Concerns: The Case of Blockchain Trade-Intent Auctions"

Abstract: Two agents want to purchase two different assets. Two heterogeneous producers compete for the right to supply them by bidding in an auction. Because of production complementarities, the auction is combinatorial. Hence, each producer may submit two individual bids and a joint bid for both assets. Our central assumption is that the assets are illiquid at the time scale of the auction: even if each asset has a notional market price, exchanging them after they are produced is subject to friction and fees. This assumption has two implications. First, a feasibility constraint rules out some well-known mechanisms (like VCG-style auctions) because the highest-value bid may produce less of an asset than the second-highest-value bid. The feasibility constraint also restricts the possible bids. Second, fairness is a concern, as the highest-value bid may be worse for one of the two agents than some other bid. We propose a novel definition of fairness tailored to these auctions and explore various auction formats that satisfy this criterion. Our main application is blockchain trade-intent auctions.

- **Julien Prat** *(IP Paris, France):* "Systemic Risk in Decentralized Lending Protocols"

Abstract: We study financial contagion in Compound V2, a decentralized lending protocol deployed on the Ethereum blockchain. We explain how to construct the balance sheets of Compound's liquidity pools and use our methodology to characterize the financial network. Our analysis reveals that most users either borrow stablecoins or engage in liquidity mining. We then study the resilience of Compound v2 through a series of stress tests, identifying the pools that are most likely to set off a cascade of defaults.

Euler Room: Recent advances in MLMC methods for computational finance and Financial Risk management *(chair: Chiheb Ben Hammouda)*

- **Jonathan Spence** *(Edinburgh, UK):* “Hierarchical and adaptive methods for accurate and efficient risk estimation”.

Abstract: Motivated by problems arising in financial credit risk management and option pricing, this talk considers novel multilevel Monte Carlo estimators within two frameworks: Firstly, we develop a hierarchy of nested MLMC estimators to estimate systems of repeatedly nested conditional expectations given approximate samples of an underlying SDE evaluated at a discrete sequence of time points. Secondly, we consider an adaptive MLMC scheme to approximate point evaluations of the distribution of an underlying quantity of interest. Both methods are combined to compute the probability of significant financial losses arising from the credit valuation adjustment. The hierarchical estimator is shown to have a cost that is orders of magnitude less expensive than standard nested Monte Carlo estimation.

- **Azar Louzi** *(LPSM, Université Paris Cité, France):* “Adaptive multilevel stochastic approximation of the Value-at-Risk and expected shortfall”

Abstract: Crépey, Frikha, and Louzi, 2023 introduce a multilevel stochastic approximation algorithm to compute the value-at-risk and the expected shortfall of a given financial loss that can only be simulated by a nested Monte Carlo. For a prescribed accuracy $\varepsilon > 0$, this algorithm achieves an optimal complexity of order $\varepsilon^{-2-\delta}$, where $\delta > 0$ is a parameter depending on the integrability degree of the loss. We extend this work by leveraging an adaptive Monte Carlo technique in order to further reduce the optimal complexity of such an algorithm to an order of $\varepsilon^{-2} \mid \ln \varepsilon \mid$ on average.

Crépey, S., N. Frikha, and A. Louzi (2023). A Multilevel Stochastic Approximation Algorithm for Value-at-Risk and Expected Shortfall Estimation. arXiv: 2304.01207 [q-fin.CP].

- **Tony Ware** *(Calgary, Canada, and Cardiff, UK)*: “Weighted multilevel Monte Carlo”

Abstract: The Multilevel Monte Carlo (MLMC) method pioneered by Giles over the last 15 years or so has become an essential tool for Monte Carlo simulations where it is only possible to generate approximate samples, and where reducing the bias in those samples requires increasing computational effort. The approach works by exploiting a telescoping sum of differences between samples generated at different levels of resolution. We propose the use of *weighted* differences, with the weights playing a similar role to the role they play when reducing the variance using control variates. We demonstrate that this can reduce the total work significantly, particularly when the coarsest resolution level is low. We also show that similar generalizations are available for the multi-index case. This is joint work with Yu Li.

- **Josha Dekker** *(U. Amsterdam, NL):* “Optimal Stopping with Randomly Arriving Opportunities to Stop”

Abstract: We develop methods to solve general optimal stopping problems with opportunities to stop that arrive randomly. Such problems occur naturally in applications with market frictions. Pivotal to our approach is that our methods operate on random rather than deterministic time scales. This enables us to convert the original problem into an equivalent discrete-time optimal stopping problem with natural number-valued stopping times and a possibly infinite horizon of which we establish the theoretical properties. To numerically solve this problem, we design a random times least squares Monte Carlo method. We also analyze an iterative policy improvement procedure in this setting. We illustrate the efficiency of our methods and the relevance of randomly arriving opportunities in a few examples.

Hypatia Room: Computational Finance IV, Energy Markets *(chair: Matthias Ehrhardt)*

- **Carlos Vazquez Cendon** *(A Coruña, Spain):* “Modelling and numerical methods for pricing in renewable energy certificates markets”

Abstract: Some new pricing methods for Renewable Energy Certificates (RECs) or green certificates and associated derivatives products are presented. For this purpose, starting from a system of FBSDEs and using Ito lemma, we first propose a mathematical model based on a semilinear PDE arising from the consideration of two stochastic factors: the accumulated green certificates sold by an authorized generator and the natural logarithm

of the renewable electricity generation rate. One main novelty of the work comes from the numerical treatment of the nonlinearity that appears in the term containing first order derivative in the PDE. Aproppriate numerical strategies to solve the nonlinear model are proposed. Moreover, we state the mathematical model that governs the valuation of derivatives whose underlying is a REC, in particular we study European options and futures contracts. Assuming that the price of the REC has been obtained from the semilinear PDE, we derive a linear PDE model to price these derivatives, study the existence of solution and propose how to solve the models by using appropriate numerical techniques. Finally, we show some numerical results that illustrate the performance of the proposed model and the numerical methods. This is a joint work with María Baamonde and M. Carmen Calvo-Garrido, both from Department of Mathematics and CITIC, University of a Coruña (Spain).

- **Joanna Janczura** *(Wroclaw, Poland):* "Product of VAR time series with an application to electricity load prediction errors"

Abstract: In this work we focus on a time series constructed as a product of a bivariate vector autoregressive (VAR) model components, being frequently used approach for modelling economic variables. We study its statistical properties and illustrate how the cross-dependence between the VAR model components influences characteristics of their product. The approach is then applied for the electricity market case study, in which we analyze the financial cost of balancing load prediction errors after the day-ahead market settlement and prior to delivery. That cost is equal to the spread between the day-ahead and balancing prices multiplied by the size of the load imbalance. Such approach yields a model that is consistent for both variables as well as their product and, on the other hand, can be an economically grounded alternative for statistical evaluation of the load (or price) forecast accuracy.

- **Arkadiusz Lipiecki** *(Wroclaw, Poland):* "Probabilistic forecasting of electricity prices with isotonic regressions"

Abstract: Forecasting of electricity prices is an essential tool for supporting decision-making of electricity markets' participants. However, simple point forecasts provide limited information. Hence probabilistic forecasts, represented as distributions of future prices, gain increasingly more attention, as they allow to assess and mitigate the risks connected with high volatility of electricity prices. In my talk I will discuss models for probabilistic forecasting of day-ahead electricity prices that rely on point forecasts as input. This approach allows to borrow the complexity of expert point forecasting models and build relatively simple probabilistic forecasting models. In particular, I will focus on the application of stochastic order and discuss Isotonic Distributional Regression, which has not been previously studied on electricity markets.

- **Tomasz Weron** *(Wroclaw, Poland):* "Bootstrap-based forecasts in battery charging strategies"

Abstract: Nowadays more and more renewable energy sources (RES) emerge across Europe. Their most important advantage over the conventional ones – little to no environmental pollution. What is healthy for our planet however, is not necessary beneficial for energy markets. With their volatility and uncertainty of generation, RES greatly destabilize power grids. To address this issue energy storage systems, such as batteries, are becoming more common. Such installations not only provide safety but offer new trading possibilities as well. Although they main role is to ensure stability, batteries can also be used to buy energy when the price is low, store it, and then sell it – when high. In this study, we propose a new autoregressive bootstrap-type approach to provide probabilistic forecasts of day-ahead market prices. Utilizing them, we develop several trading strategies. We use German, Spanish and Danish markets' data to evaluate our methods. We show that our approach can outperform simple autoregressive models in terms of Value-at-Risk and average profit per trading day.

Ada Room: Interest rate models *(chair: Lech Grzelak)*

- **J.G. López-Salas** *(A Coruña, Spain):* "PDEs for pricing interest rate derivatives under the new generalized Forward Market Model (FMM)"

Abstract: The LIBOR Market Model (LMM) [1, 2] was extensively used by banks in order to price interest rate derivatives based on IBOR rates. In view of several well-known IBOR scandals, financial authorities worldwide replaced IBOR rates by Risk Free Rates (RFRs), which are based on historical transaction data. Having in mind this

IBOR transition, A. Lyashenko and F. Mercurio proposed in [3, 4] the generalized Forward Market Model (FMM) to model the dynamics of RFRs. In our work we obtain partial differential equations (PDEs) for pricing interest rate derivatives under the recently presented FMM. Additionally, for the numerical solution of the derived PDEs, we design AMFR-W finite difference methods [5], which are very efficient for the treatment of spatial mixed derivatives. Finally, Monte Carlo pricing methods are developed and their results are compared with the ones given by the numerical solution of the PDEs.

[1] A. Brace and D. Gatarek and M. Musiela. The Market model of interest rate dynamics, Mathematical Finance, 7(2), 127—155, 1997.

[2] D. Brigo and F. Mercurio. Interest Rate Models - Theory and Practice. With Smile, Inflation and Credit, Springer, 16(4), 2007.

[3] A. Lyashenko and F. Mercurio. Looking Forward to Backward-Looking Rates: A Modeling Framework for Term Rates Replacing LIBOR, SSRN, 2019.

[4] A. Lyashenko and F. Mercurio. Looking Forward to Backward-Looking Rates: Completing the Generalized Forward Market Model. SSRN, 2019.

[5] J.G. L´opez-Salas, S. P´erez-Rodr´ıguez and C. V´azquez. AMFR-W numerical methods for solving high dimensional SABR/LIBOR PDE models, SIAM Journal on Scientific Computing, 43, B30–B54, 2021.

- **Thomas van der Zwaard** *(Rabobank, Utrecht U., NL):* "Short-rate models with smile and applications to Valuation Adjustments"

Abstract: Affine Diffusion (AD) dynamics are frequently used for Valuation Adjustments (xVA) calculations due to their analytic tractability. However, these models cannot capture the market-implied skew and smile, which are relevant when computing the xVA metrics. Hence, additional degrees of freedom are required to capture these market features. In this talk, we address this through an SDE with state-dependent coefficients. The SDE is consistent with the convex combination of a finite number of different AD dynamics. We combine Hull-White one-factor (HW) models where one model parameter is varied. We use the Randomized AD (RAnD) technique to parameterize the combination of HW models, and refer to our SDE with state-dependent coefficients and the RAnD parametrization of the HW models as the rHW model. The rHW model allows for fast semi-analytic calibration to European swaptions through the analytic tractability of the HW dynamics. A regression-based Monte Carlo simulation is used to calculate exposures. In this setting, we assess the effect of skew and smile on exposures of interest rate derivatives.

- **Riccardo Brignone** *(U. Freiburg, Germany):* "Exact simulation of the Hull and White stochastic volatility model"

Abstract: We show how to simulate exactly the asset price and the variance under the Hull and White stochastic volatility model. We derive analytical formulas for the Laplace transform of the time integral of volatility conditional on the variance level at the endpoint of the time interval and the Laplace transform of integrated variance conditional on both integrated volatility and variance. Based on these results, we simulate the model through a nested-conditional factorization approach, where Laplace transforms are inverted through the (conditional) Fourier-cosine (COS) method. Under this model, our approach can be used to generate unbiased estimates for the price of derivatives instruments. We propose some variants of the exact simulation scheme for computing unbiased estimates of option prices and sensitivities, a difficult task in the Hull and White model. These variants also allow for a significant reduction in the Monte Carlo simulation estimator's variance (around 93-98%) and the computing time (around 22%) when pricing options. The performances of the proposed algorithms are compared with various benchmarks. Numerical results demonstrate the faster convergence rate of the error in our method, which achieves an $O(s^{-1/2})$ convergence rate, where s is the total computational budget, largely outperforming the benchmark.

- **Guido Germano** *(UC London, UK):* "Matrix and vector Heston stochastic volatility models with stochastic interest rates"

Abstract: We cover affine matrix and vector extensions of the Heston stochastic volatility model with stochastic interest rates. The variance and the interest rates have an arbitrary number of components, and thus the model has an arbitrary number of parameters larger or equal to the five parameters of the scalar Heston model. The matrix Heston model is based on the Wishart process, which is a matrix extension of the square Bessel process used in the vector and scalar Heston models. The vector Heston model is a special case of the matrix Heston model when all matrices are diagonal. Besides affinity, these multidimensional extensions preserve the consistency of the Heston model with respect to price multiplication and thus are suitable as coherent large market models, especially but not only in the FX. Using matrix and vector notation, we derive the characteristic function correcting an error

in the publication that originally introduced this model. We validate the characteristic function numerically with Monte Carlo computing the empirical characteristic function and European option prices for a 4x4 variance matrix. We discuss the algebraic structure of the characteristic function with respect to that of the scalar Heston model and extensions of it.

10:45 – 11:15: Coffee break

11:15 – 12:30: Turing Room, **Industrial panel:** ***New trends in academic finance, industrial finance, climate finance, need for machine learning, comp. methods in industry*** *(moderator: Mike Staunton)*

Panel: prof. Irene Monasterolo (Climate Finance, Utrecht University), **Dr. Fang Fang** (FFQuant and Delft U.), **Dr. Roger Lord** (Cardano), **Dr. Diederik Fokkema** (EY*)*

12:30 – 13:30: Lunch

Afternoon:

13:30–14:45: Mini-symposia session 6 (4 presentations), 3 rooms

Turing Room: Stochastic volatility models *(chair: Karel In 't Hout)*

- **Simona Sanfelici** *(Parma, Italy): "*Identifying the number of latent factors of stochastic volatility models"

  Abstract: We provide a procedure to identify the number of latent factors of stochastic volatility models. The methodology relies on the non-parametric Fourier estimation method introduced by [Malliavin and Mancino, 2002] and applies to high-frequency data. Based on the Fourier analysis, we first estimate the latent volatility process and other quantities, such as volatility of volatility and leverage. The analysis of the eigenvalues spectrum of the Gram matrix can reveal information about the actual number of factors driving the process at hand. We corroborate our analysis by numerical simulations on single and multi factor models. Finally, we apply our methodology to intraday prices from the SP 500 index futures.
  P. Malliavin and M.E. Mancino, Fourier series method for measurement of multivariate volatilities, Finance and Stochastics, 4: 49--61, 2002

- **João Guerra** *(ISEG-Lisbon and U. de Lisboa, Portugal):* "Stochastic Volterra rough volatility models and Markovian approximations"

  Abstract: We present a framework for rough volatility models where the volatility of the volatility (vol-of-vol) is the solution of a stochastic Volterra equation. These kinds of models can be considered as stochastic Volterra models. In certain cases, the numerical method of least square Monte-Carlo (LSMC) can be applied. However, the non-Markovianity of the rough vol-of-vol model will greatly increase the number of predictors for the regression in the LSMC. As an alternative, we explore the application of a multi-factor Markovian approximation of the vol-of-vol process. In particular, we identify a martingale condition which allows to express the VIX in terms of the

solution of a certain Riccati ordinary differential equation. We derive this equation and provide sufficient conditions for the existence of solutions.

- **Léo Parent** *(PRISM Sorbonne, France):* "Rough path-dependent volatility models"

  Abstract: This presentation aims to investigate different approaches to modeling rough path-dependent volatility (RPDV) and their consistency with market data. We conduct a comparative study of various RPDV model specifications using the realized volatility data of five stock indices. Our discussion covers the implications of these results in terms of modeling choices, specifically addressing whether the volatility process should depend on a historical volatility factor and how to integrate the exogenous component of volatility. Additionally, through numerical simulations, we analyze the properties of volatility dynamics generated by a specific RPDV model. Our experiments demonstrate that this modeling approach can replicate most properties characterizing empirical volatility dynamics. Furthermore, we show that the apparent positive volatility feedback observed in market data can be explained, at least partially, by the effect of the exogenous component of volatility.

Euler Room: Investment, strategies *(chair: Christina Christara)*

- **David Itkin** *(Imperial College London, UK):* "Are linear strategies nearly optimal when trading with superlinear frictions?"

  Abstract: We consider an investor with mean-variance preferences who trades on a noisy signal in the presence of transaction costs. When the costs are quadratic in the trade size, the celebrated results of Garleanu & Pedersen (2013) establish that the explicit optimal strategy is a linear feedback function of the current signal and position size. However, empirical evidence suggests that for many assets costs are superlinear, but not quadratic. In this case no explicit solution is available and the optimization problem can be computationally intensive to solve. Motivated by the quadratic cost case we consider a tractable one parameter class of linear strategies. We show that under realistic choices of the parameters the best strategy in this class performs nearly as well as the true optimum, which we compute with a brute force numerical method. Our result gives a simple and practical rule of thumb that can be efficiently implemented and yields nearly optimal performance. This is joint work with Xavier Brokmann, Johannes Muhle-Karbe and Peter Schmidt.

- **Cláudia Nunes** *(Univ. Lisboa and CEMAT, Portugal):* "Innovation and product positioning in a monopoly"

  Abstract: After introducing one product in the marketplace, a monopoly firm faces the investment decision of adding a new product. When facing this decision, the firm considers how to differentiate the new product from the old one (horizontal differentiation), the amount of R&D for the new product (vertical differentiation), the timing of the investment and the new prices.
  We solve this optimal stopping problem for a class of terminal functions with some interesting features, showing, in particular, that the firm either chooses to introduce a new product of similar quality to the old one, but differentiates it to capture the missing market share, or introduces a higher quality product that has full market share, replacing the old product entirely. We also prove that, under some conditions, the optimal strategy is not a threshold one, but instead is a non-connected interval leading to a hysteresis region.
  (joint work with Anne Balter (Tilburg Univ.), Peter Kort (Tilburg. Univ) and Diogo Pereira (IST/CEMAT)

- **Pietro Manzoni** *(Milano, Italy):* "Managing overconfidence in time series probabilistic forecasting with an application to electricity load"

  Abstract: Neural networks (NNs) are highly accurate modelling tools for prediction tasks involving time series patterns. However, obtaining accurate forecasts is often not enough: in various real-world decision-making contexts, it is also crucial to precisely quantify predictive uncertainty, and NNs have been found to poorly predict probabilities. The overconfident forecasts of NNs could cause unintended consequences in safety-critical applications, especially in domains like the financial and the energy finance sector, where attaining a precise probabilistic description is generally more important than having accurate point predictions. We propose a simple method to detect overconfidence in time series probabilistic forecasting. We introduce two new (improper) loss functions that adjust forecasts for overconfidence. Applying the new loss functions to the forecast of electricity load, we show that the reliability of out-of-sample forecasts improve significantly.

Hypatia Room: Computational Finance V *(chair: Daniel Sevcovic)*

- **Kristian Debrabant** *(Odense U., Denmark):* "Weak second-order stochastic Runge-Kutta methods with optimal stage number"

  Abstract: Stochastic Runge-Kutta methods are a popular class of numerical methods used to solve stochastic differential equations. While strongly convergent methods approximate single solution paths accurately but have typically very low convergence order, weakly convergent methods are taylored at approximating the expected value of a functional of the solution at a given time and can achieve higher order, typically order two. In this talk, we introduce some new stochastic Runge-Kutta methods that are weakly convergent of order two while needing to fulfill less restrictive order conditions than previously known methods, thus allowing for methods with a lower number of stages than previously seen. The contents of this talk are joint work with Adrien Laurent (INRIA Rennes) and Anne Kværnø (NTNU Trondheim).

- **Eike Brinkop** *(Reading, UK):* "Deep learning for pricing time contextual data"

  Abstract: We propose a new way of pricing information in a predictor and time space. The combination of adding time space and using contextual deep learning architectures with convolutional-transformer architecture enhances pricing. Using US stocks between 2003 and 2020, it improves the model accuracy and performance, increasing Sharpe ratios of managed portfolios from 0.9 for a feed-forward approach to over 1.2. The methodology gives insights on the factors that pricing depends on in the time and predictor space, making momentum factors less and size factors more important. We examine the use of autoencoder networks for preprocessing and discover that autoencoders compress information in the input without loss of generality. With Hyperband hyperparameter pre-optimisation, we remove model selection bias and find the ideal structure of the model with computational efficiency.

- **Rayan Ayari** *(Zeppelin U., Germany):* "Beyond the efficient frontier and 1/N: How to beat the market with deep reinforcement"

  Abstract: This paper presents a new approach to the risk-return optimization in continuous portfolio construction using Deep Reinforcement Learning by including higher-order moments of return distributions and enhancing applicability with locally integrable loss functions. We model stock returns by a Markov Decision Process, employing the Twin Delayed Deep Deterministic Policy Gradient algorithm within a specialized trading strategy that accommodates many assets and mimics real-world financial decisions. We backtest S\&P100 constituents using daily data from 2015-2021 and show our model's superiority. Furthermore, we assess the impact of extended features on portfolio performance and analyze allocation behaviors heuristically.

15:00: Closing of ICCF24