Abstract list

Workshop on Stochastics, Statistics, Machine Learning and their Applications of Sustainable Finance and Energy Market

- **Margaux Bregere** (University of Sorbonne; EDF, Paris.):

Title:
Bandit algorithms for demand response.

Abstract:
As electricity is hard to store, the balance between production and consumption must be strictly maintained. With the integration of intermittent renewable energies into the production mix, the management of the balance becomes complex. At the same time, the deployment of smart meters suggests demand response. More precisely, sending signals - such as changes in the price of electricity - would encourage users to modulate their consumption according to the production of electricity. The algorithms used to choose these signals have to learn consumer reactions and, in the same time, to optimize them (exploration- exploration trade-off).
Our approach is based on bandit theory and formalizes this sequential learning problem. We propose a first algorithm to control the electrical demand of a homogeneous population of consumers and offer $T^{1/2}$ upper bound on its regret. Experiments on a real data set in which price incentives were offered illustrate these theoretical results. As a "full information" dataset is required to test bandit algorithms, a consumption data generator based is built.
In order to drop the assumption of the population homogeneity, we propose an approach to cluster households according to their consumption profile. These different works are finally combined to propose and test a bandit algorithm for personalized demand side management.

- **Giorgia Callegaro** (University of Padova):

Title: A McKean-Vlasov game of commodity production, consumption and trading.

Abstract:

We propose a model where a producer and a consumer can affect the price dynamics of some commodity controlling drift and volatility of, respectively, the production rate and the consumption rate. We assume that the producer has a short position in a forward contract on λ units of the underlying at a fixed price F, while the consumer has the corresponding long position. Moreover, both players are risk-averse with respect to their

financial position and their risk aversions are modelled through an integratedvariance penalization. We study the impact of risk aversion on the interaction between the producer and the consumer as well as on the derivative price. In mathematical terms, we are dealing with a two-player linear-quadratic McKean–Vlasov stochastic differential game.
Using methods based on the martingale optimality principle and BSDEs, we find a Nash equilibrium and characterize the corresponding strategies and payoffs in semi-explicit form. Furthermore, we compute the two indifference prices (one for the producer and one for the consumer) induced by that equilibrium and we determine the quantity λ such that the players agree on the price. Finally, we illustrate our results with some numerics. In particular, we focus on how the risk aversions and the volatility control costs of the players affect the derivative price.
This is a joint paper with R. Aid, O. Bonesini and L. Campi.

- **Roxana Dumitrescu (Kings College London):**

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

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

- **Paul Eisenberg** (University of Economics Vienna):

Title: Finite dimensional energy NA-consistent term structures with free diffusion coefficient.

Abstract:

We consider a finite dimensional manifold of possible instantaneous futures price curves for the energy futures market. We would like to be able to estimate a diffusion coefficient from data (interpreted on the given manifold of possible curves) and still obtain an NA-model. This requires mathematically that for any, possibly state-dependent, tangential diffusion coefficient there is an accompanying drift coefficient such that the resulting model is free of arbitrage. We show that this condition implies that the manifold is a submanifold of an affine space of the same dimension. In particular, such possible instantaneous futures price curves can always be written as a finite linear combination of base curves.
Moreover, we also state the corresponding result for forward rates of interest rate markets where such manifolds CANNOT be affine.

- **Matheus Graselli (McMaster University, Canada):**

Title: Sensitivity analysis of climate-economic models.

Abstract:
Assessing the economic impacts of climate change, as well as the effects of economic activity on the climate, requires the use of complex models with high computational costs and a very large number of parameters. In this talk, I will apply global sensitivity analysis techniques from statistics (such as Sobol indices) and machine learning (such as random forests) to representative climate-economic models in order to identify and rank the most important parameters and quantify their effect on select output variables. This will then be followed by both backtesting and exploration of forward scenarios under these models, taking parameter uncertainty into account. In particular, I will describe the effect of uncertainty on the expected result of policiers such as carbon taxes, green financing, and green investment.

- **Rüdiger Kiesel** (University Duisberg-Essen):

Title: Uncertainty-based Risk Management for Climate Risk.

Abstract:

By now it is widely agreed that climate change poses a substantial risk to financial markets and institutions. We discuss risk management strategies in this context and advocate the use of a pre-commitment approach. Utilizing our general framework, we turn to several specific examples relating to the measurements of risks for insurance and financial companies. We also develop a method to assess the credibility of net-zero commitments, which may be applied to control the carbon budget in loan and investment portfolios.

The talk relies on joint work with Gerhard Stahl, (HDI), Andrej Bajic (Deloitte FSI-AuditGarage), Alexander Blasberg and Kateryna Chekriy (both University Duisburg-Essen).

- **Thomas Krabichler** (Ostschweizer Fachhochschule):

Title: Automated Market Makers and their Implications for Liquidity Providers.

Abstract:

Automated market making for crypto tokens is an extremely attractive and efficient way to establish decentralized exchanges. An inevitable prerequisite for this type of market is the willingness of participants to provide liquidity. Except in the case of two correlated pairs, providing liquidity is often sub-optimal. In fact, one often faces significant opportunity cost commonly referred to as impermanent loss. Prevailing transaction fee levels, even with levered positions, are often insufficient to compensate for the opportunity costs incurred. Marketability and exchangeability are essential prerequisites for attributing value to many crypto tokens. Therefore, when issuing fiat tokens for the viability of intriguing business models, one ends up with the chicken-or-the-egg causality dilemma; how to achieve sustainable incentives to the liquidity provision for an abstract good whose intrinsic value is defined solely by that liquidity system? This talk derives and discusses useful formulas for the quantitative risk management in the context of automated market makers. In addition, order size and pool size dependent transaction costs are proposed that may incentivize the desired level of liquidity.

- **Silvia Lavagnini** (Norwegian Business school):

Title: Local Volatility Models for Commodity Forwards.

Abstract:

We present a class of Hilbert-space valued local-volatility models designed specifically for forward curves in commodity markets. These models are governed by a stochastic partial differential equation, and we establish the existence and uniqueness of solutions within our framework. Our approach encompasses a wide range of specifications, including a constant elasticity of variance (CEV)-type model. However, we find that the CEV model lacks the flexibility required to reproduce the smile-shaped implied volatility observed in electricity markets, among others. Motivated by empirical findings, we propose a local volatility specification for forwards curves that offers the necessary flexibility to capture the volatility

surface. We then introduce a machine learning approach for pricing and model calibration. This methodology enables us to overcome some of the inherent numerical complexities associated with this class of models. Joint work with Nils Detering.

- **Teemu Pennanen** (Kings College London):

Title: Convex Stochastic Optimization.

Abstract:

We study dynamic programming, duality and optimality conditions in general convex stochastic optimization problems introduced by Rockafellar and Wets in the 70s. We give a general formulation of the dynamic programming recursion and derive an explicit dual problem in terms of two dual variables, one of which is the shadow price of information while the other one gives the marginal cost of a perturbation much like in classical Lagrangian duality. Existence of primal solutions and the absence of duality gap are obtained without compactness or boundedness assumptions. In the context of financial mathematics, the relaxed assumptions are satisfied under the well-known no-arbitrage condition and the reasonable asymptotic elasticity condition of the utility function. We extend classical portfolio optimization duality theory to problems of optimal semi-static hedging. Besides financial mathematics, we obtain several new results in stochastic programming and stochastic optimal control.

- **Dylan Possamai** (ETH Zürich):

Title: Pollution regulation for electricity generators in a transmission network.

Abstract:
In this paper we study a pollution regulation problem in an electricity market with a network structure. The market is ruled by an independent system operator (ISO for short) who has the goal of reducing the pollutant emissions of the providers in the network, by encouraging the use of cleaner technologies. The problem of the ISO formulates as a contracting problem with each one of the providers, who interact among themselves by playing a stochastic differential game. The actions of the providers are not observable by the ISO which faces moral hazard. This is a joint work with Alejandro Jofré and Nicolás Hernández Santibáñez.

- **Dennis Schroers** (University of Bonn):

Title: Robust nonparametric analysis of the term structure of volatility.

Abstract:

This talk presents a jump-robust nonparametric method for estimating the volatility term structure in the general term structure model of [3] along with empirical findings. The conventional belief that the term structure of bond markets could be adequately explained by a small number of linear factors has recently been called into question. In [4], it was discovered that this pattern might be artificially generated due to the substantial local correlation in yield curves. To mitigate this problem, the authors proposed i.a. an alternative approach using so-called “difference returns” which involves differencing yield curve data not only along the temporal but also the maturity dimension. It turns out that economically motivated difference returns coincide with a discretized version of semigroup adjusted increments that where derived in [1] and [2] from a statistical perspective, in the context of continuous arbitrage-free term structure dynamics. This observation allows for formal infill asymptotics for difference returns in the fully general term structure setting of [3], viewing the corresponding scaling limit as the time-varying realized volatility term structure rather than a static covariance. The presented theory can be applied in any term structure model and, in particular, energy markets.

REFERENCES [1] F. E. Benth, D. Schroers, and A. E. Veraart. A weak law of large numbers for realised covariation in a Hilbert space setting. Stoch. Proc. Applic., 145:241–268, 2022. [2] F. E. Benth, D. Schroers, and A. E. D. Veraart. A feasible central limit theorem for realised covariation of spdes in the context of functional data. Available at ArXiv:2205.03927, 2022. [3] T. Bjork, G. Di Masi, Y. Kabanov, and W. Runggaldier. Towards a general theory of ¨ bond markets. Finance Stoch., 1:141–174, 1997. [4] R. K. Crump and N. Gospodinov. On the factor structure of bond returns. Econometrica, 90(1):295–314, 2022

- **Carlo Sgarra** (Politecnico Milan):

Title: Portfolio Optimization for a Hilbert-Valued Stochastic Volatility Model with Jumps.

Abstract: Benth, Ruediger and Suss (SPA, 2018, 128, 461-486) have recently proposed an operator-valued stochastic volatility model with jumps in order to describe the dynamics of forward prices in power markets, recently extended by Benth and Sgarra (2022) in order to include the leverage effect. In the present paper we want to deal with the portfolio optimization problem in this setting. We formulate the optimal stochastic control problem, and we discuss existence and uniqueness of the solution. We provide some qualitative analysis of the solution obtained. Moreover, we show that an explicit solution can be obtained for the NO-Leverage case. (Joint work with F.E. Benth and A. Cosso).

- **PeterTankov** (ENSAE, Institute Polytechnique de Paris):

Title: Decarbonization of large financial markets.

Abstract:

We build a model of a financial market where a large number of firms determine their dynamic emission strategies under climate transition risk in the presence of both greenminded and neutral investors. The firms aim to achieve a trade-off between financial and environmental performance, while interacting through the stochastic discount factor, determined in equilibrium by the investors' allocations. We formalize the problem in the setting of mean-field games and prove the existence and uniqueness of a Nash equilibrium for firms. We then present a convergent numerical algorithm for computing this equilibrium and illustrate the impact of climate transition risk and the presence of green-minded investors on the market decarbonization dynamics and share prices. We show that uncertainty about future climate risks and policies leads to higher overall emissions and higher spreads between share prices of green and brown companies. This effect is partially reversed in the presence of environmentally concerned investors, whose impact on the cost of capital spurs companies to reduce emissions. However, if future climate policies are uncertain, even a large fraction of green-minded investors is unable to bring down the emission curve: clear and predictable climate policies are an essential ingredient to allow green investors to decarbonize the economy.
Joint work with Pierre Lavigne.

- **Joseph de Vilmarest** (LPSM, Sorbonne Université & EDF R&D):

Title: Adaptive Probabilistic Forecasting of Electricity Net-Load.

Abstract:
Electricity load forecasting is fundamental for power system operators and electricity market participants. That task is increasingly challenging as the underlying characteristics of electricity consumption evolve. The proliferation of local generation, demand response, and electrification of heat and transport are changing the fundamental drivers of electricity load and increasing the complexity of load modelling and forecasting.
We address this challenge in two ways. First, our setting is adaptive; our models take into account the most recent observations available, yielding a forecasting strategy able to automatically respond to changes in the underlying process. Second, we consider probabilistic rather than point forecasting; indeed, uncertainty quantification is required to operate electricity systems efficiently and reliably.
We apply our methodology to the regional net-load in Great Britain; by net-load we denote the difference between the consumption and the embedded generation (mainly wind and solar energy). Indeed, as the production of new renewables increases, that quantity is becoming more popular.

The presentation is based on a joint work with J. Browell, M. Fasiolo, Y. Goude and O. Wintenberger available online (https://hal.science/hal-03934739/document).

- **Hanna Sophie Wutte** (ETH Zürich):

Title: Deep Dynamic Decision Making in Mathematical Finance.

Abstract:
Dynamic decision making in mathematical finance typically arises in form of trading in a financial market, often including very general constraints (e.g., on liquidity and trading volumes) for purposes of hedging, pricing or portfolio optimization. Neural networks are increasingly leveraged in that optimization via parametrizations of trading strategies that can easily incorporate common market frictions. In order to choose an appropriate deep learning algorithm from a large pool of existing approaches, it is indispensable to understand their assumptions and the implications of their use. We contrast common approaches to deep dynamic decision making, in particular with a view to portfolio optimization in energy markets.

Graduate Lectures 11.09.2023

- **Matheus Graselli (McMaster University, Canada):**

Title: Finance and Climate Change.

Abstract:
Climate risk is arguably the most important long-term risk faced by investors worldwide. The most obvious source of risk are losses caused by extreme climate events, which according to Allianz – a multinational insurance company – could grow by 30% per year in the next 10 years, reaching an annual average cost of $1 trillion. The second largest source of risk relates to stranded assets, namely assets that are destined to lose value during the transition to the low-carbon economy that is necessary to meet the 2C target specified in the Paris Agreement. This includes the assets of fossil fuel companies, whose reserves need to be left untapped if we are to remain within the carbon budget compatible with the 2C target, but also countless other companies whose future revenues depend on a "carbon bubble".

On the other hand, the amount of financing that is needed to achieve the low-carbon transition remains well above current financial flows to green projects. According to one estimate provided by the Global Commission on the Economy and Climate, the required lowcarbon infrastructure investment ranges from 5% to 15% of global infrastructure investment, itself around $6 trillion per year. This does not include the cost of adaptation, which are estimated to range from $150 to $300 billion per year by 2030. When this $450 to $1,200 billion range is compared with the current annual financial flow of $400 billion directed towards green investment, we see that current flows need to be tripled in order to cover the funding gap for the low-carbon transition.

The two sides of this problem – enormous risks and great need of funds – present a formidable challenge to the financial industry, but also unparalleled opportunities. In these lectures, I will review state-of-the-art integrated assessment models (IMA) for climate and macroeconomics, including the DICE model for which William Nordhaus won the 2018 Nobel Prize in Economics but also some other alternatives, and use them to evaluate the impact of financial innovations such as green bonds and carbon derivatives, as well as policy tools such as carbon taxes, green central banking, subsidies, and the Green New Deal.

- **Roxana Dumitrescu (Kings College London):**

Title: Mean-field game theory for energy transition to clean energy**.**

Abstract:

This lecture focuses on the modelling of the energy transition to a clean energy by using tools from mean-field game theory. According to International Energy Agency, to limit the global temperature increase to 1.75◦C by 2100 (Paris Agreement range midpoint), the energy sector must reach carbon neutrality by 2060. This objective is achievable only through massive deployment of renewable electricity. Game theory can be employed as a modelling tool to understand the dynamics of electricity markets under large scale renewable penetration, as well as to implement demand-response programs to deal with the variability of the renewable energy. We shall use the setting of mean-field games to describe the evolution of the future electricity markets in the long term under different incentive schemes and to design dynamic pricebased demand side management short term models to adjust consumption to better match demand with supply. Mean-field game theory represents the study of strategic decision making by small interacting agents in very large populations. It lies at the intersection of game theory with stochastic analysis and control theory. The use of the term mean field is inspired by mean-field theory in physics, which considers the behavior of systems of large numbers of particles where individual particles have negligible impacts upon the system. This theory was introduced in the engineering literature by Minyi Huang, Roland Malhame, and Peter E. Caines and independently and around the same time by mathematicians Jean-Michel Lasry and Pierre-Louis Lions. In the first part of the lecture I will introduce the mean-field game theory and the different

approaches which can be used to solve this class of problems, and in the second part I will discuss the applications to energy transition.